Students as partners and students as change agents in the context of university mathematics

By

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A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University

June 2017

Certificate of Originality

This is to certify that I am responsible for the work submitted in this thesis, that the original work is my own except as specified in acknowledgements or footnotes, and neither the thesis nor the original work contained has been submitted to this or any other institution for a degree.

…… ……………………………………………………..(Signed)

…………22 June 2017……………………………………………….(Date)

ABSTRACT

The research reported in this thesis investigated staff-student collaboration in advanced undergraduate mathematics course design and delivery at a research-intensive UK university. Staff and students collaborated to redesign and deliver two courses: Vector Spaces and Complex Variables. The collaboration in the *design* of the two courses involved students who had completed the courses and then who worked as interns together with a small team of academic staff. The collaboration in the *delivery* of the two courses involved the implementation of a Peer Assisted Learning (PAL) scheme in which third-year students facilitated the learning of second-year students in optional scheduled sessions. The study employed a mixed-methods research strategy involving an ethnographic approach to the study of the course design process and PAL sessions followed by an observational study (a quasi-experimental design) to investigate the impact of PAL attendance on the achievement of PAL participants.

This thesis reports findings from a three-phase research design. Phase one explored the nature of the collaborations in course design and its impact on staff teaching *practices* and on the student collaborators. Phase two investigated the *characteristic*s of the PAL sessions for the advanced undergraduate mathematics courses and the roles played in those sessions. Phase two also explored the impact of PAL in qualitative terms on both PAL participants and PAL leaders. Phase three investigated the impact of PAL in quantitative terms on the achievement of students who participated as PAL participants. The study found that staff-student collaboration in course design and delivery led to emergent Communities of Practice in which staff and students engaged in mathematics practice which led to *identity transformation* of student collaborators, *a deeper understanding of the mathematics* on which the students worked and some change in staff *teaching and course design practice*. The also showed that staff-student collaboration in the delivery of course units via PAL resulted in a *learning community* in which PAL participants and PAL leaders engaged in mathematics practice which led to increased student achievement and enhanced affective outcomes for both PAL participants and PAL leaders.

ACKNOWLEDGEMENTS

The research involved prolonged absence from home, living and working outside London. Therefore, I thank Jaydene Duah and Jesse Duah for their understanding, support and sacrifices for my studies. I also thank Mrs Joanna Offori Appiah for an equally valued support she gave me throughout the three years of my PhD studies.

Throughout the period of my PhD studentship, I received enormous help and support from many people and I owe them all a debt of gratitude. I thank Professor Tony Croft, my supervisor, particularly for offering me the opportunity to study for a PhD in Mathematics Education; pastoral and financial support which made it possible for me to attend several national and international conferences to disseminate the findings of my research. I thank Professor Duncan Lawson and Professor Yvette Solomon for reading and providing feedback on the early drafts of the thesis which bear no resemblance to what it is today. Writing a thesis, sometimes, comes with challenges and an author may need endowed wisdom to stay the course. Therefore, I thank Professor Barbara Jaworski for her advice and counsel without which this thesis would not have come to fruition given all the challenges I faced as I wrote the thesis. I also thank past and present students, academic and administrative staff at the Mathematics Education Centre and Department of Mathematical Sciences at Loughborough University for their help in their own individual ways. I thank Nina Attridge specially for providing me with shelter when I felt vulnerable while undertaking this research.

Friends, at home and abroad, whose counsel, hospitality and financial support made a difference to my research life deserve the final thank you: Dr. Thomas Gyebi for hosting me at the Kruger National Park, Phalawbower, South Africa, while I attended the ISTE International Conference in 2012; Mr Kofi Siaw and Mr Sylvester Peprah for their support and encouragement; Mr Michael Mireku for his advice and friendship ever since we met at St Peters Secondary School, Nkwatiah, Ghana; Mr George Kusi-Manu for his hospitality and financial support and Mr James Osei, my dad, for providing support when he could, from within the UK and afar.

DEDICATION

This thesis is dedicated to my

Mum

Agnes Kusi Ama Bono

and

Aunt

Joanna Offori Appiah

RELATED PUBLICATIONS

PEER REVIEWED ACADEMIC PAPERS

Duah, F. and Croft, T. (2014). Faculty-student partnership in advanced undergraduate mathematics course design, *Learning and Teaching Together in Higher Education*, *2014*(13).

Solomon, Y., Croft, T., Duah, F. and Lawson, D. (2014). Reshaping understandings of teaching-learning relationships in undergraduate mathematics: Activity theory analysis of the role and impact of student internships. *Learning, Culture and Social Interaction*, *3*(4), 323-333.

Duah, F. Croft, T., and Inglis, M. (2014). Can peer assisted learning be effective in undergraduate mathematics. *International Journal of Mathematical Education in Science and Technology*, *45*(4), 552-565.

Croft, T., Duah, F. and Loch, B. (2013). "I'm worried about the correctness": Undergraduate students as producers of screencasts of mathematical explanations for their peers - lecturer and student perceptions. *International Journal of Mathematical Education in Science and Technology, 44(7),* 1045-1055.

PEER REVIEWED CONFERENCE PAPERS

Duah, F. K. and Croft, T. (2012). Staff-student partnership in mathematics course design: An ethnographic case study. In D. Mgari, A. Mji, and U. I. Ogbonya (Eds.), *ISTE. International Conference Proceedings*, 22-25 October, Mopani Camp, Kruger National Park, South Africa, pp.391 - 401.

Duah, F. K. and Croft, T (2012). Students As Partners in Mathematics Course Design. In Waller D. (Ed.), *CETL-MSOR Conference Proceedings*, CETL-MSOR Conference, 5 - 6 September, Coventry, UK, pp. 49 – 55.

PROFESSIONAL JOURNAL ARTICLES AND NEWSLETTERS

Duah, F. K. (2013). Education Grant Report. *Mathematics Today*, 33 (1), 11-44.

Duah, F. K. and Croft, T. (2011). Students as Partners in Mathematics Course Design: An ethnographic case study. *CULMS Newsletter*, *4.*

Duah, F. K. and Croft, A. C. (2011). What the Engaged Students Tell Us About Mathematics. *MSOR Connections*, *11*(2), 17.

Duah, F. K. (2011). What the Engaged Students Tell Us about Mathematics, *British Mathematics Colloquium*, Leicester University, 19th April 2011.

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LIST OF ABBREVIATIONS

CoP	Communities of Practice/Community of Practice
CV	Complex Variables
HEdCert	Higher Education Certificate
HE	Higher Education
HEIs	Higher Education Institutions
MMath	Masters in Mathematics
NUS	National Union of Students
PAL	Peer Assisted Learning
PLS	Peer Learning Support
SSLCs	Staff-Student Liaison Communities
TC	Teaching Centre
VS	Vector Spaces
VLE	Virtual Learning Environment
ZAP	Zone of Actual Development
ZPD	Zone of Proximal Development

CHAPTER 1 INTRODUCTION

1.1 An overview of staff-student partnerships

In the United Kingdom, there is an ongoing debate that centres on *widening participation, learning enhancement* and *student engagement*. Widening participation, a major UK government policy that is aimed at increasing participation in Higher Education (HE) amongst some groups of the population, poses challenges for university teachers across all disciplines. A consequence of the widening participation policy is that non-traditional students with varying entry qualifications are now able to enter UK Higher Education Institutions (HEIs) and study for a wide range of degrees including undergraduate mathematics. Thus, the backgrounds of students entering UK HEIs to study for a degree in mathematics is now more diverse than ever before. The challenges resulting from the diversity of students appear to be even more marked for both students and lecturers of undergraduate mathematics due to the very nature of the discipline and its enduring traditional pedagogy.

New pedagogical strategies are required not only to support non-traditional students in their learning but also those students who enter universities with higher A-level or equivalent grades. Staff-student partnerships in course design and delivery offer university mathematics teachers opportunities to deploy new kinds of pedagogies that have the potential to enhance the student learning experience (e.g. see Cook-Sather, Bovill, & Felten, 2014; Little, 2012; Werder & Otis, 2011) and increase student engagement with undergraduate mathematics.

It is well known that when students enter university to study for a degree in mathematics or other disciplines which draw heavily on mathematics, they face transition challenges (see e.g. Hawkes & Savage, 2000; Williams, 2015). These challenges include but are not limited to the need for students to adjust to the traditional university mathematics pedagogy and the very nature of university mathematics and its practices which are different from those of school mathematics. While transition from school to tertiary mathematics has been of interest to mathematics education researchers for some time, other forms of transitions within undergraduate mathematics education are now beginning to get attention (see e.g. Winsløw, Barquero, Vleeschouwer & Hardy, 2014). In Chapter 2 (see Section 2.2), I will review and discuss some of these new types of transitions. Here, it suffices for me to say that transition to second-year undergraduate mathematics or from one mathematical content area to another also does pose challenges for some students.

As students transition from first year to second year undergraduate mathematics degree programmes, some may experience what some researchers have called “cooling off” (Daskalogianni & Simpson, 2002) and “sophomore slump” (McBurnie, Campbell, & West, 2012; Thompson, et al., 2013) – two phenomena that may need addressing by university mathematics teachers so that these students can progress through their degree programmes. Daskalogianni and Simpson (2002) used the term “cooling off” to refer to “students’ developing loss of interest in mathematics due to a combination of cognitive and affective factors” (p. 2). McBurnie et al. (2012) defined ‘‘sophomore slump’’ as the “lack of engagement that can be experienced by students entering their second year at university” (p.14). The consequence of either of these phenomena is low levels of student engagement with their course units and in university life.

The challenges students face due to “cooling off” or ‘‘sophomore slump’’ are not unique to undergraduate mathematics students or one specific discipline. However, it would appear that some undergraduate mathematics students are much more affected by these phenomena. One possible explanation for the differential effect of these phenomena for undergraduate mathematics students is that when students are unable to solve problems set as assignments for the course units on which they are enrolled, lack of success or progression becomes more obvious. In this situation, some undergraduate mathematics students disengage from the subject and become alienated and marginalised (Solomon & Croft, 2015).

High levels of student engagement with their subject of study are believed to be related to high levels of student achievement. For example, Carini, Kuh and Klein, (2006) have shown that increased levels of student engagement within HE and with their discipline could lead to increased student achievement and satisfaction. Other researchers have also established positive correlations between student involvement in a subset of educationally purposeful activities and student academic achievement, persistence, social engagement and satisfaction (Astin, 1999; Berger & Milem, 1999; Chickering & Gamson, 1987; Goodsell, Maher, & Tinto, 1992; Kuh, 1995; Kuh et al., 2005; Kuh & Vesper, 1997; Pace, 1995; Pascarella & Terenzini, 2005).

In the light of the above research findings, it is not surprising that UK HEIs and other institutions around the world have shown interest in student engagement and educational developments aimed at influencing student engagement. The international interest in student engagement is reflected in the HE research literature. For example, the Higher Education Academy (HEA) for England commissioned a literature review (see Trowler, 2010) on student engagement in order to collate the evidence base of student engagement for academic practice in the UK. An outcome of Trowler's literature review has been, in my view, the increased focus on student engagement activities within UK HE sector. This increased focus by institutions aims to enhance the student learning experience.

Drawing on definitions from the literature, Trowler suggests that:

> *Student engagement is concerned with the interaction between the time, effort and other relevant resources invested by both students and their institutions intended to optimise the student experience and enhance the learning outcomes and development of students and the performance, and reputation of the institution. (p.4)*

In light of this suggestion, I argue that student engagement through curriculum development projects in course design, resource development, and co-delivery of course content can foster interaction between staff and students and could potentially enhance the student learning experience. The potential benefit of enhancing the student learning experience through staff-student partnership is that the "cooling off" or the "sophomore slump" phenomenon experienced by some undergraduate mathematics students may be ameliorated, at least for some students.

Student engagement may be at a number of different levels (see e.g. Duah & Croft, 2011; Healey, O'Connor, & Broadfoot 2010; Trowler, 2010). Thus, students may be engaged through institutional representation and governance. At institutional level, students may be engaged through staff-student liaison committees (SSLCs) which are examples of staff-student partnerships in which students contribute to departmental and institutional change in relation to matters concerning departmental programmes of study and students' learning experience. These SSLCs usually have a wide remit. Deliberations at the committee meetings may not have direct student input into courses that pose challenges to students. Hence, there is an increasing trend to move beyond SSLCs to a much deeper, richer kind of staff-student partnership.

Student engagement with curriculum activities related to their disciplinary subject or courses are likely to enhance their learning and to increase their achievement in those subjects and courses (Carini et al., 2006). Students may engage in curriculum activities that include curriculum design, course design, development of teaching approaches (Bovill, Cook-Sather, & Felten, 2011). In addition, students may engage in some aspects of course delivery. The most common form of student involvement in course delivery at undergraduate level is Supplemental Instruction (SI) or Peer Assisted Learning (PAL) (see e.g. Arendale, 2001; Harding, Engelbrecht, & Verwey, 2011; Miles, Polovina-Vukovic, Littlejohn, & Marini, 2010). When students engage in SI or PAL, they do not act as surrogate teachers. Rather, they facilitate the learning of their peers. PAL programmes do not consider the "peer helper as a surrogate teacher, in a linear model of the transmission of knowledge, from teacher to peer helper to learner" (Topping, 2005, p. 631). The peer helper does not need to be amongst the "best students" to facilitate the learning of his/her peers.

In recent years, increasing calls have been made to HEIs to involve students more in the planning and design of their courses and the development of teaching approaches (e.g. see Bovill et al., 2011; Werder & Otis, 2011). In the UK, early calls came from the former 1994 Group of Universities and the National Union of Students (NUS). A policy statement of the 1994 Group of UK universities, "*Enhancing the Student Experience*", stated that:

> *Students know how they want to be taught and have ideas about how techniques can be improved. They play an important role as "change agents", challenging the established modes of learning and teaching, and contributing to making it more exciting and relevant for themselves and future generations of students. (Kay, Marshall, and Norton, 2007, p.4)*

Similarly, in 2008, the then Vice President of the UK National Union of Students, Aaron Porter, also issued an impassioned plea to HEIs: "I ask you to begin to explore, within your own context, new ways to engage students in their learning, to involve students in your internal quality assurance systems, and in the design and planning of courses" (Porter, 2008). Since these calls, the UK Quality Assurance Agency (QAA), for example, has included student reviewers in its institutional review teams. A rising number of HEIs have also been engaging students as partners in institutional governance and development of learning and teaching approaches. Thus, increasingly students are being involved to shape their own learning in UK universities.

The call for student involvement in the planning and development of learning and teaching approaches is not only limited to the United Kingdom but is also being made in other parts of the world. Recent publications entitled *Engaging Student Voices in the Study of Learning and Teaching* (Werder & Otis, 2011) and *Engaging Students as Partners in Learning and Teaching* (Cook-Sather et al., 2014) provide examples of staff-student partnerships that actively involve students in course design and delivery. Similarly, Healey, Flint and Harrington (2014) report examples, from around the world, of case studies of staff-student partnerships across a wide range of academic disciplines. The case studies *of* and empirical research *on* the staff-student partnerships in these publications provide evidence of the scholarship in the field of staff-student partnerships. In Chapter 2, examples of the case studies and related empirical research will be reviewed. Some of the case studies can be classified as Scholarship of Teaching and Learning (SoTL) activities.

SoTL involves systematic study of teaching and/or learning and dissemination of such work through presentations or publications to a wider community. SoTL emerged as a unique academic activity in response to Boyer's (1990) broadened definition of scholarship which includes all aspects of academic work. Boyer noted that "Scholarship means engaging in original research. But the work of the scholar also means stepping back from one's investigation, looking for connections, building bridges between theory and practice, and communicating one's knowledge effectively to students" (p. 16). In stepping back, scholars need not reflect in isolation, but may do so in collaboration with other colleagues and students. The staff-student partnership in course design and delivery which was the focus of the current research is a SoTL activity

The staff-student partnership in course design and delivery, which is the focus of the current study, provided opportunities for staff to reflect *on* and *improve* learning and teaching and for students to engage with mathematics in ways which hitherto they had not done. As a form of scholarship, the thesis offers a means for disseminating the findings that emerged from the analysis of staff and students' reflections and students' new ways of engaging with mathematics in collaborative ways. Hence, I see this research as a contribution to the emerging field of university mathematics teachers' engagement with SoTL – a complementary academic activity to *disciplinary research*. In Section 1.2, I discuss the research problem and questions which I set out to study.

1.2 **Research problem and questions**

1.2.1 *Research problem*

The calls for greater student involvement in the planning, development of teaching, and their learning have a number of underlying assumptions that may not necessarily hold true. First the calls assume that students are willing and prepared to be engaged in collaborative course design and delivery processes. For those students who are willing to engage in such processes, there is also an underlying assumption that they will be able to contribute tangibly and intangibly to the process, and that they will have the *subject knowledge* and *tacit pedagogical knowledge* to enable them to contribute to the process. However, there is a paucity of *empirical* research evidence to suggest that such assumptions will hold true in the context of *advanced undergraduate mathematics* (see definition on p.15).

This thesis explores staff-student partnership in the context of advanced undergraduate mathematics course design and delivery. Given the hierarchical nature of the content of undergraduate mathematics courses and the high level of knowledge and expertise that course lecturers draw upon to design their courses, questions remain as to the contribution students can make towards a collaborative course design and delivery process. If schools and departments of mathematical sciences in HEIs are to involve undergraduate students in the planning, design and delivery of mathematics courses, it will be helpful not only to have models of such collaborations for best practice, but also to have the research evidence base to support academic practice. In light of this, I started this research by exploring the literature on the most widely reported issue in undergraduate mathematics education research – the well-recognised "mathematics problem".

Within the last two decades, schools and departments of mathematical sciences in UK HEIs have made strenuous efforts to address "the mathematics problem" that beset many new entrants into higher education. The phrase "mathematics problem" (Hawkes & Savage, 2000) is commonly used to refer to the under preparedness of first year undergraduates for the mathematics elements of their degree programmes in a range of disciplines. Support for students unprepared for the study of tertiary mathematics has been provided in the form of online resources such as the mathcentre (http://www.mathcentre.ac.uk) and mathtutor (http://www.mathtutor.ac.uk) websites and mathematics learning support centres (Croft & Grove, 2006; Lawson, 2015). Mathematics learning support centres, originally provided to assist first year students in their learning while they make transition from school to university mathematics, have been extended to second-year students at some institutions (Croft, Grove, & Bright, 2009; Solomon, Croft, & Lawson, 2010).

However, a variant of the mathematics problem appears to be surfacing among undergraduate mathematics students making the transition from first year to second year (see Chapter 2, Section 2.2 for research on transitions). At the time this research began at Middle County University (MCU) – a pseudonym for the research site – this new variant of the mathematics problem was attributed to some historically problematic courses that needed redesign and development. The problem was evident in two courses Vector Spaces and Complex Variables, where, for a number of years, the pass rate had been significantly lower than in some other second year courses. Students who have coped satisfactorily with their first year of study have struggled in their second year. During the academic year 2010/11, the Department of Mathematical Sciences at the MCU decided to take steps to seek to address this problem.

In order to address the second-year transition challenges faced by some students in undergraduate mathematics, staff (including two course leaders, the learning and teaching coordinator of the mathematics degree programmes, members of the learning and teaching committee and a mathematics education specialist) at MCU discussed a curriculum development project aimed at improving the learning experience of future cohorts of second year students. A grant was successfully secured from the National HE-STEM programme to undertake the curriculum development project.

A unique feature of the curriculum development project was the recruitment of four student interns whose role was to collaborate with staff to redesign the two courses by creating new resources and improve existing ones such as lecture notes. In addition, a Peer Assisted Learning (PAL) scheme was implemented and attached to the redesigned courses. PAL was a collaboration between staff and third year students in course delivery. PAL is a form of participatory pedagogy. Solomon (2007) advocates participatory pedagogies as means to enhance the learning experiences of all students. In this thesis, the third-year students will be referred to as PAL leaders. The PAL leaders, who had previously taken and passed the two courses, were recruited to facilitate PAL sessions. The *student internship* and the *PAL scheme* were two features of the staff-student partnership which challenged the traditional staff-student roles in undergraduate mathematics education. I developed a personal interest in researching the staff-student partnership in the learning and teaching of Vector Spaces and Complex Variables because my preliminary readings highlighted the work of other researchers who have found that these two courses pose particular difficulties for students generally (see e.g. Britton & Henderson; 2009; Danenhower, 2000; Maracci, 2008). Rather than studying and describing the conceptual difficulties that students have in these courses, I thought it would be worthwhile to study the staff-student partnership process. I thought my study will he me to learn and understand how the partnership enhances the student learning experience; and increases student engagement with the courses.

In March 2011, I conducted a preliminary literature search on active student involvement in mathematics course design but the search did not reveal examples or case studies in undergraduate mathematics to inform the curriculum development project at MCU. As I will describe in the literature review (Chapter 2), I found some empirical research on student involvement in course design but the context of the research was in non-mathematical sciences disciplines. Although examples of student involvement in course design can be found in the literature, there is limited literature on student involvement in the design of advanced undergraduate mathematics courses. In contrast, the literature search revealed a great deal of empirical research on the most common form of student involvement in course delivery: PAL. In Chapter 2, I will discuss the literature relating to PAL in more detail.

For the purposes of the research reported in this thesis, I define advanced undergraduate mathematics as a course unit that can be studied by single or joint honours students after they have completed introductory first year mathematics course units. Undergraduate mathematics courses are designed hierarchically with year two courses requiring pre-requisites from year one. Material taught in the second year and beyond is very different from that studied by students at A-level or equivalent. The extent to which students, who had not completed their degree, can contribute actively to the design of resources for future cohort of students and to facilitate the learning of their peers was not certain. Given the level of abstraction and difficulty of second year courses, it was not clear to what extent third-year undergraduate mathematics students had the background knowledge and confidence to facilitate PAL sessions for second-year students.

When PAL sessions are offered to first year students, as they are all new to the university, it is more likely that they would want and need this form of support. However, after a year at university, second year students would have formed friendship and informal peer learning support groups and become accustomed to a teaching style for which they may not want change. This is because, as Duah, Croft and Inglis (2014) noted, the students would have formed a "didactic contract" (Brousseau, 1986, 1997) with their university mathematics teachers and this may need renegotiation if they were to engage with a new teaching approach such as PAL. The theory of didactic contract is used to describe "a system of rules, mostly implicit, associating the students and the teacher, for a given piece of knowledge" (Brousseau 1997, p.15). The rules of the didactic contract are general and not specific to mathematics, but they may need to be renegotiated when they deviate from the expected rules. Hence it was not clear to what extent second year students would want to engage with PAL. This research therefore sought to explore staff- student partnership in advanced undergraduate mathematics course design and delivery in order to answer the research questions posed in the next section.

1.2.2 *Research questions*

The overall goal of this research was to explore the impact of staff-student partnership in learning and teaching in both qualitative terms (*qualitative impact*) and quantitative terms (*quantitative impact*) for staff and student partners. The research was conducted in *three phases* each with its own focus. Each phase investigated one or more research questions of which there were five. In Chapter 3, Section 3.2.5, I provide a motivation and rationale for the research questions I set out to investigate which are as follow:

1. When undergraduate students are provided with an opportunity to collaborate as interns with staff in advanced undergraduate mathematics course design what is the nature of that collaboration?
2. How does the collaboration in course design impact on the student interns and staff?

3. What are the characteristics of PAL sessions for advanced undergraduate mathematics?
4. What is the qualitative impact of the staff-student collaboration in course delivery via PAL on PAL participants and PAL leaders?
5. What is the quantitative impact of the staff-student collaboration in course delivery via PAL on PAL participants?

Research questions one and two were investigated in *phase one*; research question three was investigated in *phase two*; and research questions four and five were investigated in *phase three*. In order to answer these research questions, a theoretical framework was chosen as a lens to analyse a range of qualitative data on the staff-student partnership in course design and delivery. A model of the relationships between a set of achievement and attendance variables was also created to explore the quantitative impact of staff-student partnership in course delivery via PAL on student achievement. The theoretical framework and the model of variable relationships are briefly outlined in section 1.3.

1.3 Theoretical framework for the study

This study employed Communities of Practice (henceforth CoP) (Lave & Wenger, 1991; Wenger, 1998) theory to explore the range of qualitative data in relation to the nature and characteristics of the partnership process and its qualitative impact on students and staff. The CoP theory had been used to explore learning in formal settings such as schools and informal social settings such as apprenticeships and play grounds, where formal teaching from a teacher is not required. I studied the staff-student partnership in course design and delivery over 15 months (March 2011– May 2012). During this period, I studied the student interns and staff co-creating teaching and learning resources during a six-week full-time internship; and students learning collaboratively in voluntary but scheduled PAL sessions. The internship working environment and the PAL sessions were informal social settings in which there was potential for learning and enculturation into the study of advanced undergraduate mathematics. I chose CoP theory as a lens to analyse these settings because they were both informal university environments in which students, and to an extent staff, had the opportunity to learn. Formal teaching did not take place during the internship or PAL sessions. Formal teaching in this context is teaching delivered by academic staff or graduate teaching assistants.

Williams et al. (2010) identified Communities of Practice as a possible theoretical framework for exploration of staff-student partnerships. Drawing on the ideas of Williams et al., Duah and Croft (2011) applied the Communities of Practice theory to analyse a *small* set of data on staff-student partnership in mathematics course design. The purpose of Duah and Croft's work was to test the applicability of Communities of Practice theory to staff-student partnership in advanced undergraduate mathematics *course design*. Healey et al. (2014) have recently proposed *partnership learning communities* as a potential theoretical lens for exploration of staff-student partnerships. More recently Biza and Vande Hey (2014) also explored a staff-student partnership in the development of learning resources for statistics. Their work provided inspiration and ideas of how Communities of Practice may be used as a lens in the analysis of data collected about staff-student partnerships in undergraduate mathematics.

In respect of the current research, I applied the Communities of Practice theory to a large and eclectic dataset (see Chapter 4, Section 4.8) on staff-student partnership in advanced undergraduate mathematics *course design* and *delivery*. In mathematics education research, the Communities of Practice theory has been operationalised to research learning and teaching practices in school mathematics classrooms, teacher education and professional development, the study of mathematical proof, and mathematics students' and teachers' identities. Hence, I chose Communities of Practice theory because examples of application of the theory, methods and procedures for data collection and analysis were available in the literature for critique, adoption or adaptation. Using Communities of Practice enables the social theory of learning to be tested against the qualitative data on course design and delivery.

In order to investigate the quantitative impact of staff-student partnership in course delivery via PAL on student achievement, I identified relevant dependent, independent and confounding variables from the existing research literature on PAL and showed diagrammatically (see Chapter 3, Section 3.3, p86.) how they are related. The variables and related data types which were needed to investigate the quantitative impact of PAL are also shown in Figure 3.4. In the next section, the research methodology employed in this current study is briefly described and discussed.

1.4 Research methodology

The research methodology adopted for the study was a mixed-methods design in which qualitative and quantitative data were collected in parallel. In phase one of the study, an ethnographic approach was used and methods of data collection included: surveys, interviews, focus groups, diaries, field notes, and documentary analysis. In phase two of the study, an ethnographic approach was again adopted to investigate the characteristics of PAL sessions and the qualitative outcomes of PAL for PAL participants and PAL leaders.

In phase three of the study, a quasi-experimental design was adopted to investigate the impact of PAL attendance on student achievement in each of the two courses, Vector Spaces and Complex Variables. An independent *t*-test, chi-square/Fisher exact tests, correlation and regression analysis were the main statistical analyses which were carried out to explore the relationship between PAL attendance and achievement and hence the effectiveness of PAL as a pedagogical intervention.

1.5 Contribution to knowledge

In Chapter 8 (see Section 8.3 pp.252-255), I outline the contribution made by this thesis to the knowledge base of *undergraduate mathematics education*, *academic development*, and *staff-student partnerships in learning and teaching*. The thesis contributes to knowledge in a number of ways.

First, as I noted earlier (see Section 1.2, pp.6-11), there is a paucity of empirical research into staff-student partnerships in which students play roles as *partners* and *change agents* in course design in advanced undergraduate mathematics. Therefore, this study adds to a small number of studies on staff-student partnerships in course design. This study responds to Healey et al.’s (2014) call for further research into staff-student partnership pedagogies across disciplines. The study found that staff-student partnership in undergraduate mathematics course design lead to enhanced relationship between staff and students; deepen students' understanding of the mathematics courses which they co-design; and lead to some change in university mathematics teachers' pedagogical practice. These findings are consistent with those reported in the literature in the context of other disciplines such as education (Bovill et al. 2011; Cook-Sather, 2014), geography (Moore & Gilmartin, 2010), history (Richardson, Schatz, & Owen, 1973) and more recently in mathematics and statistics (Rapke, 2016; Biza & Vande Hey, 2014). In this regard, this study broadens our understanding of staff-student partnerships in STEM disciplines generally.

Second, this study contributes to the knowledge base in undergraduate mathematics education research in that until this research was undertaken, little had been reported on the effectiveness of PAL for advanced undergraduate mathematics courses; little was known about the characteristics of PAL sessions for advanced undergraduate mathematics courses (Dawson, et al., 2014). It was unclear whether undergraduate students can facilitate the learning of their peers in advanced undergraduate mathematics courses such as Vector Spaces and Complex Variables. This study found that third-year students can facilitate PAL sessions for second-year courses and that PAL sessions foster a learning community in which trained senior students deploy "participatory pedagogy" that supports student engagement in mathematical practices that drive active learning.

Finally, the study also found that students who participated in PAL sessions had higher achievement in the final examinations of the redesigned courses even after accounting for prior attainment and lecture attendance. In this respect, this study has shown that PAL can be an effective and inclusive partnership pedagogical strategy in advanced undergraduate mathematics education. However, it does not completely resolve the problem of disengagement arising from "cooling off" or "sophomore slump". Furthermore, "participatory pedagogy" may be rejected by some students because they might have an implicitly established didactic contract on which they may be unwilling to renege.

1.6 Definition of terms

For the purposes of this thesis, the following terms have the meaning indicated.

Advanced undergraduate mathematics: an undergraduate mathematics course which is studied by single or joint honours students following introductory first year mathematics courses at university.

Course: a study unit or module which is taken by students over one academic year or semester.

PAL leader: refers to a student who facilitates the learning of other students in regularly scheduled sessions.

PAL participant: a student whose learning is facilitated by a PAL leader.

Peer: refers to another student in a lower, the same or higher year.

Peer Assisted Learning (PAL): is a voluntary peer learning support scheme in which students from higher years facilitate the learning of their peers from lower years in scheduled sessions that focus on disciplinary content.

Peer Learning Support: refers to all forms of learning support that are offered to students by their peers in order to enhance their learning experience and achievement.

Qualitative impact: refers to the impact of an intervention explored in qualitative terms.

Quantitative impact: refers to the impact of an intervention explored in quantitative terms.

Student satisfaction: a measure of students' contentment with their educational experience in and outside the classroom.

Student engagement: time and effort that students devote to educationally purposeful activities offered by a HEI to enhance the learning experience and to increase academic achievement.

Supplemental Instruction (SI): is an international programme of peer learning support in which SI leaders, who are peers from a higher year, facilitate the learning of their peers from lower years in SI sessions which focus on both course content and study skills.

1.7 Summary and thesis structure

In this Chapter, I have outlined the challenges students face as they transition from first year to second year. It is believed that these challenges could be addressed through active student involvement in course design and the introduction of participatory pedagogy such as advocated by Solomon (2007). PAL offers university mathematics teaching staff the space and resources to deploy such participatory pedagogy.

In Chapter 2, I present a review of the literature on staff-student partnerships in learning and teaching. The review first looks at the debates on transitions within undergraduate mathematics. This is then followed by a review of case studies and empirical research on staff-student partnerships in learning and teaching. Research on staff-student partnerships in course design and delivery via PAL is then discussed. In the same chapter, I review staff-student partnerships across disciplines generally and then focus on undergraduate mathematics where there have been prior studies on the topic. Chapter 3 outlines the theoretical framework and the model of relationships between variables explored in the current study. In Chapter 4, I discuss the research design and methodology.

The findings of the study are presented in Chapters 5, 6, and 7. Chapter 5 focuses on student involvement in the course design process; the nature of the collaboration; and outcomes for student collaborators and staff. Chapter 6 focuses on the implementation of PAL and the characteristics of PAL sessions. In Chapter 7, I present the results of the relationship between PAL attendance and student achievement in each of the two courses: 1) Vector Spaces and 2) Complex Variables.

Finally, in Chapter 8, I discuss the findings and the results presented in Chapters 5, 6 and 7 and outline the implications of the study for academic practice in undergraduate mathematics. I also highlight the limitations inherent in the study. I reiterate the original contribution of the research to the knowledge base of undergraduate mathematics education and academic development more generally. These are followed by suggestions for future research work and conclusions.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

As I discussed in Chapter 1, some students face academic and non-academic challenges when they transition *to* and *within* undergraduate mathematics. These challenges can have direct and indirect impact on the students' progression and retention (see e. g. Brown, Macrae, Rodd, & Wiliam, 2005; Daskalogianni & Simpson, 2000, Grove, Croft, Kyle, & Lawson. 2015). However, the emerging scholarship on staff-student partnerships in learning and teaching suggests that such partnerships can help ameliorate the challenges that some students face when they transition to and within undergraduate mathematics. Consequently, there is a growing recognition of the importance of staff-student partnerships in learning and teaching in the HE sector.

The growing recognition of staff-student partnerships has led to an international movement advocating for greater student involvement in the design of learning and teaching. Leading advocates of the movement for staff-student partnerships in learning and teaching include scholars in the field of academic and educational development (e.g. Cook-Sather, Bovill, & Felten, 2014; Healey, Flint & Harrington, 2014). These scholars have contributed to the empirical research on staff-student partnerships and findings of their studies indicate potential positive outcomes for staff and students who engage in these partnerships.

A recent special issue of the *International Journal of Academic Development* focused on staff-student partnerships in the HE sector (Bovill & Felten, 2016). Academic practice reports and various empirical research articles published in the journal indicate growth in the number of staff-student partnerships being created on many campuses. Healey et al. (2014) also report on case studies and examples of such partnerships in which students play roles as partners and change agents in curriculum and course design. Some partnerships occur at institutional and programme levels and others at course unit level. Other partnerships are not linked to specific course units. Rather, they focus on improving the overall student learning experience. This literature review is limited to staff-student partnerships that focus on learning and teaching development.

Hitherto, in the HEIs sector, the development of learning and teaching, and course design and delivery have been the sole province of academics and educational developers. Therefore, staff-student partnerships represent a paradigm shift in the roles and responsibilities of staff and students in the learning and teaching process. Healey et al. (2014) and Cook-Sather et al. (2014) have argued the pedagogical case for staff-student partnerships, as we shall see in Section 2.3. However, as Healey et al. (2014) point out, there is a need for investigations into disciplinary pedagogies that sustain staff-student partnerships in learning and teaching.

In light of the foregoing, in Section 2.2 of this chapter, I discuss issues on transition to and within undergraduate mathematics education. In Section 2.3, I focus on the nature of staff-student partnerships in learning and teaching generally. Relevant studies on staff-student partnerships in undergraduate mathematics will be highlighted and reviewed. More specifically, Section 2.3 will focus on the literature on students as partners in: pedagogical consultancy and research; curriculum and course design; and teaching via Peer Assisted Learning (PAL). Section 2.4 reviews approaches to researching staff-student partnerships. In Section 2.5, I also review the findings of the research on staff-student partnerships reported in the case studies discussed in Section 2.3. I summarise the chapter in Section 2.6.

2.2 Transitions in undergraduate mathematics education

Transitions *to* and *within* undergraduate mathematics education have been well researched (see e.g. Gueudet, 2008; Hernandez-Martinez et al. 2011; Kajander & Lovric, 2005; Tall, 2008; Winsløw, Barquero, De Vleeschouwer, & Hardy, 2014; Williams, 2015). The research indicate that some students face challenges with their studies on entry onto mathematics degree programmes. Others may also face challenges with academic work as they progress through their degree programmes. While many students succeed in their studies and relish the challenges that come along the way, for some, these challenges result in disengagement and alienation from the discipline (Solomon & Croft, 2016).

There are several contributing factors to these challenges. In relation to transition from school to tertiary mathematics, the challenges had been attributed to students' under-preparedness for undergraduate mathematics study (e.g. Hawkes & Savage, 2000; Hoyles, Newman, & Noss, 2001). If students are not well prepared for university mathematics study because they lack competency in skills and knowledge required for embarking onto a mathematics degree programme, this may affect their achievement and progression throughout their degree programmes. Even if they progress, some students may disengage due to lack of success arising from the fact that they are unable to do assignments set for course units on which they are enrolled (Brown et al., 2005). Brown et al. suggest that undergraduate mathematics is unlike other disciplines in that lack of success is more obvious because when students are unable to solve problems set as assignments, they are in no doubt of their struggles. When these struggles continue throughout the students' learning journey beyond the first year, it should be expected that some would disengage.

Other factors that contribute to the transition challenges that students face on entry onto their degree programmes are: wrong course choice; the traditional university mathematics pedagogy; and the nature of university mathematics and its practices which are both different from those of school mathematics and its practices. (Hawkes & Savage, 2000).

The traditional university mathematics pedagogy is described by several researchers as being transmissionist in style (see e.g. Sharp & Berry, 1999; Williams, 2015). Reporting on the findings from the Transmaths project, Williams (2015) note that "transmissionist" teaching was prevalent in the university and college lectures which were observed by researchers on the project. Thus, in the contemporary teaching environment in undergraduate mathematics, transmissionist teaching approach can still be observed in scheduled lectures and seminars. Williams argues that this traditional pedagogy leads some students to disengage and underachieve and eventually withdraw from their degree programmes. He goes on to provide evidence that shows that transmissionist teaching (as reported by teachers) correlated negatively with students' dispositions towards mathematics. Thus, the attitudes of students of transmissionist teachers declined more sharply than those in less transmissionist classrooms.

As some students transition from school to undergraduate mathematics, they may lose interest in the subject. Drawing on Clark's (1960) theory of "cooling-out", Cooper (1999) described the developing loss of interest in mathematics by some first-year students, as "cooling-off". Daskalogianni and Simpson (2002) also argue that some students who "cool-off" due to loss of interest may bounce back and begin to warm to the subject. However, other students, they suggest, never bounce back and eventually drop out or switch their degree programmes. Daskalogianni and Simpson referred to this state of affairs of the students who never bounce back as "cooling-out. Cooling-out or disengagement from the subject could also be explained by the reasons students give for choosing to study mathematics at university.

Students choose to study undergraduate mathematics for a variety of reasons. These reasons might include: 1) the generic skills that the study of the subject develops in graduates which align with some students' career aspirations, and 2) students' previous success at school and college (Brown et al., 2005; Hoyles et al., 2001). As students transition from secondary to tertiary mathematics or from one level of undergraduate mathematics to the other, this variety of reasons for studying mathematics may engender different motivations for engagement with the subject. Those students who perceive the mathematics they are studying to be too abstract to have any value in their future careers may become disillusioned. Those who find that they are no longer successful at the subject as they used to might also become disengaged from the subject (Brown et al., 2005). When students become disillusioned and disengaged from undergraduate mathematics, their success and progression on their degree programmes is not guaranteed.

Some researchers have drawn on “didactic contract” (Brousseau, 1997) to examine and explain student disengagement in undergraduate mathematics when they transition to and within undergraduate mathematics. Didactic contract is a construct of Brousseau’s theory of didactical situations and may be used as a lens to understand the relation between teachers and students with respect to learning and teaching. Warfield (2006) brought the term, didactic contract, to English speaking audiences as the original writing of Brosusseau was in French. She explained that in a classroom there is:

> *a complex set of relationships of obligations between teacher and student. Sometimes explicitly, but more often implicitly, a determination is reached about what each has the responsibility for managing. The resulting system of reciprocal obligations resembles a contract. The part of that contract that is specific to the target mathematical knowledge is called the didactical contract. (Warfield, 2006, p. 33)*

The didactic contract, then, is an implicit relationship between the teacher and students with respect to mathematical knowledge. This relation comes with reciprocal responsibilities and expectations of both the teacher and the students. When these responsibilities are not fulfilled and the expectations are no met, either party to the contract may become unhappy.

Trouche (2005) draws on the construct of didactic contract to suggest that students can expect the teacher to have taught them what they need to know to solve problems and complete assignments and examinations successfully. With this expectation, students may become unhappy if they are faced with problems on a mathematical topic that they cannot do. In this scenario, students may attribute their inability to solve problems to the teacher not having taught them well and not upholding his/her side of the didactic contract. Trouche also suggests that students also have responsibilities under a didactic contract. He argues, that teachers can expect their students to take reasonable steps to learn the material that has been taught and that they can also become unhappy if students do not carry out their part of the didactic contract.

As I noted earlier, some first-year students choose to study mathematics because they have enjoyed it at school and have been good at solving problems successfully (Brown et al., et al., 2005). However, Pritchard (2015) points out that these successful students would have had didactic contracts with their schools or post-16 college mathematics teachers. These didactic contracts would have involved teachers providing, frequent and regularly, set of problems to their students which they can solve with procedures supplied by their teachers. The teachers would have provided regular feedback on performance. In addition, students would be taught in small classes where collaboration and frequent communication in class is allowed. Pritchard suggests that when students enter university, this prior didactic contract may be threatened as university teachers expect students to be become independent. In addition, the large class sizes coupled with less frequent staff feedback and also a reduction in one to one support may leave some students feeling that they are struggling.

Based on Trouche (2005) and Pritchard (2015) arguments above, I will suggest that students may have expectations of their university mathematics teachers that are based on their prior learning and teaching experiences. Therefore, when students enter into their degree programmes, if their expectations are not met they may disengage with the subject. Thus, among other things, when students are unable to reconcile their pre-university didactic contract with the didactic contract that they implicitly sign up to on entry to university mathematics studies, they may face learning challenges which could lead to disengagement from the subject.

Many UK universities recognise the challenges that students face with their studies of undergraduate mathematics particularly in the first year. I noted in Chapter 1, Section 1.2 that much has been done by UK HEIs to enhance the mathematics learning experience of first-year undergraduate students. For example, many UK HEIs now have mathematics learning support centres where students may obtain support for their learning (Lawson, 2015). Support at these centres may be provided by staff or postgraduate tutors. These support centres were originally set up to support students as they adjust to a new learning environment and new ways of teaching. These support centres may be accessible to second-year students. However, the focus of many mathematics learning support centres is very much on first-year students.

Research show that, across all disciplines, when students transition into the second year (also known as “sophomore year” in the USA) some may disengage and underperform in their studies. This phenomenon of disengagement and underachievement is referred to in the literature as “sophomore slump” or “second year slump”. McBurnie, Campbell and West (2012) define “sophomore slump” as the “lack of engagement that can be experienced by students entering their second year at university” (p.14). Many factors may contribute to the sophomore slump or second year slump. Some of these factors include stresses, lack of motivation, struggle with learning which leads to student disengagement in university life in the second year (Loughlin et al., 2013; McBurnie et al., 2012; Thompson, et al., 2014)

Research also show that some undergraduate mathematics students also continue to face challenges in their learning as they transition from the first year through to the final year (see e.g. Brown et al. 2005). While much has been done to enhance the first year learning experiences of undergraduate mathematics students, Croft, Solomon, & Bright (2007) argue that it is important that we do not forget continuing students who have completed their first year studies. It is in the second year that for the first time, the mathematics content may become unfamiliar to students with the introduction of courses such as Vector Spaces/Advanced Linear Algebra, Complex Variables/Introduction to Complex Analysis, and Real Analysis. Proofs begin to feature often in most courses after first year. Students begin to see a major difference between the learning experiences of advanced mathematics courses (see definition on p 15) and introductory first-year mathematics courses the content of some of which may be akin to A-level mathematics. The difference in the learning experiences between the first year and the second year can be a source of frustration for some students who may wonder whether they are good enough to succeed on their degree programme.

Learning and teaching undergraduate mathematics involves engagement with university mathematics praxeologies (Winsløw et al. 2014) and for students there are transition points during the engagement process. When students enter into university to study tertiary mathematics, they are expected to align with and engage with university mathematics praxeologies. However, students may be unfamiliar with these praxeologies and as assessments are often based on these, they may face transition challenges which can impact on their achievement.

Winsløw et al. drew on the work of Chevallard (1987) to discuss two types of transitions within undergraduate mathematics – *transition to theoretical blocks* and *transition to practical block*. The first type of student transition within university mathematics study involves the transition to the theoretical blocks. The theoretical blocks, Winsløw et al. argue, often develop within some branches of the mathematics discipline before the practical blocks, and yet often mathematicians work with both blocks. As students' progress through their study, they may be expected to draw on their knowledge of the theoretical blocks to work with the practical blocks, which is the second type of transition within university mathematics. However, unless students' theoretical blocks have been well developed, their engagement and alignment with the practical blocks may prove challenging for them.

Given the growing calls for staff-student partnerships in learning and teaching and their potential positive outcomes for student engagement with their studies, a reasonable conjecture is that staff-student partnerships in learning and teaching in undergraduate mathematics may help lessen, at least for some students, the challenges that students face as they transition to and through their undergraduate mathematics degree programmes. In the next section, I discuss the nature of staff-student partnerships in learning and teaching.

2.3 Staff-student partnerships in learning and teaching

In Section 2.1, I noted the growth in staff-student partnerships in learning and teaching on campuses around the world. I also noted staff-student partnerships aim to enhance the student learning experience; to increase student engagement with their studies; and foster student integration into the university community more generally. Although there has been a growth in staff-student partnerships in recent years, these partnerships do not constitute a new phenomenon in the education literature. Bovill (2014) points out that staff-student partnerships have their origins in critical pedagogy and in pretertiary education literature. Furthermore, as we shall see in Sections 2.3.1-2.3.2, there are examples of staff-student partnerships in learning and teaching in the literature that date back to the 1970s.

In the HE context, there is so much diversity of initiatives reported as staff-student partnerships such that the term *staff-student partnership* might be a slippery one to define (Cook-Sather et al., 2014). The UK Quality Assurance Agency for example, suggests that:

> *"the terms 'partner' and 'partnership' are used in a broad sense to indicate joint working between students and staff. In this context partnership working is based on the values of: openness; trust and honesty; agreed shared goals and values; and regular communication between the partners. It is not based on the legal conception of equal responsibility and liability; rather partnership working recognises that all members in the partnership have legitimate, but different, perceptions and experiences. By working together to a common agreed purpose, steps can be taken that lead to enhancements for all concerned. The terms reflect a mature relationship based on mutual respect between students and staff (QAA, 2012, p. 5).*

The preceding quote from QAA indicate that staff-student partnership does not absolve staff of their role as university teachers and that staff-student partnership is not a legal relationship between staff and students. So the legal and contractual responsibility for the development of learning and teaching in HEIs where such partnerships exist still rests with university teachers. The National Union of Students (NUS) in England also suggests in its Manifesto that:

> *At its roots partnership is about investing students with the power to co-create, not just knowledge or learning, but the higher education institution itself … A corollary of a partnership approach is the genuine, meaningful dispersal of power … Partnership means shared responsibility – for identifying the problem or opportunity for improvement, for devising a solution and – importantly – for co-delivery of that solution (NUS, 2012, p. 8).*

The NUS description of staff-student partnership above uses the term partnership in the broad sense, encompassing all areas of staff student relationships that support a universities mission in teaching and research. Staff and students work in partnerships in many areas of university life. For example, as I noted in Chapter 1, it is common practice for staff to involve students in institutional governance and to invite them to serve on university committees. It is also common practice for HEIs to also involve students in their quality assurance processes; development of institutional strategies and policies; estates and facilities development; community engagement and extra curricula activities (Healey, et al., 2014). These partnerships, important as they are, may not necessarily have direct influence on what goes on in lecture halls, tutorials and seminars rooms.

Cook-Sather et al. (2014) provide a definition of staff-student partnership that directly includes terms that are related to learning and teaching. Cook-Sather et al. define staff-student partnership as a "reciprocal process through which all participants have the opportunity to contribute equally, although not necessarily in the same ways, to curricular or pedagogical conceptualisation, decision making, implementation, investigation, or analysis" (p.6). The notion that staff-student partnership in learning and teaching is a process is echoed by Healey et al. (2014). They suggest that staff-student partnership in learning and teaching is not a product but a process for enhancing the student learning experience.

In a staff-student partnership in learning and teaching, the roles that students can play are varied. Healey et al. (2014, pp.7-8) outline four broad areas in which students can work with university staff as partners in learning and teaching. These four broad areas are:

1. learning, teaching and assessment;
2. subject-based research and inquiry;
3. scholarship of learning and teaching;
4. curriculum design and pedagogic consultancy.

Healey et al. describe in detail each of the above areas in which students can work as partners and change agents in learning and teaching. They describe the specific activities in which students can engage and contribute either to their own learning or to the learning of their peers. For example, Healey et al. suggest that as partners in learning, teaching and assessment, students may work with staff as active participants in their *own* learning, and be involved in the teaching and assessment of their peers and *themselves*. When students partner with staff to support the learning and teaching of their peers, they engage in *peer learning*, a process which can be distinguished from *peer mentoring*. The former focuses on subject content while the latter focuses on social, emotional and motivational aspects of learning. I will return to peer learning in Section 2.5.

Healey et al. also suggests that students may work with staff as partners in disciplinary research or research that forms part of inquiry based learning. Staff who undertake Scholarship of Teaching and Learning (SoTL) activities may partner with students who are then engaged in research projects that investigate aspects of learning and teaching on a course with the view to improve student learning. Students may also partner with staff to co-create curriculum and provide pedagogic consultancy. As co-creators of curriculum and pedagogical consultants, students may contribute to course design and the development of teaching, observe teaching and provide feedback to staff.

In the context of undergraduate mathematics education, the notion of students as partners in pedagogical consultancy and research, may be seen as a novelty at best, and at worst as revolutionary. Some academic staff will argue that undergraduate students do not have adequate subject knowledge, let alone pedagogical knowledge, to make meaningful contribution as pedagogic consultants. However, staff-student partnership in learning and teaching positions staff and students jointly as both teachers and learners (Cook-Sather, et al., 2014; Healey, et al. 2014). Each party comes to the partnership with different but equally valuable expertise. Staff-student partnership in learning and teaching development challenges the traditional relationship between academic staff and students; a relationship based on the notion of expert and novices in the learning and teaching of an academic discipline (Bovill et al., 2011). Staff-student partnership in course design and delivery redefines the traditional roles of staff and students in the course design and delivery process.

Similarly, Bovill et al. (2015) describe three specific roles that students may play in a staff-student partnership that focuses on what they call the “co-creation of teaching and learning”. They suggest that the roles that students play in such partnerships include students as: *co-researchers*, *consultant*s, and *pedagogical co-designers*. As co-researchers, students may work with staff in disciplinary research or pedagogic research. As consultants, students may be involved in teaching observations or play active roles in the evaluation of teaching and course design. As pedagogical co-designers’ students may co-create learning and teaching resources for VLE and design a new course unit.

Like Bovill et al., Healey, Bovill and Jenkins (2015) describe three specific student roles in staff-student partnerships in learning and teaching. These, they suggest, are students as teachers, scholars and change agents. The description of student roles as teachers may raise concerns amongst university mathematics teachers as they may view students as untrained and unqualified to teach. However, it appears Healey et al. use the term teachers to refer to student roles as peer learning facilitators or similar roles such as peer tutor.

As scholars, students may engage in research which is embedded in the disciplinary subject which students study or is related to pedagogical developments. Where students’ scholarly activity also leads to change in teaching and learning practices at departmental or institutional levels, the students may also be described as change agents (Dunne & Zandstra, 2011) within the partnerships of which they are part.

It seems, from the discussion so far, that staff-student partnerships afford students opportunities to participate actively in some aspects of learning and teaching development. However, Cook-Sather et al. (2014) point out that such partnerships do not assume that staff and students have equal powers in the collaborative relationship, a point also made in the QAA’s definition of staff-student partnership.

The research on staff-student partnerships consistently report potential positive outcomes of staff-student partnerships for the staff and student partners. I will return to the findings on the outcomes in Section 2.5. Here, I wish to point out that research findings on the potential and reported outcomes of staff-student partnerships have led to increasing calls to higher education institutions (HEIs) to actively involve students in shaping and developing their own learning and that of their peers' (see e. g. Cook-Sather et al., 2014, Healey et al., 2014). In Chapter 1, I indicated that the National Union of Students and the former 1994 Group of Universities called for greater student involvement in the development of learning and teaching. I also indicated that the UK Quality Assurance Agency (QAA) identified staff-student partnerships as good academic practice which aims to enhance the student learning experience. Staff-student partnerships in learning and teaching are not panaceas and are by no means without challenges.

Bovill, Cook-Sather, Felten, Millard, and Moore-Cherry (2015) argue that there are potential challenges involved in staff-student partnerships that engage students as co-creators in curriculum and course design and offer suggestions as to how such challenges may be addressed. These challenges include staff and students' resistance to the notion of students as partners; their negotiation of institutional structures, and policies particularly those related to course specification, design, delivery, and assessment; and dealing with inclusivity, an issue also raised by Healey et al. 2014. Bovill, et al. (2015) suggest that staff should embrace these challenges and attempt to address them because the benefits of staff-student partnerships in co-creation is worthwhile. They suggest good communication with all stakeholders and institutional support through funding as some of the ways in which these challenges may be addressed. It is not possible for staff and students in a partnership to anticipate all the challenges that may come their way. However, through dialogue and good communication these challenges may be addressed.

Empirical research into staff-student partnerships in the development of learning and teaching in many disciplines is still a young field and even more so in undergraduate mathematics education. Healey et al. (2014) suggest that further research into staff-student partnerships is needed for a much broader understanding of how partnerships work in disciplines in which there are limited case studies and empirical research on staff-student partnerships. Such research they argue, might highlight disciplinary pedagogies which are appropriate and relevant for successful and sustainable partnerships. In Sections 2.4 and 2.5, I describe and discuss examples of staff-student partnerships in the development of learning and teaching in general; how they have been researched; and the outcomes for staff and students who were involved in such partnerships.

2.3.1 *Students as partners in pedagogical research and consultancy*

Sandover, Partridge, Dunne, and Burkill (2012) discuss the Students as Change Agents (SCA) project based at the University of Exeter. In their paper, Sandover et al. report on two SCA projects in which students made meaningful contributions to enhancing the learning experiences of Bioscience and Business students.

In the first project, students conducted pedagogical research within the Bioscience department and used the evidenced gathered from the findings to create significant change in the learning experience of their peers. The student partners in the SCA project surveyed first-year and second-year Bioscience students about their learning experiences and found that the majority of students struggled with writing. Although support for writing at the time was available to students, it appeared that the support did not meet their needs. So the student partners surveyed staff and students about the specific nature of the problem and how that can be addressed. The findings from this second survey led to the students co-creating material to address the problem with writing students were facing. A guide book on writing was produced and made available to students.

The second project that Sandover et al. reported on involved students researching the use of new technologies in the Business School. The students found through a student led focus group, interviews, and survey that 75% percent of 207 respondents to the survey made use of video recordings when they had difficulties understanding lectures. The findings from the data also suggested that students reported that the use of electronic voting systems (EVS) kept them focused in lectures and they appreciated the interactivity that EVS allowed. These students’ perspectives on the use of technology became the driver for the Business school to push for the strongest use of technology.

While the changes made in the Biosciences Department and the Business School may not be entirely attributed to the actions of the student partners in the SCA project, Sandover et al. report that the findings from the student research provided the evidence base needed to justify the expense on the new technologies. Thus, in some respect the students contributed to institutional change and thus acted as change agents.

When students play active roles as pedagogic consultants in a staff-student partnership, they are typically deployed as observers of teaching in lectures, tutorials and/or seminars. Staff-student partnerships in which students act as pedagogic consultants may have different names on different campuses. The most often cited pedagogic consultancy partnerships are *Students as Learners and Teachers (SaLT)* (Cook-Sather, 2008), *Students Consulting on Teaching (SCOT*) (Crawford, 2012) and *Student Observer Program*[sic] (2015). Despite their different names, these programmes share the same overarching goal – to enhance the quality of teaching with the view to improve the student learning experience and achievement.

As an example, at Bryn Maw College in Pennsylvania, USA, Cook-Sather (2011) report that there have been 137 staff-student partnerships as part of the college's programme called SaLT. In this programme, staff and students are invited to engage in reflective dialogue about teaching. Staff initiate the process and an academic developer facilitates the partnership process. Across the college, staff with varying levels of experience, from new staff to those with 45 years' experience had formed pedagogic consultancy partnerships with students. Fifty-seven students have also acted as student consultants. These consultants do not enrol in the course for which they serve as consultants.

In the SaLT programme, a student consultant meets with staff at the start of a semester for two hours to define and clarify expectations and goals of the consultancy relationship. Thereafter, the student consultant visits classes which are taught by the staff in order to observe the staff teach and take notes on pedagogical issues which the staff partner had identified. If the staff requires, the student consultant may survey and/or interview some of the students in the lecture observed. The student consultant meets with staff weekly to discuss the teaching observation notes and provide feedback to the staff. Feedback is provided to staff half way through the semester and at the end of the semester. In addition, the student consultant meets weekly with the SaLT coordinator staff to discuss progress. The student consultant also visits the staff seminars five or more times over the semester. There is also a closed blog to which the student consultant and staff can post their thoughts about teaching; and there is a portfolio of activities developed for the staff and the student partner pairs.

In the UK, it is now common for university teachers to be observed teaching particularly if they are new to university teaching. These observations are often part of the performance review process but can also be informal peer-to-peer observations. In these peer-to-peer collaborations, one academic member may invite another to observe his/her teaching in lectures and/or seminars. These observations are conducted amongst equals (except perhaps in terms of professorial ranks) as part of the professional development of the academic staff being observed. Thus, I will argue that pedagogic consultancy offered by students is an additional professional development activity which has the potential to enhance the student learning experience just as staff peer-to-peer observations may also do.

Like the SaLT partnership programme, SCOT invites students to observe staff teach and to provide feedback to the staff. Crawford (2012) reports on a UK project that implemented SCOT at the University of Lincoln. Initially six students were employed on an hourly basis to observe teaching and offer their individual student perspective on teaching episodes to staff. Before undertaking any observations, students are offered training. The student consultants observe courses which they have not taken before. They do not observe the teaching of a course they currently take. Ten academic staff took part in the SCOT programmes and 15 consultations were offered by students to staff. Some scholars in the field claim that student observations of university teachers' teaching are effective compared to observations conducted by institutions to satisfy human resources requirements. For example, Crawford argues that "performance-led approaches to gaining feedback on the student experience … are at best impersonal, untimely and ineffective and at worst de-skilling and devaluing of professional practice in higher education" (p.52).

It is worth pointing out that student observation of teaching in tertiary institutions is not a new phenomenon. Hagström, Oslon and Cross (2015) note that the Student Observer Program [sic] began in the 1970's at Carleton College in the US, and it is still a part of their well-established staff mentoring programme. The programme is separate from the observations that may be conducted for performance review purposes. The programme, like all the other schemes described previously, is a partnership between staff and students. However, as Hagström et al. note, the students are hired and trained by the college's learning and teaching centre (LTC). The training emphasises confidentiality and observation techniques. The observation is focused on how the class runs rather than the disciplinary content. As such no attempt is made to match students disciplinary background to the classes they observe.

Hagström et al. also note that it is staff who request observation, with most request coming from new staff. Staff and the student observer meet to discuss the focus of the observation before it takes place. They also meet after the observation to discuss how well the class has run. Examples of things that students may observe are class dynamics, how well discussions run, staff rapport with students, students' attentiveness, and staff response to questions and similar class related things.

The case studies of students as pedagogic consultants do not always report the subjects in which students have observed teaching. This may be due to the fact that the partnerships are often centrally run rather than being locally situated within specific disciplinary boundaries. Reports on activities of these partnerships therefore tend to be generic and not discipline specific. Hence there is a paucity of case studies on students as partners in pedagogic consultancy in undergraduate mathematics. Also, the case studies reviewed in the next Section can inform practice and research because although there are many case studies of staff-student partnerships in curriculum and course design, and assessment there is also a paucity of empirical research that focuses on these partnerships in undergraduate mathematics.

2.3.2 *Students as partners in curriculum and course design and assessment*

Scandrett, O'Leary & Martinez (2005) describe a project known as "Agents for Environmental Justice". The project was funded by the Community Fund set up by the Scottish government. The funding supported several environmental activists (known as 'agents') through the Higher Education Certificate (HEdCert) in Environmental Justice programme which is validated by Queen Margaret University College. This certificate course, also described by Bovill et al. (2011), presents students with a course framework defined by staff to satisfy university validation conditions. The framework included the delivery of science and law modules on the HEdCert course.

The content of each module, however, was decided upon by students enrolled on the course. Bovill et al. (2011) reported that students on such a course may negotiate with staff to study, for example, legislation (law module) and the chemistry (science module) relating to toxic waste. Students on the Environmental Justice course played a role as partners in the negotiation of the course content. The students decided on the content by drawing on their own experience, skills and interest. However, they needed to develop the skills required to discuss, compromise and agree on the course content to meet university regulations, the needs of communities in which they operate, and their own needs as activists. Scandrett et al. (2005) note that this type of partnership has a "distinctively dialogical epistemology". The knowledge of the content is derived from the body of knowledge that exists within the university, the skills and experience of people in the communities in which the students acted as agents.

While the approach to partnership described by Scandrett et al. (2005) may have worked successfully for the students, it may have limitations in some disciplinary contexts. The number of students on the Environmental Justice course was small, about at 16 students. The notion of asking each student's view regarding what they would like to be covered in a course may not be pragmatic for first-year or second-year mathematics courses with a hundred or more students. For many mathematics courses, students may not have the epistemological knowledge and experience to decide on the content that they wish to study as in the case of the Environment Justice course.

When undergraduate mathematics students set out to undertake an independent study which culminates in either a dissertation, a report or an essay, it is plausible that staff and students could negotiate the topic of the dissertation or report. However, it is worth pointing out that some courses, such as the Environmental Justice course, are not regulated by external professional bodies. Although undergraduate mathematics courses are not regulated in the same way as medicine or law, in the UK, they are designed according to benchmarks endorsed by members of the learned mathematical societies such as London Mathematical Society, the Institute of Mathematics and Its Applications and regulatory bodies such as the Quality Assurance Agency for Higher Education (QAA). Moreover, university systems, procedures and policies may not be flexible enough in all institutions to allow for dynamic changes in course content.

Students may partner with staff to co-design a course they have previously taken. Richardson, Schatz and Owen (1973) report a case study in which a History course was redesigned through a partnership of staff and students at Syracuse University. This 1973 case study also illustrates that staff-student partnerships in course design, like the Student Observer Program [sic], is not a new phenomenon. The History course had an average enrolment of 400 students. The course was taken by first-year and second-year students. The History course was redesigned to improve the learning experience of future cohorts of students. This staff-student partnership involved thirteen honours students who played roles as course "content team" experts.

Staff decided to form a partnership with students to co-create the history course because they wanted to see what would happen when students were given a key role in decision-making regarding course design. Staff wanted to know whether students bring new insights into the course development process and whether students could handle the responsibility as content experts. Staff had several questions they wanted to find answers to through the partnership process. These questions included: What problems would be involved? Would student ideas offer new insights into course development? Would their suggestions prove feasible? Could students handle this much responsibility, and could a group of this size work together effectively? Staff hoped that the project could help answer these and other questions so that the they could learn how to involve students in course redesign in the most productive way possible.

The first step in the course design process was that the team established their goals based on the staff ideas and philosophy; and the ideas and philosophies of the 13 student partners. Next, the team of 13 honours[sic] students discussed the content of the new History course based on their ideas and philosophies. This was followed by a survey of the 400 students enrolled on the course. The survey had questions which sought background data about the students, the History content areas in which they had interest, their likes and dislikes about the course, and their goals in taking the course. Of the 400, 250 responded to the survey. The survey also had open ended questions such as: "What are some of the most important things you expect to learn in this course?" "What would 'turn you off' in a history course?" (p.4). The 13 students engaged in discussions to explore what needed to be done based on their findings. As we shall see in Chapter 5, this approach to course redesign resonates strongly with the staff-student partnership in undergraduate mathematics course design which is the focus of the current study which is reported in this thesis.

Similarly, Mihans et al. (2008) report a case study of a staff-student partnership in which a course design team which included two academic staff, seven undergraduate students, and one academic developer was assembled to redesign an education course. The education course was chosen for redesign as students, who were prospective teachers, had been unsatisfied with both the syllabus, teaching and resources such as textbooks. The two academic staff initiated the course redesign process. It was then that students were invited to apply to join the course design team. Students who joined the course design team were paid for their role as co-creators of course design. The students' role was to take active part in the discussion on course description and materials, textbook selection, assignments and assessment policy. The syllabus was then constructed by staff considering students' perspectives on learning and teaching within the local institutional framework and policies.

Mihans et al. further report that some students were motivated to partner with staff because they wanted to improve on the learning experience for future cohorts of students. Others were motivated to partner with staff because the course that required redesign was of importance to the students' current curriculum. Mihans et al. also note that as academic staff, their "goal was to honor [sic] students' needs while at the same time, maintaining the integrity of the course". This is important because, as I have noted earlier, staff-student partnership in course design is not about staff relinquishing their roles and responsibilities as experts in the discipline to students. Rather, staff-student partnership is about staff recognising the equally valuable expertise that students have – they are experts on being university students. Therefore, they bring to bear on the course design process what works best for them as learners and what does not work.

Similarly, Moore and Gilmartin (2010) describe a staff-student partnership in which three undergraduate students, who had previously taken and successfully completed their second year were recruited as interns to develop content for a first-year Geography course. The course usually has around 400 enrolled students. Staff identified four case studies for which additional material was to be produced by the student interns for a Virtual Learning Environment (VLE). The material to be produced included videos of the case studies. The student interns were given the autonomy to produce content that they considered to have the potential to engage future cohorts of first-year students. In this partnership, the student partners also met weekly with staff to review progress and deal with any challenges that arose. the student partners were given access to iMac computers, video cameras, digital photo cameras and the Internet, tools that were necessary for anyone creating VLE content. Following the internship, the staff reviewed the material that had been produced and made any changes that were necessarily to ensure that the academic integrity of the learning material was maintained.

Thus far, the case studies in co-created curriculum and course design that I have described have focused on disciplines in non-mathematical sciences. However, research into staff-student partnerships in course design and assessment are beginning to emerge in undergraduate mathematics education (e.g. Biza & Vande Hey, 2014; Rapke, 2016). Biza and Vande Hey (2014) explored a staff-student partnership in which students were engaged as partners to co-create resources for learning and teaching statistics. Three student partners worked as summer interns to create resources for second-year students who studied a statistical methods course unit.

In addition, eight third year undergraduate mathematics students who were completing their studies undertook dissertation projects in which they developed and evaluated resources for learning and teaching statistics in non-mathematical sciences disciplines. These projects were undertaken in collaboration with staff and fitted the notion of scholarship in learning and teaching. I discuss the research methodology employed by Biza and Vande Hey in Section 2.4. Here, it is worth pointing out that, the motivation of the eight students for participating in the partnership was masked by the fact that their contribution to the partnership was subject to a summative assessment and the results of which contributed to their degree classification. It is hard to disentangle the conflict between the competing goals of the student partners in this partnership – that which is to gain a good grade towards their degree and that which is to contribute to enhancement of the learning and teaching of their peers. However, it is not unusual for students to work as partners in learning and teaching and be given credit for their efforts.

Assessment is an important component of course design. Research into student peer assessment in undergraduate mathematics education and other disciplines in HE has received considerable attention in recent years (see e.g. Jones & Alcock, 2014; Topping, 2009). Peer assessment is a form of partnership in which students collaborate with staff and their peers in the assessment of disciplinary tasks. These assessment tasks may be formative or summative. Peer assessment is typically a reciprocal process and both the assessor and the assessee receive feedback which may be immediate. Thus, a benefit of peer assessment for learning is therefore the immediacy of feedback for both the peer assessor and assessee. Assessment tasks, whether they are formative or summative, are traditionally created by staff. Undergraduate mathematics summative tasks in the UK are often paper and pencil written examinations and the examination questions items are written by staff. However, Rapke (2006) dared to challenge this mode of assessment by involving students as co-creators of final examinations items.

Rapke reports on a case study of a staff-student partnership in the development of a closed-book examination paper. Thus, the student partners in the study were co-creators of assessment material. All students for a bridging mathematics course were involved in the co-creation activity at a Canadian university. Each student had to create two mathematics assessment tasks. The students initially developed two question items for a practice examination paper together with the mark scheme. Students exchanged their assessment material and in pairs sit each other's papers.

Subsequently, the staff used questions from the practice papers in constructing the final summative assessment that all students had to sit and answer questions in the assessment material given to them. This case study was indeed an all-inclusive partnership and perhaps one of few such partnerships since in many partnerships student partners are chosen from a cohort of students. Peer assessment can informally take place in peer-to-peer learning support sessions. Next, I discuss students as partners in teaching through peer learning support sessions.

2.3.3 *Students as partners in teaching*

Traditionally, undergraduate teaching is delivered through a mixture of lectures, seminars, tutorials, staff office hours, laboratory work, workshops, work-based learning and individual private study. With the advent of new technologies teaching is now also delivered via VLE. Academic and related staff and postgraduate teaching assistants usually work in partnership to deliver course content through one or more of the above means. However, in the last forty years, there has been continuous growth in the number of staff-student partnerships in which undergraduate students take active part in the delivery of course content. These partnerships, as we shall see, are not uncommon and there is an extensive research base that looks into the effectiveness of these partnerships in raising the achievement of students in many subjects.

Staff-student partnerships may engage students in peer learning. Topping (2005) defines peer learning as:

> *"the acquisition of knowledge and skills through active helping and supporting among status equals or matched companions. It involves people from similar social groupings who are not professional teachers helping each other to learn and learning themselves by so doing" (p.631).*

This definition encompasses a variety of peer-to-peer relationships which for the purposes of the current research I will term peer learning support (PLS[1]). In the HE sector, typically, staff-student partnerships in teaching involve student partners who provide out of lectures PLS which aims to enhance the learning experience of other students. A PLS programme in HEIs may not focus on course content but rather would entail the enculturation of students who participate in them into the university community. There are many variants of PLS schemes. Sinka and Kane (2011) report many of these variants in their survey of good practice in undergraduate peer support in mathematics departments in the UK HE sector. Similarly, a report commissioned by the HEA also highlights variants of PLS schemes across disciplines (Keenan, 2014).

PLS schemes include Peer Mentoring, Peer Tutoring (Topping, 1998) and Peer Teaching (Goldschmid & Goldschmid,1976). Topping (2005, p.632) notes the confusion between "tutoring" and "mentoring" in the research literature. Indeed, there is a clear distinction between peer tutoring and peer mentoring. While peer tutoring focuses on subject content, peer mentoring need not involve discussions of course content at all. Topping argues that mentoring, on the one hand, is a one-to-one relationship in which the mentor provides encouragement and support to the mentee; enacts positive role modelling, motivates and raises the aspirations of the mentee. Peer tutoring, on the other hand, is also often a one-to-one relationship where the peer tutor

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[1] See Arendale (2000) for an extended list of other PLS programmes.

"teaches" the tutee. Peer tutoring often takes the form of remedial action where the tutor helps the tutee to master a subject that perhaps he/she finds challenging or difficult.

PLS programmes also include Supplemental Instruction (SI) (Arendale, 2014) and other learning assistance programmes modelled on SI. Dr. Deanne Martin developed SI in 1973 at the University of Missouri-Kansas City (UMKC) and it has been adapted and implemented in HEIs around the world (Arendale, 2001; Zerger, 2008). The UMKC defines SI as:

> *An academic assistance program that utilizes peer assisted study sessions. SI sessions are regularly-scheduled, informal review sessions in which students compare notes, discuss readings, develop organizational tools, and predict test items. Students learn how to integrate course content and study skills while working together. The sessions are facilitated by "SI leaders", students who have previously done well in the course and who attend all class lectures, take notes, and act as model students (UKMC, para. 1, 2017).*

This definition suggests that SI has distinguishable features from other PLS schemes or learning assistance programmes. For example, SI schemes are attached to "at-risk courses" rather than "at-risk students" so that they are not seen as remedial programmes by students. At risk courses are defined as those with high student failure or withdrawal rates at 30%. This criterion for selecting a course to which SI sessions may be attached is not strictly adhered to in countries outside the USA. For example, in the UK, PLS schemes modelled on SI may be attached to courses which students find challenging or difficult and not necessarily because the courses have high failure or withdrawal rates. Science, Technology, Engineering and Mathematics (STEM) courses are often cited as some of the challenging courses to which SI may be attached.

In a description of the basic SI model, Hurley and Gilbert (2008) note that in the sessions, SI leaders/session facilitators do not lecture, teach or reteach the content of the course to which the SI sessions are attached. Rather, the facilitators use collaborative learning strategies to help participants in the SI sessions to further engage with the content that they have previous been taught. The session facilitators help students learn effective note taking, develop the attitudes and willingness to work in small study groups. The SI session leaders help students to review notes taken and complete any gaps that may exist in the notes. I shall return to the prescription of how SI sessions should unfold.

Various nomenclatures are used to describe PLS models based on SI. For example, in Canada, the University of Guelph uses the term Supported Learning Groups to describe their adapted form of SI (Schmidt & Kaufman, 2005). PASS is the preferred nomenclature for adapted schemes of SI in Australasia (Paloyo, Rogan, & Siminski, 2016). In the UK, the University of Glamorgan uses the term Peer Assisted Study Support (PASS) to describe their adapted form of SI while the University of Manchester and Kingston University use the term Peer Assisted Study Sessions (PASS). Bournemouth University, one of the early adopters of the SI model in the UK uses the term Peer Assisted Learning (PAL) (Capstick, 2005). The variety of nomenclatures used to describe schemes modelled on SI can be a source of confusion for both researchers, practitioners and institutions wishing to implement a PLS scheme based on the SI model. As Dawson et al. note, just because a PLS is named SI does not mean it adheres to the principles and philosophies of SI. Equally, a PLS may have a nomenclature such as University of Guelph's Supported Learning Groups, and yet adhere to the principles of SI.

Institutions wishing to implement SI or schemes modelled on SI would have staff who are trained and certified as SI supervisors by an accredited national/regional centre[2]. At the time of writing this review, the following known national/regional SI accredited centres were known: University of Wollongong in Australia; University of Guelph, Canada; St. George's University, Granada; Nelson Mandela Metropolitan University, South Africa, Lund University, Sweden; and University of Manchester. UK. In a recent communication, it has become apparent that the University of Manchester had opted to strategically cease to be the UK national centre of PAL/SI (Odi, M, personal

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[2] National/regional SI centres are accredited by the International Centre for Supplemental Instruction, UMKC. Trainers of SI Supervisors are certified by UMKC.

communication, July 10, 2016). Knowledge of these national/regional accredited centres is important because each centre provides professional development, training and support for staff running SI schemes or other schemes modelled on SI.

In the remaining sections of this chapter, I will discuss empirical studies on PAL, SI or schemes modelled on SI. However, I will use the term PAL to refer to SI or other schemes modelled on SI such as PAL/PASS which subscribe to the 21 principles of SI as defined by the International Centre for Supplemental Instruction in the SI Supervisors' Manual (see University of Missouri Kansas City, 2014, p. 23). Indeed, in the remainder of this thesis, SI and PAL are interchangeable despite the subtle differences between the two in terms of the logistics of the implementation.

Much of the research on PAL has been evaluative research with a strong emphasis on examining the effectiveness of PAL in raising achievement. This strong focus on the effectiveness of PAL has inadvertently resulted in little attention being paid to the nature of PAL as a process and as a staff-student partnership. Given the growing interest in staff-student partnerships in the HE sector it seems worthwhile to explore the collaborative relationship between staff, PAL leaders and PAL participants (see definitions on p.14) in the teaching and learning process. The most often cited studies on PAL for STEM related subjects include: Burmeister et al., 1996; Cheng & Waters, 2009; Congos & Schoeps, 1993; Fayowski & MacMillan, 2008; Kenney & Kallison, 1994; Malm, Bryngfors, & Mörner, 2012; McCarthy, Smuts, & Cosser, 1997). Many of these studies focused on first year students' participation in PAL sessions.

Some studies have also focused on first-year mathematics courses for non-specialists (e.g. Harding et al., 2011; Malm, et al., 2012). However, it appears from the PAL research literature that little attention has been paid to PAL schemes attached to post first-year tertiary mathematics courses which are typically studied by single or joint honours undergraduate mathematics students.

As we shall see, much of the research evaluated the impact of the number of PAL sessions attended on student achievement in the courses to which the PAL scheme was attached. Others simply investigated the impact of participation in PAL on achievement. While some studies have focused on evaluating PAL sessions attached to a single discipline (e. g. Cheng & Waters, 2009, Rath, Peterfreund, Bayliss, Runquist & Simonis, 2011), others have focused on a range of disciplines (Hensen & Shelley, 2003; Miles, Polovina-Vukovic, Littlejohn & Marini, 2010).

Studies which have explored what goes on in PAL sessions are limited. Studies such as Peterfreund et al. (2008) which report on what goes on in PAL sessions often lack empirical data and describe what Dawson et al. (2014) refer to as ideal PAL sessions to which the PAL implementers aspire. These ideal PAL sessions, described in SI manual, may not be realised in practice, with PAL leaders and PAL participants developing facilitation and learning practices that suit their own learning preferences.

For PAL sessions modelled on SI, The International Centre for Supplemental Instruction recommends to PAL leaders that PAL sessions should be structured as follows:

> *1.Introductions (first few sessions of the semester)*
>
> *2. Addressing student needs/allowing students' input to agenda (What would the students like to address before they leave the session? Remember, don't address these needs yet.)*
>
> *3. Setting agenda (The Leader tells the students what he/she has planned for them.)*
>
> *4. Strategies (The Leader facilitates the three or four activities planned for the session.)*
>
> *5. Closure (How can the group summarize [sic]what they have learned this session? (UKMC, p.32)*

In the few sessions early on in the semester, it is also recommended that PAL leaders start off sessions with introductions which are to encourage PAL participants to get to know each other. In these early sessions, PAL leaders could help participants to learn effective note taking strategies and how to work in small study groups.

In addition, it is recommended that PAL leaders draw on techniques which have been proven to be effective in fostering interactions between students and lead to increased understanding for students. Three of these techniques highlighted in the SI manual and recommended to be used throughout every session are: *redirecting questions, wait-time,* and *checking for understanding*. Redirecting questions is a key feature of PAL sessions and is premised on the notion that student gain increased understanding of something if they can explain it to someone else. Wait-time refers to the time that a PAL leader waits for a response after asking students a question. It is suggested that after 5 to 10 seconds the PAL leader can directly ask someone else or ask students to respond to parts of the question. It is important to point out that, in addition to the canonical strategies stated above, there are many suggested strategies that PAL leaders can use to meet the needs of their PAL participants. Data collected through observations of SI sessions can provide insights into the strategies used by PAL leaders.

Burmeister et al. (1994) observed three SI sessions which were attached to undergraduate algebra and calculus courses. In one session, the SI leader and SI participants focused on reviewing a small part of a lecture on derivatives. In the session, the SI participants were facilitated to understand the definition of derivative. The SI leader adopted "questions and answers" as a strategy to help the participants to develop the definition of the derivative as the limit of the difference quotient. It is clear from the dialogue presented by Burmeister et al. that the SI leader was leading from the front but not necessarily "telling" the students the mathematics. For example, the SI leader asked the participants to name two points on a curve drawn on a board. A student responded: $(a, f(a))$ and $(b, f(b))$. The leader then asked: what happens if the first point was $(x, f(x))$? Another student replied that the second point will be further on the curve. The SI leader asked the SI participants if the points $(x, f(x))$ and $((x+\Delta x), f(x+\Delta x))$ could be equally good names for the points. There was no indication as to the response from the participants. The SI leader asked the participants how they could find the gradient of the line between the two points. Another student suggested that they could divide $f(x+x\Delta) – f(x)$ by Δx. The dialogue continued until the group could deduce that the limit of the difference quotient was equal to the derivative of $\frac{dy}{dx}$., i. e. $\frac{dy}{dx} = \frac{f(x+x\Delta)-f(\mathrm{x})}{\Delta x}$.

Although the SI leader used “questions and answers” strategy which can be SI leader centred, the strategy seemed to have worked well for the SI participants. The dialogue was interactive. It is clear from the account presented by Burmeister et al. that at least five SI participants responded to questions posed by the SI leader.

In a different SI session, which focused on understanding conics, Burmeister et al observed that the SI leader asked participants to work in groups. A page of equations was given to each group. The equations included:

i). $9x^2 + 18x + 4y^2 - 24y = -9$

ii). $9x^2 + 18x + 4y^2 + 24y = 63$

iii) $(x-2)^2 = y - 3$

Each group was asked to classify the equations as straight line, a parabola, a circle, an ellipse, or hyperbola. The groups were given time to discuss their equations and to work together to organise the equations into a chart or table or matrix by identifying the equations, standard forms, information and graph shape. The matrix allows patterns to emerge. The strategy used by the leader in this session is deliberately built into the SI programme and can be found in the SI training manuals. It is worth pointing out that when compared with the prevision sessions, this session was SI relatively student centred and perhaps more active than the previous session.

Finally, Burmeister et al. reported that in another session observed by them, the SI leader asked students to think about one or more examinable topics. SI participants were then asked to predict examination types questions, concepts on the topic(s) that may be linked together in a single examination type question, and mistakes students were likely to make when answering the questions identified. In this session, the students’ focus on examination questions practice could be viewed as the students taking the instrumental or strategic approach to learning. However, the importance of assessment literacy suggests that such strategy is helpful to students. There is clearly a distinction between assessment literacy and strategic approaches to learning. It is argued that an expert is one who knows what mistakes can be made in his or her field, how things can be improved, what is salient. I argue that the strategy used in this session can be seen as an aspect of *assessment for learning*.

Due to differences in disciplinary culture and practices, PAL facilitation strategies that work in disciplines such as History, Politics and English may not necessarily work in PAL sessions attached to undergraduate mathematics courses. Zerger (2008) advocates the need for PAL to be adapted to suit disciplinary practices. Given the paucity of studies on live PAL sessions, it is argued that further research is needed to establish the strategies PAL leaders use in PAL sessions for advanced undergraduate mathematics; and the extent to which they use or adapt prescribed or recommended strategies in sessions. It is also argued that further research is needed to establish the strategies PAL leaders use in sessions and to discuss those strategies in relation to whether they contribute to deep, surface, or strategic learning (Biggs, 1978; Entwistle & Ramsden, 1983; Marton & Saljo's, 1976; Ramsden, 1988) of PAL participants.

The case studies and the examples of staff-student partnership in pedagogic research and consultancy; curriculum and course design, and PAL presented in Section 2.3 have been subjected to empirical research. Findings from the research indicate positive outcomes of the partnerships for both staff and students. In Section 2.4, I review some of the research methodologies that had been employed in studies cited in Sections 2.3. In Section 2.5, I then look at the outcome of the partnerships primarily for students but also staff.

2.4 Methodological approaches used in partnership research

The majority of the research on the staff-student partnerships in pedagogic consultancy and research, and curriculum and course design and assessment had involved small groups staff and students as partners who work together to improve learning and teaching. Evaluative research of these partnerships has also explored the partnership process and outcomes for staff and students. Accordingly, the majority had adopted the interpretive paradigm and had employed qualitative methodology and approaches to researching those partnerships.

Bovill et al. (2011) report that the SaLT programme in which students acted as pedagogic consultants was investigated through action research. In this process, staff and students engaged in a “spiral of ‘reflective cycles’ of planning change, acting and observing the consequences of the change, reflecting on these process and consequences and then re-planning (Kemmis & Wilkinson, p. 4). The data which were collected about the SaLT programme were analysed through the application of the grounded theory and constant comparison (Creswell, 2006, Strauss, 1987).

The partnership on which Scandrett et al. (2005) reported was also investigated through a case study methodology. The partnership programme coordinators and other related academic staff were interviewed. Documentary analysis was undertaken to understand the process. Grounded theory was adopted to analyse the qualitative data collected about this partnership. The analysis of the data collected involved the identification of within-case themes followed by the identification of cross case-themes.

Richardson et al. (1973) report that the staff-student partnership in which students co-created a history course was investigated through the use of focus groups with the student partners. The student partners were also asked to write a reflective account of their experience of the partnership and to describe the extent to which their role has contributed to the growth in their understanding of History. In addition, the staff who taught the course were also interviewed. Richardson et al also note that focus groups have limitation in that some participants of the focus group dominated discussion making it difficult for the researchers to know the individual views of other student partners.

The approach to researching the course design partnership described by Mihans et al. (2008) was similar to the research approach adopted for the SaLT programme. Mihans et al. report that researchers asked staff and students to keep reflective journals. Staff and students were also interviewed via a video recording. The course design process was observed by a researcher and fieldnotes were taken. However, findings from the interviews and the observation fieldnotes were not reported in Mihans et al.'s (2008) paper. In fact, Mihans et al. acknowledged that at the time of reporting, the data had not been analysed. In an international study on staff-student partnerships, Bovill et al (2011) reported that Mihans et al. adopted action research methodology to study the collaboration and that the data qualitative data were analysed using grounded theory and constant comparative analysis (Creswell, 2013; Strauss, 1987).

In the Section 2.3.2, I noted the relevance of the work of Biza and Vande Hey (2014) and Rapke (2016) to the current study. These studies are methodologically sound. However, they adopt different methodological approaches and theoretical frameworks, therefore providing future researchers into staff-student partnerships in curriculum, course design and assessment models of research design to adopt or adapt. On the one hand, Biza and Vande Hey (2014) explored the staff-student partnership in which students played roles as co-creators through the lens of Communities of Practice. They collected data about the partnership using semi-structured interviews with the three summer interns; an initial survey of the eight final year mathematics students; and final feedback from the eight final year students on completion of their dissertation project. Feedback was obtained from six of these students through small group interviews. The remaining two sent written responses. Data about the resources produced were examined. It is not apparent in their study what method of analysis was conducted. The discussion of the findings under themes would suggest that implicitly a thematic analysis may have been employed.

On the other hand, Rapke (2016) adopted a phenomenological methodology to study the experiences of seven students who played roles as co-creators of assessment material. Rapke conducted video interviews with the seven students after the final examination had taken place. The seven students were those who had volunteered to be interviewed. The objective of the study was to describe the process involved in the staff-student partnership and to account for participants' experience of the process. The research question which was posed in this study was: "How did students experienced the process of developing the final examination with their instructor?" Rapke reports that the interview data was analysed in accordance with a phenomenological approach. Rapke's description of the analysis suggests that there was no transcription of the video. Rather, summaries of the students' narratives as they relate to the research question were made. These summaries were then grouped into seven categories following what Marton's (1994) calls a "pool of meanings" (p. 428). These were then narrowed into two main categories of how the students' experienced their role as co-creators of three assessment items, one with three sub-categories and the other two with two sub-categories. In this case study, students experienced the co-creation role as a way of preparing to sit a mathematics examination, and "as teachers". The findings from this research is further discussed in Section 2.5.1

Unlike the research approaches described so far, Moore and Gilmartin (2010) report a mixed methods approach to the evaluation of the redesigned first-year Geography course unit. The evaluation of the redesigned course included two separate focus group of tutors and first-year students who studied the redesigned course. These focus groups involved general discussion of participants' experiences of the course and their reactions to it. Data were collected on students' perceptions of the redesigned course at three time points, week 1 (time 1), week 6 (time 2), and week 11 (time 3) using the Students' Experiences of Teaching and Learning Questionnaire (SETL). The evaluation instrument, SETL, covered issues including engagement, attendance, social experience and perception of the course. Students' perception of the course in comparison to other courses in the first-year programme was also evaluated. A descriptive analysis of the data was undertaken and frequency tables of the responses across time were reported.

Although Moore and Gilmartin collected data on students' perceptions of the redesigned course at three time points, they did not analyse the data using repeated measures ANOVA. Rather, they performed a series of multiple paired *t*-tests to examine differences in perceptions between the time points. The views of the student partners on their involvement in the partnership and the course design process was not accounted for in the report on the evaluation of the partnership. It is plausible that the views of the student partners were not the focus of the work reported in their paper.

Most evaluative research studies on PAL typically adopt quasi-experimental design to assess the outcomes of participation in PAL for PAL participants (e.g. Burmeister et al., 1996; Cheng & Waters, 2009; Congos & Schoeps, 1993; Fayowski & MacMillan, 2008; Malm, Bryngfors, & Mörner, 2012; McCarthy, Smuts & Cosser, 1997). In these studies, data on PAL attendance, prior achievement, and examination performance in the courses to which PAL was attached were collected from administrative records. The effectiveness of the PAL programme is then assessed by comparing the examination performance of PAL participants and non-PAL participants enrolled in the attached courses. In these studies, students were often not randomly assigned to the PAL participant group and non-PAL participant group. As PAL sessions are often voluntary, PAL participants (i.e. the PAL treatment group) are often self-selected. It is possible that students who are highly motivated or high achievers would participate more in PAL sessions. Equally, students who are less able may be more likely to participate in PAL sessions with the view to improve their grades. Either of these two scenarios may confound the effect of PAL attendance or PAL participation on achievement. Some studies have compared the achievement of PAL participants and non-PAL participants in the attached courses after controlling for student motivation to participate in PAL sessions, prior academic achievement, ethnicity and gender.

In many of the PAL evaluative studies included in this review, researchers decided on an arbitrary minimum number of PAL sessions students needed to attend before they were classified as PAL participants or not. For example, Burmeister et al. (1996) classified students as PAL participants if they attended one or more sessions. Fayowski and MacMillan (2008) also classified students as PAL participants if they attended 5 or more PAL sessions. They argue that as there were ten weekly PAL sessions in the semester in which they carried out their research, it was reasonable to assume that students attending every other week would be regular participants as they would have attended more than half the number of available sessions.

Miles et al. (2010) also chose not to treat PAL attendance as a binary variable – participants and non-participants. Rather, they divided students into three groups: those who did not participate in PAL (0 sessions), those who participated less frequently (1 to 4 sessions inclusive) and those who participated regularly (5 or more sessions). They argued, just like Fayowski and MacMillan (2010), that students who attended every other week (5 sessions out of 12 sessions) in a 12-week semester could reasonably be considered as regular participants in PAL sessions.

Some researchers have argued that a better approach to determine the effectiveness of PAL is to treat PAL attendance and hence participation as a discrete scale variable measured as the number of sessions attended rather than a binary variable participation and non-participation (e.g. Cheng & Waters, 2009) or some other nominal variable (e.g. Fayowski and MacMillan, 2010; Miles, et al. 2010). However, as we shall see, it is possible to employ other advanced statistical techniques (e.g. logistic regression) to deal with the shortcomings of the binary treatment of PAL attendance in the evaluation of its impact on achievement.

Much of the early evaluative research into PAL used independent *t*- tests and chi-square tests alone to evaluate the effectiveness of PAL. On the one hand, Congos and Schoeps (1993) report an evaluative study in which an independent *t*-test was used to compare the mean course grades[3] of PAL participants and non-PAL participants. On the other hand, Burmeister et al., (1996) used a chi-square test to explore the association between participation in PAL sessions and course grade categories. These tests are useful when data on PAL are being explored but on their own, they are not robust enough to measure the effectiveness of PAL schemes.

Accordingly, an earlier critique of the statistical techniques which had been used in the evaluation of PAL programmes was published by McCarthy, Smuts and Cosser (1997) who point out that these tests do not allow researchers to address self-selection

[3] On a scale of *A*-4, *B*-3, *C*-2, *D*-1, 0-*E, F*, *W*

bias. Furthermore, they argue that these tests do not enable researchers to control for confounding variables that might affect achievement in courses to which PAL sessions are attached.

Reporting on a case study of a South African PAL scheme, McCarthy et al. Smuts and Cosser described an analytical procedure that involved the use of multiple linear regression analysis to develop a model for determining a student's final examination performance in a first-year Electrical Circuit course given the number of PAL sessions attended. Other variables included in the model were academic ability at university (as measured by adjusted first year mark which is a weighted mean of students' marks in common courses with the exception of the Electric Circuit course), and the level of preparedness for university study (as measured by the university admission rating which ranges from 0 to 20 points) in the South Africa context. McCarthy et al. advocates that PAL researchers should use statistical techniques such as multiple linear regression to control for confounding variables. In addition, McCarthy et al. suggest that practitioner researchers should consider adopting mixed-methods approaches that draw on both quantitative and qualitative data to evaluate the effectiveness of PAL programmes.

Recent evaluative studies on PAL have begun to respond to McCarthy et al's. suggestions for future research work on PAL to explore both the quantitative and qualitative impact of PAL on PAL participants and PAL leaders. Miles et al's. (2010) employed a mixed-methods approach to investigate the impact of PAL on PAL participants' achievement and affective dispositions. Their study also investigated the outcomes of PAL for PAL leaders and staff. Dobbie and Joyce (2008) and Dobbie and Joyce (2009) took a different approach. They employed quantitative and qualitative approaches respectively to establish the efficacy of PAL in raising the achievement and enhancing the affective dispositions of students who participated in PAL sessions either as PAL participants or PAL leaders. However, the results and the findings of the studies of Dobbie and Joyce were reported separately. This way of reporting the results and the findings maintains the distinction between the quantitative and qualitative research redesign, a distinction which it has been it been suggested, may be unhelpful.

Dobbie and Joyce (2008) held three focus groups. The first group had three PAL participants, the second seven and the third two. The purpose of the focus groups was to explore with participants, the benefit of participation in a PAL scheme, the strengths and weaknesses of the scheme and how it can be improved. While the findings of this study, which I discuss in Section 2.5.2, contribute to our understanding of PAL, some qualitative studies are often not informed by theoretically strong and robust qualitative approaches. Criticisms of some of these qualitative studies centre on the fact that findings are often about what Healey et al (2014) call "students' likes and dislikes" of the partnerships in learning and teaching. The rigour and objectivity of these studies may be questioned by those with strong positivistic views on knowledge creation.

A significant contribution to the ever growing research work on PAL is the work of Congos and Schoeps (1999) who discuss a catalogue of statistical techniques that may be used to evaluate the effectiveness of PAL schemes in raising achievement and enhancing the student learning experience. They also emphasised the need for researchers to use a combination of a number of inferential statistics to evaluate the effectiveness of PAL rather than descriptive statistics. The inferential statistical techniques they advocate include (a) chi-square tests, (b) independent *t*-tests, and (c) analysis of covariance (ANCOVA). However, as I have already pointed out above, the use of the first two tests alone does not provide robust results to evidence the effectiveness of PAL. When used in combination with ANCOVA or multiple linear regression, more robust results may be obtained that account for self-selection bias and/or confounding variables.

Cheng and Walters (2009) and Fayowski and MacMillan (2008) employed logistic regression analysis to develop a model to predict the odds of students' chances of success in a course given a student's level of participation in PAL sessions and other demographic variables. For Fayowski and MacMillan, participation in PAL session was at three levels and was treated as a nominal variable. Logistic regression was used to control for self-selection bias in addition to estimating students' chances of success in the mathematics course to which PAL was attached. They also used ANCOVA to control for differences in PAL participants and non-PAL participants in terms of their prior grade point average (GPA[4]) – the latter being treated as a covariate.

A limited number of studies have conducted randomised controlled trials to evaluate the effectiveness of PAL. These experimental designs can be controversial. In these designs, some students may be permitted to attend PAL sessions and others denied as they form the control group. The denial of students from attending PAL sessions may be viewed as ethically indefensible even though other options such as the traditional tutorials may be available to them. Parkinson (2009) conducted an experimental study in which he randomly assigned a first-year Biotechnology cohort of students (N=67) to a PAL participants group (experimental group) and non-PAL participant (control group). All 67 students had volunteered to take part in PAL sessions but only 24 were assigned to the PAL participant group. Thus, 43 students did not participate in the PAL sessions. Parkinson reported that the experimental group was a representative sample of the whole class.

Similarly, Lewis, O'Brien, Rogan and Shorten (2005) randomly assigned students who were studying a statistics course into three groups of equal sizes in 2003: (a) a control group, ineligible to attend PASS sessions but allocated to normal tutorials with standard class sizes, (b) a group eligible to attend both PASS sessions and normal tutorials, and (c) a group ineligible to attend PASS sessions but allocated to tutorials with smaller class sizes. The rationale for these groupings was not given. Lewis, et al. employed Heckman's two-stage correction technique (Heckman, 1979) to analyse the PAL data. First, the technique was used to analyse the data collected on the 2002 cohort of students. Second, the technique was applied to the data collected on the 2003 cohort. The Heckman's technique is complex and not commonly used in the evaluative studies reported in the literature.

[4]On a scale of 1 to 4.

2.5 Research findings on partnerships in learning and teaching

Research on staff-student partnerships in learning and teaching produce a number of outcomes for staff and students. The outcomes reported in the literature are similar, notwithstanding in which of the four areas of staff-student partnerships outlined by Healey et al (2014) students work. Cook-Sather et al. (2014) report that their own individual research into staff-student partnerships in learning and teaching tend to produce three clusters of outcomes for students and staff collaborators. They describe these clusters of outcomes as *engagement*, *awareness* and *enhancement* outcomes. As the current thesis focuses on student involvement as partners and change agents in course design and delivery, I restrict my review in Sections 2.5.1 and 2.5.2 to outcomes of partnerships in curriculum and course design, and course delivery via PAL

2.5.1 *Outcomes of curriculum and course design and partnership*

Staff-student partnership in curriculum and course design enable student partner to further engage with course content outside lectures and tutorial rooms. The further engagement of with course content results in positive outcomes for the student partners The engagement outcomes of staff-student partnership for students include enhanced confidence and motivation of the students, and increased enthusiasm for their studies (Cook-Sather et al., 2014). Cook-Sather et al suggest that these engagement outcomes are contingent upon students being taking seriously and valued as partners in the course design. Thus, the driver for enhanced confidence and motivation is the efforts staff make to engage with the student partners as members of the learning community of which they become part. It is inevitably that the staff and students' interactions during the partnership in curriculum and course design will entail discourses on the disciplinary content. The staff and the student interns' interaction are most likely to result in gains in deep knowledge and understanding of the content.

Similarly, Biza and Vande Hey (2014) suggest in their study that when students play a role as co-creators of learning and teaching resources, an outcome of their engagement is the "solidification of their knowledge" (p.177). By solidification of knowledge they mean that student partners gain further insight into the knowledge of the disciplinary content on which they work. Biza and Vande Hey cite one student partner who reports gaining deep insight into the course content and learning about others:

> *'When you're making these resources, you have to have a good understanding because if you don't understand you're never going to be able to make someone else understand', 'I thought I knew quite a lot of that sort of stuff beforehand, but it just sort of solidified my knowledge, really'. (p.177)*

Staff-student partnership in the curriculum and course design shifts the focus of student activities from grades to the learning process and thereby fosters greater engagement with the content. Bovill et al. (2011) also report that staff-student partnership in curriculum, and course design and assessment enables students to gain a deep understanding of learning. They cite one student in Cook-Sather's (2008) study who reports that:

> *"You don't understand the way you learn and how others learn until you can step back from it and are not in the class with the main aim to learn the material of the class but more to understand what is going on in the class and what is going through people's minds as they relate with the material."*

The stepping back from the routines allows time for reflection and growth in metacognitive awareness.

In her study, Rapke (2016) also reports on students who collaborated with staff in the co-creation of summative assessment and reports deep approaches to learning. She cites two student partners who suggest that they had engaged in deep approaches to learning. For example, Susan is noted to have reported this when she explained that the process of students and their instructor developing the exam gave her an additional opportunity to understand the material on the exam. Similarly, Darren was noted to have reported experiencing deep approaches to learning when he claimed to have seen mathematics in a different way; he spoke about how his role as co-creator of assessment material transformed the way he viewed mathematical questions in terms of how they are constructed.

A genuine staff-student partnership in curriculum, course design and assessment shares responsibility for course design with the students. The enhanced responsibility that is given to students drives students to take ownership of their own and their peers' learning (Cook-Sather et al., 2014).

Thus, staff-student partnerships which focus on curriculum and course design offer students the time and the space to step back from the routines of lectures and tutorial, allowing students to reflect on the process of learning. Through the discourses in which they engage, students also gain deepened understanding of the academic community to which they also make a contribution. Similarly, Richardson et al (1973) found that when students collaborate with staff in course design, they gain a deep insight into the course, particularly those aspects of the course that they would otherwise not meet when the course runs.

Finally, students gain insight into the pedagogical decisions of university staff, they learn about the challenges that staff face in teaching and research and they become empathetic toward staff (Cook-Sather et al., 2014). As we have seen earlier in this chapter, participation in staff-student partnerships in curriculum and course design is often limited to a select group of students. The outcomes are important in that what the select group of student partners learn about staff perspectives on learning and teaching may be passed on to their community, thereby helping create shared understanding of staff efforts in the learning process. Richardson et al. concur and note that in the staff-student partnership reported in their paper, students gained an insight into the difficulties that staff face when they design courses and consequently they become more tolerant of staff.

Cook-Sather et al. also argue that staff gain from change in their understanding of learning and teaching through reflection and thinking about teaching practices and the insights that students bring to bear on the curriculum and course design process. Cook-Sather et al also report that staff gain a deep understanding of students' experiences and needs and become more reflective and responsive in staff-student partnership in curriculum and course design. In the usual routines of university mathematics teachers, as is the case for teachers in other disciplines, there is sometimes lack of time and opportunities for reflection on the teaching process. Staff-student partnerships, offer forums for staff to "access and revise their assumptions" about learning and teaching through reflective discourses. As Cook-Sather et al. put it, staff-student partnership then allows both staff and students to become partners in "pedagogy of mutual engagement".

The outcomes reported above are based on qualitative evaluation of staff-student partnerships in curriculum and course design. The studies from which claims of the effectiveness are made meet the trustworthiness criteria for judging qualitative research. This is because the methodologies, some of which are reported in Section 2.5, are transparent, the studies used multiple methods to collect data about the partnerships from different angles, and the data analysis which is often rooted in grounded theory are always made transparent. The studies look at the processes involved in the partnership and explore the lived experiences of the staff and student partners. Therefore, it is not surprising that qualitative approaches are the most often adopted.

2.5.2 *Outcomes of PAL partnerships*

Previous PAL evaluative studies have found PAL to be effective in improving the academic performance and the study skills of students who participate in PAL sessions. Researchers at the University of Missouri Kansas City conducted longitudinal studies into SI (Arendale, 2001). Their study collected data from the period 1980/81 to 1995/1996 and included 14, 667 students who participated in their PAL scheme. Their analysis showed that students who attended PAL sessions obtained significantly higher grades compared to students who did not (54% of participants obtained grades A and B compared to 43% of non-participants). Moreover, fewer students obtained grade D, failed, or withdrew from their courses. When differences in the background and demographic characteristics of students such as previous levels of academic achievement, motivational level and ethnicity were accounted for, the results indicated that PAL participants performed better than non-PAL participants.

Outside the USA, PAL studies have also shown that students who attended PAL sessions achieve higher grades in the courses to which PAL sessions are attached. In a Canadian study, Miles et al. (2010) also found that students who attended PAL sessions achieved higher course grades than students who did not attend. This effect was found to be greater as the number of PAL sessions attended increased. This study, which spanned two academic years, also found that students who attended PAL sessions obtained significantly lower levels of *D* grades, failure rates or withdrawal from the courses to which PAL was attached. In the UK and Sweden similar findings on the effectiveness of PAL for PAL participants have also been found in the best-known studies (Capstick, 2004; Capstick & Fleming, 2002; Coe et al., 1999). For example, Coe et al., found that the failure rates in a first-year chemistry course at the University of Manchester decreased from 20% to 10% when PAL was introduced in 1995. At the same time, students' mean examination marks were significantly higher for PAL participants than non-PAL participants.

Studies that had evaluated PAL schemes attached to mathematics courses for non-specialists have also found similar results to those discussed above (Burmeiser et al., 1994; Cheng and Walters, 2009; Fayowski and MacMillan, 2008; Harding et al., 2011; Parkinson, 2009; Malm et al., 2011; Kenney & Kallison, 1994).

In addition to the general positive effects of PAL attendance on achievement, some studies have also shown differential effects of PAL for males and females and for underrepresented students. Fayowski and MacMillan (2008) found differences in mean course grades of males and females with no significant interaction effect by gender. Peterfreund et al. (2008) compared course grade differences between males and females across a range of courses. Differences between grades of male students who participated in PAL sessions and those who did not were greater than the differences between female participants and non-participants. In addition, male students' participation in PAL sessions were found not to have exceeded one-third of the number of students attending sessions. Thus, males were found to be under represented in PAL sessions.

Studies indicate that there are differential effects of participation in PAL for underrepresented students and students from disadvantaged backgrounds (Peterfreund et al., 2007, 2008; McCarthy et al., 1997). McCarthy et al. found differential effects of participation in PAL sessions for students of African descent and of disadvantaged backgrounds. In their case study involving students who studied Electronic Circuits I, McCarthy et al. (1997) found that PAL participants performed better than non-PAL participants with the difference only reaching statistical significance in the disadvantaged group. Amongst the disadvantaged group, PAL participants achieved on average 12.5% marks higher than non-PAL disadvantaged counterparts. Peterfreund et al (2008) found similar results in a US study where African Americans were more likely to participate in PAL sessions than the majority population. Furthermore, they found that the achievement of African Americans who participated in PAL sessions exceeded the achievement of (a) non-SI African Americans and (b) non-SI students not classified as African American.

The differential effects of participation in PAL sessions for international and home based students has received little attention in the literature. This suggests a need for further exploration of the relationship between PAL attendance and students' status as international or home students and their interaction with achievement.

Although the majority of the evaluative studies on PAL schemes focus on the quantitative outcomes for PAL participants, increasingly studies are also reporting other effects of PAL on students. These have included development of students' academic skills, enhanced relationships, and increased engagement with their studies, and other affective outcomes (Longfellow et al., 2008; Ogden, Thompson, Russell & Simons, 2003; Dobbie & Joyce, 2009a)

Longfellow et al. (2008) found that respondents to their survey of PAL participants reported that they had gained effective academic writing skills. Ogden, Thompson, Russell, & Simons, (2003) also reported that respondents to their survey of PAL participants believed that they had been exposed to effective note taking and exam preparation techniques. Smith found that respondents to its survey of PAL participants reported that PAL has helped them manage their workload and time properly and this was evidenced by a mean score of agreement of 3.11 with standard deviation of 0.96. Dobbie and Joyce (2009a) also found that PAL participants reported that PAL enable social relationships to develop and increase their personal confidence.

Of course, the above skills and affective outcomes may be developed by students who attend PAL sessions attached to courses in non-mathematical sciences disciplines. Thus, the development of the above skills and affective outcomes are not unique to undergraduate mathematics students. However, given the challenges that undergraduate mathematics students face at different transition stages in their studies, the potential of PAL sessions to contribute to the personal development of undergraduate mathematics students who attend PAL sessions may be welcomed by both staff and students. The skills and personal development outcomes of participation in PAL are not limited to PAL participants. PAL leaders may also derive some outcomes from their participation in PAL sessions as learning facilitators.

When PAL leaders are carefully selected and trained, they benefit from facilitating PAL sessions in a variety of ways. For example, they increase their understanding of the course content, improve their communication skills and develop enhanced relationships with staff and other students. PAL leaders may gain in personal and professional development leading to the development of graduate attributes for future employment, and increased self-confidence (Malm et al., 2011; Stout & McDaniel, 2006).

The benefits of PAL may extend to staff, departments and institutions in which it is implemented. For example, staff who teach courses to which PAL sessions are attached may interact with PAL leaders to discuss sessions and receive feedback on aspects of the course content which students find difficult and perhaps ideas about how students can be helped to understand the content better (Zerger, Clarke-United, & Smith, 2006). PAL is a partnership that involves staff and students. It allows for interaction between staff and PAL leaders; and PAL leaders and PAL participants. Through these interactions, staff receive feedback on their teaching. Staff may learn about strategies that PAL leaders use in their PAL sessions. Thus, the partnerships fostered through PAL enable informal learning and teaching development to ensue. Also, since PAL is considered effective in increasing student achievement, PAL indirectly benefits departments and institutions as more students succeed on their courses and progress through their degree programmes, leading to lower student attrition rates (Zerger et al., 2006).

Given the body of research cited above and the evidence presented thus far, it seems reasonable for me to conjecture that second-year undergraduate mathematics students who participate in PAL sessions might perform better in the courses to which PAL is attached than those who do not. This conjecture is one I will return to in Chapter 7. The works reviewed thus far demonstrate that much of the PAL research has focussed on the outcome of PAL for stakeholders in PAL schemes (i.e. PAL participants, PAL leaders, staff, departments and institutions). The nature of PAL as a staff-student partnership in learning and teaching is less well understood and under reported. If PAL is viewed as a partnership process rather than a product, then it is plausible to suppose that PAL leaders and staff who teach the course to which PAL is attached will both gain pedagogical awareness of the student learning journey on the course to which PAL is attached. It is plausible that the identity of PAL leaders and staff may be transformed through the partnership process.

The research on staff-student partnerships in course design and teaching via PAL has been explored by different authors through different theoretical lenses and conceptual frameworks. In Chapter 3, I will discuss the theoretical lens and the model of variables which were chosen for this current three-phase research study.

2.6 Summary

The purpose of this chapter was to review the academic practice and development literature and the mathematics education research literature on staff-student partnerships in learning and teaching in undergraduate mathematics and identify gaps in the knowledge base which my own study would try to fill and thereby make an original contribution.

The findings from this review indicate that there is a growing research interest in staff-student partnerships. In addition, there has been growth in the number of staff-student partnerships in curriculum and course design and delivery via PAL. These studies are often conducted in non-mathematical sciences disciplines. While the outcomes for staff and student partners are positive, the nature of such collaboration and its impact on staff practices particularly in mathematics education still needs to be understood.

The findings from the review also indicate that there is an extensive research base for PAL. However, again, the context of the knowledge base is usually in non-mathematical sciences disciplines. PAL research in undergraduate mathematics education often focus on mathematics for non-specialists. Hence, in Chapters 6 and 7, I present evidence to address this knowledge gap in relation to PAL for advanced undergraduate mathematics courses.

CHAPTER 3 THEORETICAL FRAMEWORK

3.1 Preamble to the theoretical framework

As I noted in Chapter 1 (see Section 1.2.1, p.8) the staff-student partnership in *course design* involved a select group of four undergraduate mathematics students who worked with academic mathematicians to *restructure lecture notes* and to plan and produce *additional learning material* (screencasts, supplementary notes and practice exercises) for two second-year (level 2) courses – Vector Spaces and Complex Variables. The partnership in the *delivery* of the two courses involved the implementation of a Peer Assisted Learning (PAL) scheme. In this PAL scheme, twelve third-year students who had previously taken the two courses in the 2010/2011 academic year became PAL leaders. Their role was to facilitate the learning of some second-year students who took the courses for the first time in the 2011/2012 academic year. The current study spanned three phases. This chapter focuses on a theoretical framework (see Sections 3.2) that was employed in the phase one and two studies. In addition, it describes and discusses a model of a set of variables and their relationships (see Section 3.3) which were explored in a quasi-experimental study conducted in the phase three study. The rationale for having a theoretical framework and a model of variables used in the study is that the whole study is a mixed-methods study each component of which needs a different kind of epistemology and methodology to address its related research questions.

An ethnographic approach to research design (see Sections 4.3 and 4.4 for the methodological details) was adopted to explore the nature of the partnership *process* and the *qualitative impact* (see definition in Section 1.6, p.15) of participation in the partnership on the staff and the student partners (see Chapters 5 and 6 for the findings of the ethnographic studies). I chose *Communities of Practice* (CoP) (Lave & Wenger, 1991; Wenger, 1998) as a theoretical framework within which to explore an eclectic set of qualitative data.

To determine the *quantitative impact* (see definition in Section 1.6, p.15) of students' participation in PAL sessions on their achievement, quantitative data about the students registered on the courses were gathered and analysed (see Chapter 4 for the methodological details). A model of the relationship between PAL attendance and achievement was constructed and used to analyse the quantitative data.

In Section 3.2, I describe and discuss the emergence of the CoP *theory*. I also describe and discuss some of the analytical constructs offered by the CoP theory to mathematics education researchers. I then offer examples of how CoP has been operationalised in other studies which provided the motivation for the research design in the phase one and two studies. I note the constructs of CoP which I employed as lenses to explore the qualitative data collected during the phase one and two studies. In Section 3.3, I discuss the model of the relationship between PAL attendance and achievement. I summarise this Chapter in Section 3.4.

3.2 Theoretical framework for the ethnographic studies

3.2.1 *Emergence of the Communities of Practice Theory*

The CoP theory became part of academic discourse just over two decades ago, at a time when many were talking about the "cognitive revolution" (Schoenfeld, 1999; Resnick, 1991). The phrase "cognitive revolution" has been used to refer to the emergence *of* and the discourses *on* the *constructivist* learning theory which challenged the traditional way of understanding knowledge, thinking and learning. Constructivist learning theory suggests that each learner brings to the learning situation prior experiences and cultural factors which need consideration by educators. Constructivism has its roots in developmental psychology and it is attributed to the developmental work of Jean Piaget (1972). Constructivism has been of interest to mathematics education researchers since the 1980s.

In mathematics education research, constructivist theory of learning was often *Radical Constructivism (RC)*, derived from the work of Piaget by Ernst von Glasersfeld and colleagues (e.g., von Glasersfeld,1990). Although scholars in RC claimed that in relating learning to experiences – physical and social – in the surrounding world, the influences of the social setting or context should be included (Steffe, 1991; Confrey, 1990), others conceptualising within a Vygotskian frame, saw the historic and sociocultural influences on learning to be more profound (e.g., Lerman, 1998; Mousley, 2001).

Vygotskian perspective sees learning to take place in the social setting from which it is internalised (Vygotsky, 1978; Wertsch, 1991). Although Vygotsky's work was concerned with the development of a child, his theory has applications and relevance to the learning and development of adults. Vygotsky introduced the concepts of Zone of Actual Development (ZAD) and the Zone of Proximal Development (ZPD). In the ZAD, students can work independently and complete tasks on their own. Students undertaking tasks within the ZPD may make more progress through the support of a knowledgeable other as they cannot complete the assigned task without help. Vygotsky (1978) defines ZPD as:

> *'the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (p. 86).*

Thus, the ZPD is the space for learning where an individual can move with the support of another – a more capable and knowledgeable other. Vygotsky's work calls for learning and teaching to be designed so that learners are moved into the ZPD where cognitive change has the potential to crystalize. Vygotsky also encouraged *collaborative problem-solving* where meaning is jointly negotiated between the child and the more capable other. Vygotsky's theory of learning also posits that cognition arises through participation in a socio-cultural context (Vygotsky, 1978).

The theory of CoP was conceptualised from a Vygotskian position by Jean Lave and Etienne Wenger (1991) to emphasise the importance of 'practice' within the social setting in which learning takes place. Thus, learning takes place through interactions in social settings and within communities. This viewpoint on learning had been a focus of anthropological studies in the 90's culminating in three seminal works which offer alternative theorisation of learning to that provided by the cognitive theories. There are four main sources of CoP (see Lave & Wenger, 1991; Brown & Duguid, 1991; Wenger, 1998; Wenger, McDermott, & Snyder, 2002) theory; each with a different focus and target audience.

Lave and Wenger (1991) and Wenger (1998) are theoretical expositions of how learning takes place and both provide theoretical constructs that have helped researchers to understand *learning* and *learning interactions* in and outside the classroom. They offer two main concepts for researchers to use as lenses for exploration of data – *legitimate peripheral participation (LPP)*and *Communities of Practice*. Since their advent these two concepts have been employed and critiqued in research studies across many disciplinary fields including management (Handley, Sturdy, Fincham, & Clark, 2006; Roberts, 2006), health (Li, et al., 2009), information science (Cox, 2005) and education (Kanes & Lerman, 2008) to name but a few.

Lave and Wenger (1991) first introduced the term CoP in *Situated learning: Legitimate peripheral participation*. This work was an account of learning of five apprenticeships: Yucatec Mayan midwives in Mexico; Vai and Gola tailors in Liberia; the work learning settings of US naval quartermasters; meat cutters in US supermarkets; and the work of non-drinking alcoholics in Alcoholics Anonymous. In their accounts of the learning that takes place through apprenticeships, Lave and Wenger offered a *situated learning theory* as a critique of the cognitivist and behavioural theories which for some time had been the dominant theories employed in research into learning. Lave and Wenger questioned the pedagogic assumptions of traditional learning theories by suggesting that the process of learning should offer individual learners opportunities to participate in the practices of a community where individual identity is engendered through a sense of belonging and commitment to the community. Lave and Wenger define CoP in their accounts of the five apprenticeships as:

> *a set of relations among persons, activity, and the world, over time and in relation with other tangential and overlapping communities of practice. A Community of Practice is an intrinsic condition for the existence of knowledge, not least because it*

> *provides the interpretive support necessary for making sense of its heritage. Thus, participation in the cultural practice in which any knowledge exists is an epistemological principle of learning. The social structure of this practice, its power relations, and its condition for legitimacy define possibilities (i.e. legitimate peripheral participation) (p. 98).*

Thus, CoP involves people engaged in some form of activity over a sustained period and the activity in this context is a situated activity – activity that has real life context or simulates real life. Lave and Wenger's situated learning theory positions CoP as a social context within which individual *participation* leads to development of *practices* and *identities* pertinent to the community. In addition to CoP, Lave and Wenger proposed the concept of *legitimate peripheral participation* (LPP) to explain how newcomers or apprentices learn from, and contribute to their CoP over time.

For Lave and Wenger, newcomers to CoP learn through increasing participation in the roles of the expert members of the community. Thus, newcomers follow a trajectory of levels of participation to develop expert knowledge and skills. In their original writing, full participation in the social practice of a CoP entailed movement by newcomers to what Lave and Wenger refer to as central participation. Newcomers, such as young people in the 21st century, may bring their technological skills to the communities to which they belong and share these with old-timers.

Although Lave and Wenger first introduced the term CoP, at about the same time, Brown and Duguid (1991) used the concept of CoP to describe ways in which adult workers improvised to solve problems in organisations where "canonical" ways of doing things proved to be inadequate. In their work, Brown and Duguid argued that for the adult workers, "canonical" ways of doing things are inflexible and limited, so getting things done sometimes needed locally developed understanding of how to do things. The conclusion from Brown and Duguid's work was that CoP provide sources of help for innovation. The relevance of Brown and Duguid's work to my current study will become apparent in Chapter 6 (see p.191), when I discuss the extent to which PAL leaders followed prescribed learning facilitation strategies following training which was provided to them.

Wenger (1998) acknowledged that although CoP theory was central to their arguments in *Situated learning: Legitimate peripheral participation*, they (both Lave & Wenger) did not give sufficient attention to the CoP in this early work (i.e. Lave & Wenger, 1991). For this reason, he suggested, the concept of CoP needed further examination and rigorous empirical treatment. This view may have motivated his most well-known and cited work: *Communities of Practice: Learning, meaning, and identity* (Wenger, 1998). This influential publication builds on Lave and Wenger's work by extending and emphasising CoP and identity.

For Wenger (1998), learning occurs through identity formation of the individual members of the community. In this work, Wenger begins with a characterisation of today's educational institutions. He notes that much of the education system in developed countries is based on the assumption that "learning is an individual process, that it has a beginning and an end, that it is best separated from the rest of our activities, and that it is the result of teaching" (Wenger, 1998, p.3). Beckett and Hagger (2002) suggest that these assumptions can be clustered together as the "standard paradigm" of learning. Wenger's response to the above characterisation of learning was his proposition of a *social theory of learning* with its own set of four assumptions which I summarise as follows:

- a central aspect of learning is that humans are social beings,
- knowledge is a matter of competence in relation to a valued enterprise,
- learning is about participation in and engagement with the world,
- learning produces humans' ability to experience the world and engage with it meaningfully.

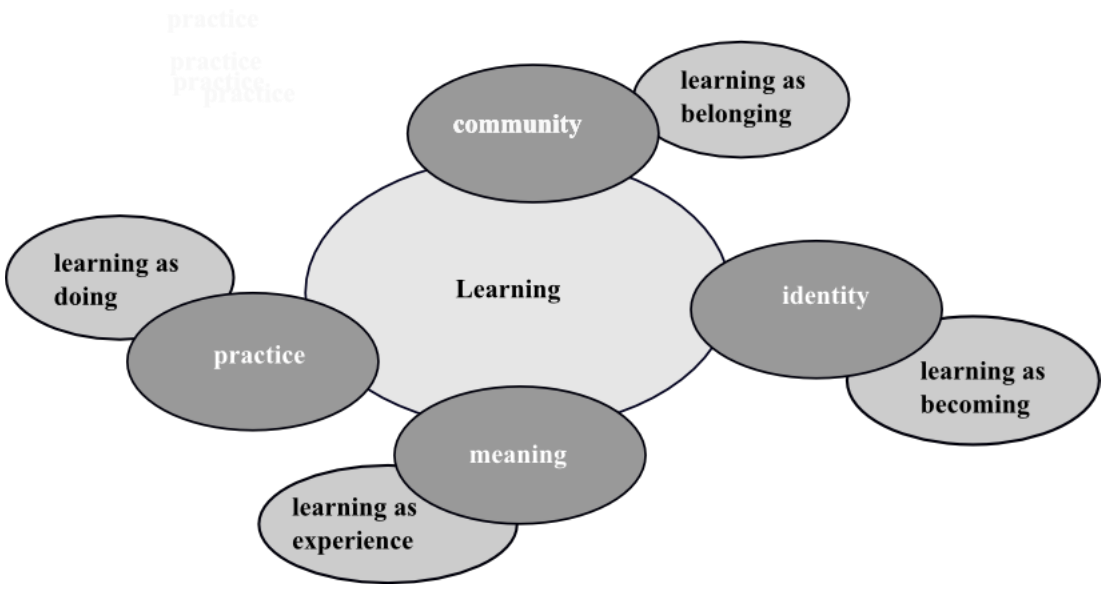


Figure 3.1. Components of social theory of learning (Wenger, 1998, p.5).

The social theory of learning that Wenger proposed to explain the learning that takes place within and/or across CoP has four components: *meaning*, *practice***,** *community*, and *identity* as shown in Figure 3.1. Wenger (1998, p.5) outlines the four components of learning as follows:

1) *Meaning*: a way in which members talk about their ability and experience of the world around them.
2) *Practice*: a way in which members talk about their shared history, resources, and perspectives that enable them to sustain their mutual engagement in pursuit of their joint enterprise.
3) *Community*: a way in which members talk about the composition and structure of the community in which the joint enterprise is being pursued, and how their competences are recognised.
4) *Identity*: a way in which members talk about the way learning impacts on them and creates shared history of the community.

The relationship between a CoP and the four components of learning can be described as follows:

> *On the one hand, Community of Practice is a living context that can give newcomers access to competence and also can invite a personal experience of engagement by which to incorporate that competence into an identity of participation. On the other*

> *hand, a well-functioning Community of Practice is a good context to explore radically new insights without becoming fools or stuck in some dead end. A history of mutual engagement around a joint enterprise is an ideal context for this kind of leading-edge learning, which requires a strong bond of communal competence along with a deep respect for the particularity of experience. When these conditions are in place, Community of Practice is a privileged locus for the creation of knowledge (Wenger, 1998, p. 214)*

Unlike Lave and Wenger (1991) who provided a definition of CoP (see p. 98), Wenger does not seem to provide an explicit *definition* but instead suggests *dimensions* of CoP. According to Wenger, the practices within CoP are characterised by: *mutual engagement, joint enterprise,* and *shared repertoire of resources*. These characteristics of CoP which Wenger refers to as *dimensions* are shown in Figure 3.2.

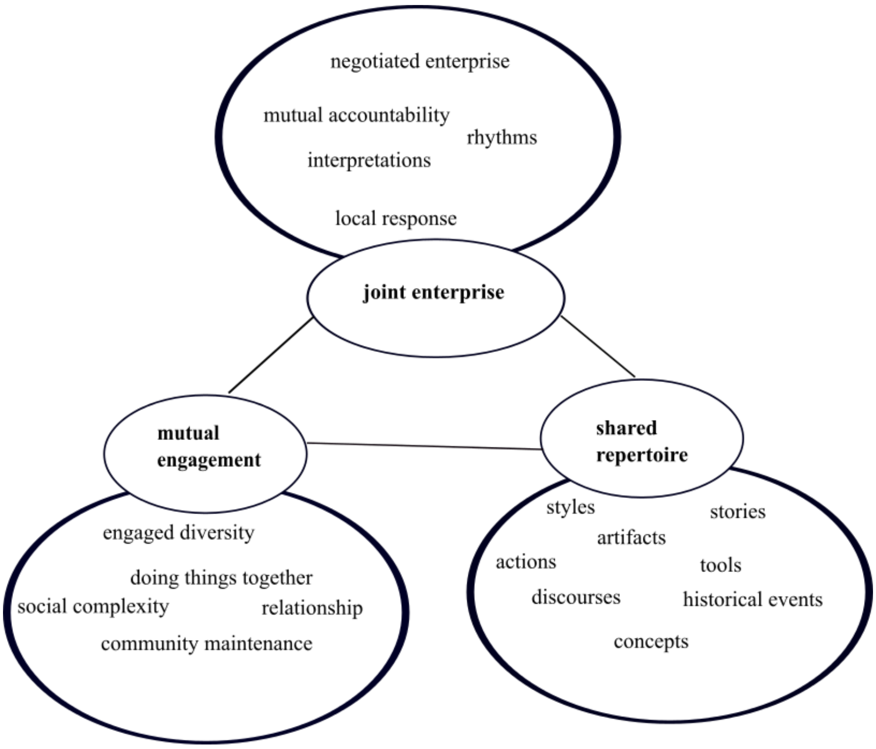


Figure 3.2. Dimensions of Communities of Practice (Wenger, 1998).

Mutual engagement, Wenger (1998) argues, is a dimension of practice and acts as a source of community coherence. Mutual engagement involves members doing things together through established relationships. Members of the community engage in actions and negotiate the meaning of those actions. In CoP, proximity of the members is not required but rather sustained personal engagements and relationships through what the members do is necessary for community coherence. Sustained personal engagements may generate tensions and conflicts which may constitute the core of the practice of the community. Homogeneity of members of CoP is not a precondition for mutual engagement.

In his argument articulating the dimensions of CoP, Wenger states that being engaged in a community is being included in what matters to the community. CoP require background coordination to ensure that things get done and this coordination, referred to as "community maintenance", requires constant attention by the community.

Joint enterprise, according to Wenger, is the second characteristic of practice as a source of coherence. Members of CoP negotiate their joint enterprise. This joint enterprise is defined by participants in pursuit of their negotiated local response to a shared problem that requires solution. The joint enterprise creates mutual accountability and it is integral to the practice of the community. Since mutual engagement does not need homogeneity of community membership, disagreement can occur and hence a joint enterprise does not mean agreement amongst members.

Shared repertoire is the third characteristic of practice as a source of coherence. Members' pursuit of the joint enterprise creates resources for negotiating meaning over time. A community's repertoire includes routines, words, tools, artefacts, ways of doing things, gestures, stories, symbols, concepts produced over time, discourse by which members create meaning as well as styles by which members express their forms of membership and the identities.

Wenger provides a list of indicators that characterise an emergent CoP (Wenger, 1998, pp.125-126):

- sustained mutual relationships –harmonious or conflictual
- shared ways of engaging in doing things together
- the rapid flow of information and propagation of innovation

- absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process
- very quick setup of a problem to be discussed
- substantial overlap in participants' descriptions of who belongs
- knowing what others know, what they can do, and how they can contribute to an enterprise
- mutually defining identities
- the ability to assess the appropriateness of actions and products
- specific tools, representations, and other artefacts
- local lore, shared stories, inside jokes, knowing laughter
- jargon and shortcuts to communication as well as the ease of producing new ones.

Wenger sums up a CoP as "community created [by people] over time by the sustained pursuit of a shared enterprise" (p.45).

Participation and *non-participation* in CoP may result in identity transformation. Wenger (1998, p.4) argues that participation refers "not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of the social communities and constructing identities in relation to these communities". Participation in a CoP also entails "*negotiation of meaning*" amongst the members and the "possibility of mutual recognition" (Wenger, 1998). However, participation does not necessarily result in "equality or respect" (Wenger, 1998; p.56). To understand how participation in CoP leads to identity formation and learning, Wenger (1998, p.174) presents and distinguishes between three modes of belonging: *engagement*, *imagination*, and *alignment* (see Figure 3.3).

Engagement entails direct and active involvement of members of a CoP and with their experience of the world in which they participate. Thus, engagement involves community members doing things together, talking, and producing artefacts. Through engagement, individual members of CoP engage in activities that are mutually negotiated. Engagement involves complex relations amongst members and these complex relations enable the establishment and maintenance of ongoing activities. Through the negotiation of ongoing activities by members, a joint enterprise develops over time.

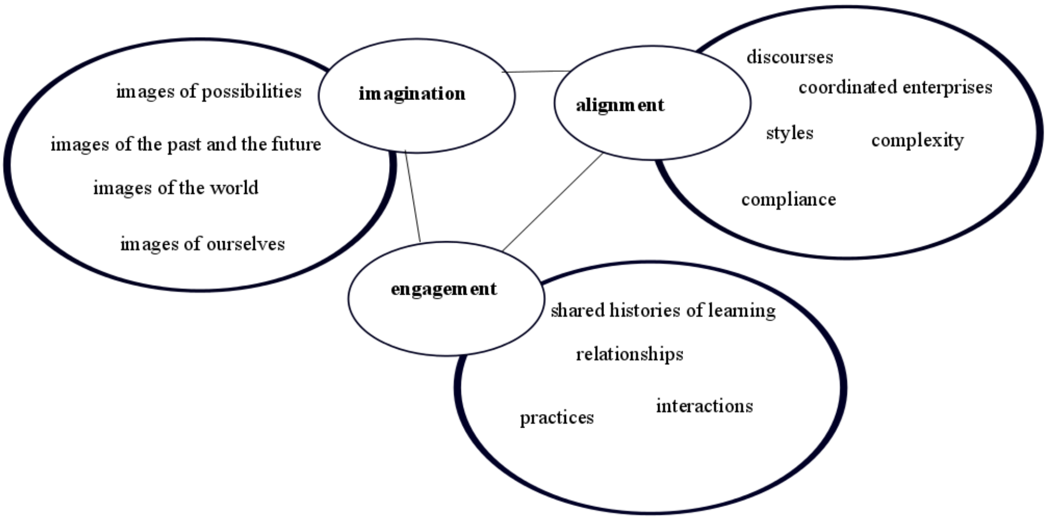


Figure 3.3. Modes of belonging (Adapted from Wenger, 1998, p. 174)

Wenger uses the concept of *imagination* to refer to "a process of expanding ourself by transcending our time and space and creating new images of the world and ourselves' (Wenger, 1998, p.176). Thus, he uses imagination to characterise the way members of CoP see themselves and the world around them and make sense of the practices in which they are involved. Imagination is important because it has implications for the way participants of CoP see themselves and how much they learn from the practices in which they are engaged. To make the meaning clearer, Wenger provides the following as an example of imagination:

> *Two stonecutters … are asked what they are doing. One responds: 'I am cutting this stone in a perfectly square shape.' The other responds: 'I am building a cathedral.' Both answers are correct and meaningful, but they reflect different relations to the world. The difference between these answers does not imply that one is a better stonecutter than the other, as far as holding the chisel is concerned. At the level of engagement, they may well be doing exactly the same thing. But it does suggest that*

> *their experiences of what they are doing and their sense of self in doing it are rather different. This difference is a function of imagination." (Wenger, 1998, p. 176)*

In the above example, as Wenger points out, although both stonecutters gave different answers, they were both correct. The answers differed because of the different ways in which the stonecutters saw the activity that they were undertaking. That difference in imagination could impact the relationship that each has and what he learns.

Alignment involves members' adherence to the global practices and discourse of a broader community which enables direct focus on a joint enterprise (e.g. in the case of thesis, the development of engaging learning material, enhancing the student learning experience). Alignment involves the establishment of common grounds and definition of a broader vision which enable the accomplishment of the joint enterprise. Wenger stresses that *engagement*, *imagination*, and *alignment* have complementary strengths and weaknesses and therefore work well together.

Wenger, McDermott and Snyder's (2002) work, *Cultivating Communities of Practice: A practical guide to managing knowledge* is "a popularization and a simplification but also a commodification" (Cox, 2005, p.533) of the notion of CoP. Wenger et al. (2002) focus on knowledge creation and development in organisations. This source of CoP has not received much attention in mathematics education research. This may well be due to the shift in focus from theory to a practical guide for developing CoP. It is worth pointing out that in this source, Wenger et al. define CoP as:

> *groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an on-going basis. [As] they accumulate knowledge, they become informally bound by the value that they find in learning together. Over time, they develop a unique perspective on their topic as well as a body of common knowledge, practices, and approaches. They also develop personal relationships and established ways of interacting. They may even develop a common sense of identity. They become a Community of Practice (Wenger et al., 2002, pp.4-5).*

The dual nature of CoP as a theory and as a social configuration of people is evident in the two pieces of work – Wenger (1998) and Wenger et al. (2002).

Individuals may belong to multiple CoP. For example, university mathematics teachers may belong to the CoP of university mathematics teachers, researcher mathematicians and a departmental research group. Similarly, undergraduate mathematics students may belong to the CoP of undergraduate mathematics students, students on a particular mathematics degree programme, and other community groups within the wider university context such as societies. Wenger (1998) notes that CoP "cannot be considered in isolation from the rest of the world, or understood independently of other practice" (p.103). Thus, engagement in one community of university mathematics practice may entail engagement in other CoP. The *multimembership* of CoP may create "continuity and discontinuity" across the *boundaries* of the various communities. Wenger uses the term *boundary objects* to describe "artefacts, documents, terms, concepts, and other forms of *reification* around which CoP can organise their interconnections."

In CoP, "certain individuals seem to thrive on being *brokers:* they love to create connections and engage in 'import-export', and so would rather stay at the boundaries of many practices than move to the core of any one practice" (Wenger, 2000, p.235). These individual members of CoP may introduce elements of practice in one community to another. Brokers create connections between CoP to which they belong and thus create possibilities for new meanings. Over time, there is a possibility for brokers to create CoP reflecting their relations with other communities, thereby providing a bridge between practices that blurs allegiance. CoP may have diverse group of members with varying experiences, expertise, age, personality, and authority and power differential which may be more evident in terms of the degree of participation. Members with full participation may have a greater role and consequently, more power in the negotiation of meaning. Hence, meanings will continue to be a reflection of the dominant source of power.

Lave and Wenger (1991) acknowledge the importance of power in shaping the participation and the legitimacy of peripherality. However, they do not explore the implications of the distribution of power when discussing the case studies of the five apprenticeships. I have, thus far, discussed the sources of CoP, highlighted some definitions and constructs underpinning the theory. The CoP theory has been criticised for having limitations when employed in the exploration of how individuals learn mathematics or learn to teach mathematics.

First, it has been criticised for not having the explanatory power to enable a deeper understanding of how individuals and groups learn mathematics, either in schools, colleges or universities (see e.g. Goos & Bennison, 2008; Graven, 2004; Kanes & Lerman, 2008). Lave and Wenger (1991) studied learning in apprenticeship settings and Wenger (1998) studied the practices of workers in an insurance company. In the settings which were the focus of these two seminal works, the activities that individuals engaged in were different from learning mathematics in schools or universities. Similarly, although university undergraduate mathematics students choose to study mathematics, they do not all aspire to become mathematicians. Therefore, the CoP construct, *legitimate peripheral participation*, might fail to explain fully mathematics learning in a school or university context.

Second, in the apprenticeship context and the insurance company studied by Lave and Wenger (1991) and Wenger (1998) respectively, teaching was not a goal. It is not therefore surprising that none of these works had any discussion of teaching. Given that school mathematics and university mathematics communities have teaching as one of their main practices and teachers have authority and power, it is perhaps arguable that these learning environments would be anything but a composition of social configurations that can be described as CoP.

Despite the above criticisms, it was my conjecture that the CoP theory could explain the process of the staff-student partnership in undergraduate mathematics course design and delivery and the impact of the partnership on the partners. This conjecture is supported by the fact that the two groups that came together to co-design the two courses had a clearly defined goal that they wanted to achieve. This goal was the enhancement of the student learning experience and student achievement in the two courses. In addition, there was no requirement for formal teaching in the two settings in which staff and students interacted while they engaged with mathematics. These settings were the *student internship* and *PAL sessions*. In these settings, learning and knowledge creation were pursued by interested parties who volunteered to be part of an identifiable community.

Moreover, my decision to apply CoP theory to investigate the staff-student partnership in course design and delivery is rooted in Healey, Flint and Harrington's (2014) proposal of *partnership learning communities* as a model which they also believe could explain how partnership operates. Their model is based on the Wenger's (1998) CoP theory. Healey et al. argue (2014) argue that staff-student partnership is more likely to be sustained where there is a strong sense of community among staff and students. Sustainability of staff-student partnership, they claim, could be achieved through the development of a partnership learning community and consideration *for* and critical reflection *on* contextual issues such as:

- inclusivity
- power relationships
- reward and recognition
- transition and sustainability
- identity (Healey et al. p.8).

3.2.2 *Operationalization of Communities of Practice in the current study*

Vygotsky's concept of ZPD discussed in Section 3.2.1 (see p.67) has relevance to the phase one and phase two studies for two reasons. In a staff-student partnership in course design, the staff are the more knowledgeable other relative to the student partners. The student partners will be able to accomplish the task assigned to them as partners and co-creators of course content if the task is within their ZPD and staff provide the necessary support through guidance and feedback.

Similarly, in PAL sessions, with support and guidance from PAL leaders, PAL participants have additional opportunity to engage with mathematical tasks within their ZPD. Zerger (2008) notes that the philosophy behind SI or models derived from it such as PAL stems from a collection of theories including that of Vygotsky's (1978) theory of socially mediated learning and social interdependence principles (Vygotsky, 1986). Attendance at PAL sessions is voluntary. Therefore, those students who choose to participate in PAL sessions are, by their actions, taking responsibility for their own learning. In the sessions, they have the opportunity to construct their own responses to, and create their own knowledge with respect to their own selected mathematical tasks. They do this without direct oversight or presence of a more powerful authority figure – the lecturer. Although in PAL sessions the PAL leader is the more knowledgeable other, the difference in the notional power and authority between the PAL participant and the lecturer is much bigger than that between the PAL participant and the PAL leader.

The staff-student partnership in which the student interns play roles as co-creators of course content naturally offers students opportunities for regular and sustained interactions between them and staff. Similarly, the PAL sessions also create opportunities for regular interactions between students from different year groups and backgrounds. In each of these scenarios, the people involved have shared goals or purpose for their interactions. It was my conjecture then, at the time the current research was conceived, that CoP might offer insights into the ways in which staff and student interns work together; and the ways in which PAL leaders and the PAL participants work in PAL sessions.

In my current research, my focus is not on individual cognition. Rather, I am interested in staff and students' views about their experiences of the partnership, and how their experience impacted on them. My interest is in both the *collective learning* of the partners in course design; and the *transformation in individual's views* about themselves and their relation to mathematics and its learning. Therefore, CoP theory and the notion of *scaffolding* seem to offer the tools that I needed to deploy to answer the research questions (see Section 1.2.2, p.10). By way of an example, Green (2005) chose Wenger's (1998) CoP; drew on Vygotsky's (1978) notion of ZPD, and Wood's (1978) scaffolding metaphor to explore the development of a group of graduate students whose joint enterprise was the development of qualitative research skills.

In her exploration of the graduate learning community, Green developed a framework she calls "spaces of influence" for evaluation of an "influential other" within a learning community. In the "spaces of influence", through the support provided by an "influential other", members of the learning community develop a sense of belonging to the community. In the "spaces of influence", none of the members of the community and the "influential other" necessarily had all the answers, but all are willing to explore the "spaces of influence" and the end of the learning journey is unknown to all.

For Green, spaces of influence are dynamic in that all participants have a collaborative problem-solving role. She notes five meta-spaces within the "spaces of influence". These are "*spaces of action*" where learners take control of their learning, "*spaces of explicit discourse*" where learners engage in discourse practices that make critical elements of a learning context clearer, "*spaces of learning*" where learners engage with content knowledge relevant to their practice, "*spaces of practice development*" where learners share examples of practice and discuss variations of processes, and lastly, "*spaces of trust*" where learner's express vulnerability and take risks in learning because of the community trust.

Solomon (2007) explores the learning experiences of twelve first-year undergraduate mathematics students through interviews. She argues, in her report, that undergraduate mathematics students may belong different CoP and this may include: 1) the community of undergraduate mathematics students, 1) the first-year undergraduate mathematics community of learners, and 3) the classroom community of learners and tutors. Solomon analysed the interview transcripts to explore the students' identities in terms of Wenger's modes of belonging: *engagement*, *imagination* and *alignment*. The interview transcripts were analysed thematically. As she notes, this entailed assigning relevant pieces of text to categories initially generated from Wenger's theoretical framework, focusing on the students' relationships to mathematics within both the wider community of mathematicians and undergraduate communities.

Hemmi (2006) also applied the CoP theory to explore proof as mathematical practice in a mathematics department in Sweden. In her exploration, Hemmi investigated university teachers' pedagogical views and intentions, students' experiences of proof and their practices in relation to proof. Hemmi employed the following CoP constructs: *mutual engagement*, *joint enterprise*, and *shared repertoire of resources*, *participation/non-participation*, *identity building*, and *negotiation/ownership of meaning* to the data she collected in her study to gain insight into the mathematics department's proof practices. The constructs provided insights into the mathematical practices, the role of proof, individuals' participation and engagement in these proof practices. Also, Hemmi employed *legitimate peripheral participation* and *transparency of mediating artefacts* to exemplify tensions and conflicts in the trajectories of peripheral participation. In her study, Hemmi (2006) suggested that members of the mathematics department that she studied belonged to the same CoP although as she points out, there were status and power differentials between students and the mathematicians.

In relation to staff-student partnerships, there has been two studies that have explored the partnership from the perspective of CoP (e.g. Flint & O'Hara, 2013; Biza & Vande Hey, 2014). While Biza and Vande Hey explored staff-student partnership in the development of statistics resources, Flint and O'Hara (2013) was non-discipline specific. Flint and O'Hara employed *engagement*, *imagination* and *alignment* to explore staff-student partnership in which students played roles in institutional governance. While this example is not rooted in a specific discipline, the choice of CoP constructs to explore the staff-student partnerships is similar to that of Solomon (2007). However, CoP was used as a reflective critical analysis of the partnerships and there was no data presented to demonstrate how these had been applied. They conclude from their critical analysis that the concept of *student voice* should be considered and then offer a model for future data analysis.

Biza and Vande Hey (2014) also explored a partnership in which students co-created statistics resources for use by students and teacher involved in learning or teaching quantitative methods or statistics in other disciplines. In their analysis, Biza and Vande Hey employed the constructs of *participation* and *identity* in their analysis of extensive qualitative data.

As the above examples show, CoP have been applied to explore university staff and students' experiences of mathematics and its practice. Advanced undergraduate mathematics courses are often designed hierarchically to build on lower level courses which are often taught in the early years of undergraduate mathematics degree programmes. As such when the staff-student partnership in course design and delivery of Vector Spaces and Complex Variables was conceived, it was not clear whether student partners would have adequate knowledge and skills to co-create resources for learning and teaching and to facilitate the learning of their peers. Thus, outcomes of the staff-student partnership in *advanced undergraduate mathematics* course design and delivery for staff and students were not at all certain. This thesis therefore sought the answers to the following five research questions:

1. When undergraduate students are provided with an opportunity to collaborate as interns with staff in advanced undergraduate mathematics course design what is the nature of that collaboration?
2. How does the collaboration in course design impact on the student interns and staff?
3. What are the characteristics of PAL sessions for advanced undergraduate mathematics and what roles are played in sessions?
4. What is the qualitative impact of the staff-student collaboration in course delivery via PAL on PAL participants and PAL leaders?
5. What is the quantitative impact of the staff-student collaboration in course delivery via PAL on PAL participants?

As I have noted earlier in this Chapter, the staff-student partnership in course design and delivery which was the focus of the current research had overlapping CoP of staff and undergraduate mathematics students who had previously taken the two course –

Vector Spaces and Complex Variables. I collected and analysed qualitative data on the partnership process and about the partners, their roles, activities and interactions during the phase one and phase two studies of the research project. I explored the qualitative data using the following constructs from Lave and Wenger (1991) and Wenger (1998) as lenses to explore the data:

- dimensions of CoP
    - joint enterprise
    - mutual engagement
    - shared repertoire
- components of learning
    - meaning
    - practice
    - community
    - identity
- modes of belonging
    - engagement
    - imagination
    - alignment
- multimembership of CoP
    - brokering
- legitimate peripheral participation

The above constructs comprised predetermined codes which were used to explore the qualitative data. Additional codes were also created in vivo (King, 2008) while the qualitative data were being analysed. King notes that in vivo coding is the "practice of assigning a label to a section of data, such as an interview transcript, using a word or short phrase taken from that section of the data" (p. 473). Therefore, in vivo coding is associated with the earlier stages of coding one's data when concepts or categories are being identified or developed. In this thesis, the codes created in vivo constituted emerging codes and were based on common meanings and patterns found in the textual data. Codes which were related were categorised under named themes. I present further details of the operationalisation of CoP theory and the data analyses in Chapter 5 (pp. 126-163) and Chapter 6 (pp. 193-214).

In the next section, I discuss the model of the variables that show the relationship between PAL attendance and student achievement in each of the two courses to which PAL was attached in the partnership for course delivery. I also describe briefly how the model was applied in the phase three study.

3.3 Variables studied in the quasi-experimental study

In phase three of the current study, I investigated the relationship between PAL attendance and student achievement in each of Vector Spaces and Complex Variables courses. I argue that student achievement in any of these two course units depends on many factors including: adjustment to the university learning and teaching environment, pre-university entry qualifications, performance in pre-requisite courses, lecture attendance, access to appropriate course material. The literature on PAL schemes for introductory first-year courses also indicate that there is a relationship between PAL attendance and examination performance in those courses to which PAL schemes are attached (Burmeiser et al., 1994; Dobbie, 2009b; Fayowski & MacMillan, 2008; Miles et al., 2010).

The relationships between PAL attendance and achievement in Vector Spaces/Complex Variables are shown in Figure 3.4 together with possible confounding variables. The staff-student partnership in course delivery is metaphorically depicted in Figure 3.4 as a machine the inputs of which are the achievements in pre-requisites courses, lecture attendance and PAL attendance. The outputs are the student achievements in Vector Spaces and Complex Variables. The confounding variables are conditions outside the machine that may affect how it operates and hence the quality of the outputs (student achievement in Vector Spaces/ Complex Variables) from the machine.

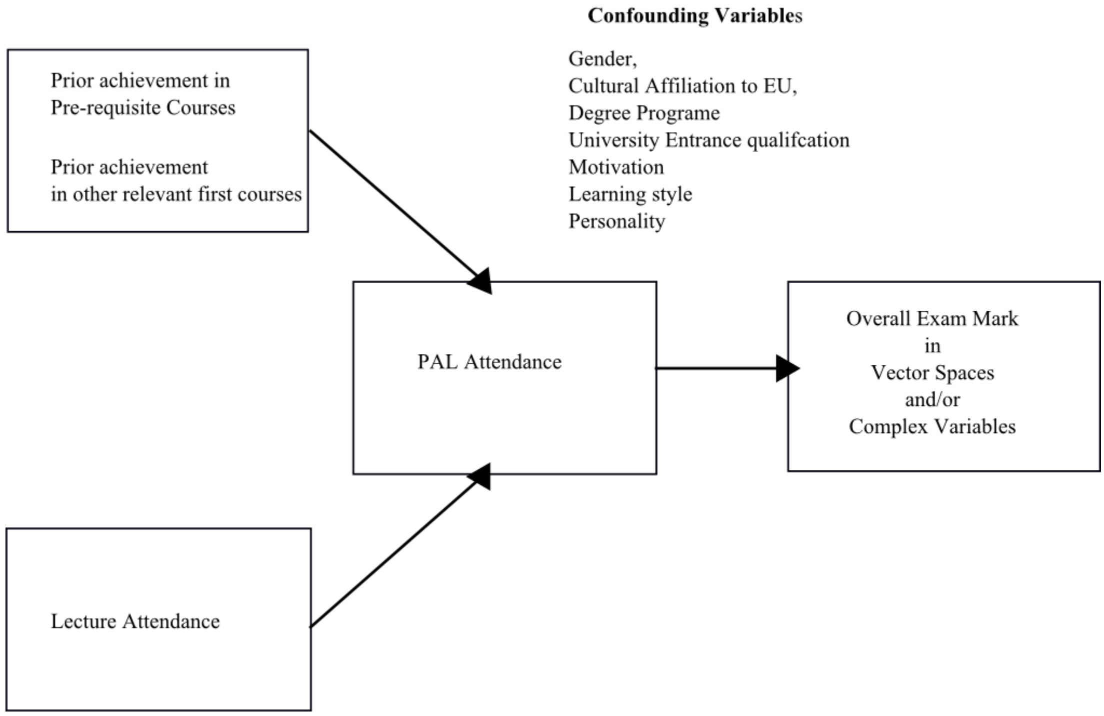


Figure 3.4. Relation between PAL attendance, achievement and other variables.

The relationships between PAL attendance and achievement was derived from the research literature (see Chapter 2, Sections 2.3-2.5) in which the courses to which PAL was attached were primarily introductory courses across a range of disciplines including mathematics for non-specialist students. However, it was my conjecture that similar relationships between PAL attendance and achievement could be found for a PAL scheme which was attached to the two second-year undergraduate mathematics courses, Vector Spaces and Complex Variables. It was not possible, however, to include an exhaustive list of all the confounding variables that might affect student performance in a course aside from the PAL intervention. The focus of Chapter 7 is the phase three study which explored the relationships between PAL attendance and achievement in Vector Spaces/Complex Variables.

3.4 Summary

In this chapter, I have described the origins and reasons for the emergence of CoP as a theoretical framework for this study. The CoP theory allows us an “entry point to a wider conceptual framework” (Wenger, 1998) and analytical constructs for researching mathematics learning in formal settings such as classroom and lectures.

However, staff-student partnership in course design and delivery naturally creates informal “collaborative spaces” in which the staff and student partners can mutually engage. Given the informal settings of the internship and the PAL sessions upon which this study focussed, I conjectured that CoP theory may provide us with insights into staff-student partnership in university mathematics course design and delivery. In Chapter 4, I provide a descriptive account of the research design and methodology adopted to investigate the staff-student partnership. In Chapters 5 and 6, I will return to the use and application of CoP in the data analysis of a range of qualitative data. In Chapter 7, I discuss the investigation into the relationship between PAL attendance and achievement in Vector Spaces/Complex Variables and the results of the investigation.

CHAPTER 4 RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

The focus of this chapter is on the research design and methodologies of each of the three studies that comprise the three-phase research project. However, before I discuss the research design and methodologies, I briefly outline the main schools of thought on the worldview of knowledge creation. In Section 4.2, I discuss the educational research paradigms that may inform a research project. The case for researchers to draw on both positivism and interpretivism research paradigms is also discussed in the same section.

In Sections 4.3 through to 4.5, I describe the three studies separately. For each phase of the study, I describe the methodology I adopted, participants, methods, and procedures I followed to collect data for analysis. In addition, I provide a brief description of the data analysis that was conducted in each phase. In Chapters 5, 6, and 7, I respectively present further details about the data analysis for phase one, two and three studies. Issues relating to validity and reliability of the study are addressed in Section 4.6 and I outline the ethical procedure I followed in Section 4.7. I then summarise the Chapter in Section 4.8.

4.2 Research paradigms and related methodologies

4.2.1 *Research Paradigms*

Researchers bring to bear on their research enterprise their experience, skills, and philosophical view on how research should be conducted (Basit, 2010; Bryman, 2008; Gratton & Jones, 2010). Two philosophical positions that may influence how a researcher conducts a piece of research are the *ontological* and e*pistemological* positions held by the researcher. Ontology is the study of the existence of knowledge of a phenomenon while epistemology is the study of how such knowledge is obtained. (Gratton & Jones, 2010). Thus, ontology is concerned with the assumptions about the nature of existence of reality and epistemology is concerned with the assumptions about the nature of the knowledge of reality. The ontological and epistemological assumptions held by a researcher may influence the methodology, the methods of data collection, how the data are analysed and interpreted, and what conclusions are drawn from such interpretations (Basit, 2010; Gray, 2013).

Research paradigm is a term which was first put forward by Kuhn who defines it as the "entire constellation of beliefs, values, techniques, and so on, shared by members of a given community" (Kuhn's, 1962, p.162). These beliefs and values may be rooted in the philosophical views of sections of the community or all members of the community. These philosophical views also centre around the ontological and epistemological positions held by sections of the community or all members of the broader community. For the purposes of the current research, undergraduate mathematics education researchers are arguably the community whose beliefs and values inform the study. Writing on Kuhn's definition further, Gray (2013) suggests that research "paradigm then consists of a set of theoretical ideas and technical procedures that a group of scientists adopt and which are rooted in a particular worldview with its own language and terminology". Research paradigm, then, refers collectively to the ontological and epistemological positions held by a researcher.

The educational and social research methods literature describes a number of research paradigms (e.g. Basit, 2010; Bryman, 2008; Creswell, 2009). I will discuss three of these paradigms here as I believe they are relevant to any inquiry into staff-student partnership in learning and teaching. Historically, positivism and interpretivism have been the two main research paradigms in educational and social research which. These two paradigms have been debated and critiqued extensively by educational and social research methodologists (e.g. Howe,1988). In these debates, these two paradigms have often been viewed as polar opposites to each other (Sale, Lohfeld, & Brazil, 2002). However, some researchers have argued for the harmonisation of the two paradigms; and for researchers to draw on the two research perspectives in their research design (e.g. Gorad, 2010; Howe, 1988).

Bryman (2008, p.13) defines positivism as “an epistemological position that advocates the application of the methods of the natural sciences to the study of social reality and beyond”. This definition suggests that researchers who adopt positivism as an epistemological position would probably employ the scientific and experimental approach to a research inquiry. Bryman (2008, p.13) further suggests that there are five principles to which positivistic researchers may adhere. These principles of positivism are:

- what can be counted as knowledge is a social phenomenon that can be observed through human senses,
- research inquiry will identify testable hypotheses based on some theory,
- knowledge is obtained by gathering facts that show causal relationships,
- research should be conducted in such a way that it is value free,
- the scientific approach should only lead to scientific statements rather than normative statements, the truth of which cannot be confirmed through observations.

These principles are indeed a description of the positivists worldview of reality. Other authors of educational research methods literature also provide similar descriptions of the positivist worldview. Basit (2010), for example, suggests that researchers who subscribe to positivism share the view that knowledge about social phenomena “can be discovered by observing, experimenting on, or interrogating a large number of subjects, resulting in findings that can be statistically analysed, and are therefore generalizable” (Basit, 2010 p.14). Positivism, from Basit’s point of view, is a position commonly associated with the natural sciences. In this sense, positivism assumes that the social world, such as education, is similar to the natural world; and that there exists cause and effect relationships between social phenomena. In the research methods literature, positivism is often contrasted with interpretivism which I discuss next.

The development of the interpretivism paradigm is rooted in the critique of positivism in the social sciences and educational research. The interpretive paradigm is concerned with the understanding and the interpretation of the lived experiences of the subjects of the social world (Ernest, 1997). Researchers who subscribe to interpretivism are believed to share the view that social phenomena which are studied in educational and social science research are different from that of the natural sciences. Basit (2010), for example, suggests that the study of the social world needs a different research approach to that of the natural sciences (Basit, 2010).

Myers (2008) also argues that "interpretive researchers assume that access to reality (given or socially constructed) is only through social constructions such as language, consciousness, shared meanings, and instruments" (p.38). Interpretivism is associated with a diverse approach to research including hermeneutics, phenomenology, and constructionism. Research studies based on interpretivism focus on meaning and may employ multiple methods of data collection in order to reflect different aspects of the phenomenon under investigation.

The interpretivism paradigm, just like positivism, has been criticized for offering partial explanations of social phenomena. For example, it is suggested that subscribers to the interpretivism explore social phenomena by focusing on the hermeneutics and technical aspects of research, ignoring the political and ideological perspectives. Critical theory paradigm has arisen in response to such criticisms of both the interpretivism and positivism paradigms.

Researchers who draw on the critical theory paradigm assumes that knowledge can be distorted and is therefore problematic (O'Donoghue, 2007). Subscribers to the critical theory paradigm assume that knowledge cannot be value free and often represents the interest of some groups of society. In this regard, subscribers to the critical theory paradigm argue that "knowledge has the potential to be either oppressive or emancipatory" (O'Donoghue, 2007, p.10). The goal of research that draws on critical theory is to expose the ideologies that continue to perpetuate the status quo by "restricting the access of groups to the means of gaining knowledge" and by raising their "consciences or awareness about the material conditions that oppress or restrict them" (Usher, 1996, p.22). Critical theory researchers, then, place emphasis on understanding the causes of the "powerlessness, recognising systematic oppressive forces and acting individually and collectively to change the conditions" (Usher, 1996, p.22). O'Donoghue (2007) suggests that in addition to the social critique by critical theorist, it is important that they are guided by the critique in taking action to improve the human condition. Thus, critical theory aims to improve the state of a phenomenon under investigations. Ernest (1997) summarises the differences between positivism, interpretivism and critical theory as presented in Table 4.1.

Table 4.1 Summary of the Three Main Paradigms of Educational Research

Assumptions	**Paradigm**		
	Positivism	**Interpretivism**	**Critical theory**
Ontology	Scientific realism (objects in physical spaces)	Subjective reality (personal meanings)	Persons in society and social institutions
Epistemology	Absolutist and objective knowledge	Personal constructed and socially constructed knowledge	Socially constructed knowledge
Methodology	Mainly quantitative and experimental involving many subjects and contexts	Mainly qualitative case studies of particular individuals and contexts	Mainly critical action research on social institutions.
Intended Outcome	Applicable knowledge and generalizable	Illuminative and subjective understandings	Intervention for social reform and social justice
Interest	To comprehend and improve (through prediction and control) the world	To understanding and make sense of the world	Social justice and emancipation

Adapted from Ernest (1997, p. 37)

It is important to point out that the paradigm within which a researcher operates determines the kind of research questions which are investigated. The paradigm within which a research operate also determines the research methodology which is adopted to investigate the research questions. There are two main types of research methodologies: quantitative and qualitative research methodologies. These methodologies are discussed in the next section. In the same section, I also discuss an approach to research – *mixed-methods approach* – which combines both quantitative and qualitative methodologies.

4.2.2 *Quantitative, qualitative and mixed methods approaches*

Some published research studies adopt either purely quantitative or qualitative approaches to research design. Studies which adopt purely quantitative approaches to research often draw on the positivistic paradigm and research methodologies such as experimental designs, quasi-experimental designs, and surveys. It is believed that experimental designs are the most rigorous research designs because these typically involve random assignment of research participants to experimental and control groups. A researcher who conducts an experimental design may obtain pre-test as well as post-test measures or observations of the treatment variable on both the experimental and control group.

The mean scores of the pre-test and post-test of the experimental and the control groups are then compared to ascertain any statistical differences that may exist between the groups. A variation of this approach is that the researcher may obtain only post-test scores on the treatment variable for both groups in order to analyse the differences in the mean scores. It is not always possible to conduct experiments in educational settings and so a researcher may instead conduct quasi-experimental study in which participants are assigned to treatment and non-treatment groups without random assignments.

Studies which adopt purely qualitative approaches to research draw on the interpretative paradigms assumptions. Strauss and Corbin (1998) define qualitative approach to research as "any type of research that produces findings not arrived at by means of statistical procedures or other means of quantification" (pp.10-11). However, increasingly, qualitative research in which verbal or textual data have been quantified are being reported (Chi, 1997; Shemmings, 2006). Frequency analysis of some aspects of the qualitative data is carried out and the results reported. Therefore, the growth in the quantification of qualitative data contrasts with the Strauss and Corbin's (1998) definition of qualitative research. Research methodologies associated with qualitative approaches to research include case study, ethnography, action research, phenomenology and phenomenography. The methods of data collection typically include interviews, focus groups and observations.

Quantitative methodologies and associated methods are increasingly being combined with qualitative methodologies and related methods. It is now common for researchers to employ a mixture of qualitative and quantitative methods in their research inquiry drawing on both the positivistic and interpretative paradigms (Howe, 1988). Such an approach to research design is increasingly being used in educational research (McMillan, 2004) and has been described as mixed-methods design. Johnson and Onwuegbuzie (2004, p.17) define a mixed-methods approach to research as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study”. Basit (2010) suggests that a mixed-methods approach offers the best of both quantitative and qualitative approaches to research by drawing upon the strengths and weaknesses of the methods and procedures used from the standpoint of positivism and interpretivism. Other authors on research methods have argued that the divide between quantitative and qualitative approaches to research is unhelpful (Gorad, 2010; Howe, 1988) and advocate an integrated approach to research design that includes both quantitative and qualitative methods.

McMillan (2004) describes three mixed-methods approaches to research design: *explanatory design*, *exploratory design*, and *triangulation design*. An explanatory design is a research design that involves the collection of quantitative data in one phase of study, followed by the collection of qualitative data in another phase depending on the results of the quantitative data analysis. In such a design, data collection in the two phases is sequential. The purpose of the qualitative data is to elaborate the results of the quantitative data analysis.

An exploratory mixed-methods design is a research design that involves the collection of qualitative data in one phase of the study followed by the collection of quantitative data in another phase of the study in a sequential manner. In an exploratory mixed-methods design, the qualitative findings are used to identify themes, ideas, or perspectives to be used in a large scale quantitative survey. In a triangulation mixed-methods design qualitative and quantitative data are collected simultaneously or in parallel at about the same time.

I adopted a triangulated mixed-methods design to inquire into the staff-student partnership in advanced undergraduate mathematics course design and delivery. As we shall see, I adopted a triangulation mixed-methods design, collecting qualitative and quantitative data in the three overlapping phases of the research. I adopted a triangulated mixed-methods design so that I could carry out an *in-depth* investigation into active student participation in the collaborative course design and delivery of the two undergraduate mathematics courses, Vector Spaces and Complex Variables. I deployed mixed-methods approach so that I could 1) have a rich understanding of the partnership process, 2) *evaluate* the impact of the staff-student partnerships on the partners, and 3) to evaluate the impact of the partnership on the students who are at the receiving end of the pedagogical intervention – staff-student partnership in course design and delivery.

Accordingly, in the current research, I drew on the interpretivist and positivistic assumptions to guide my research decisions regarding my choice of methodologies and methods for each phase of the research taking into account the nature of the research questions set out in Chapter 1 (see p. 10).

I indicated earlier in Section 4.1 that the research upon which this thesis reports was conducted in three phases. Phase one focused on a *student internship* which was a key aspect of the partnership in university mathematics course design. In this phase I explored the nature of the partnership and its impact on the staff and student partners. Phase two focused on a partnership in course delivery via PAL. In this phase, I studied the characteristics of PAL sessions and the qualitative impact of participation in PAL on PAL participants and PAL leaders. Phase three was a follow up to the phase two study in that I studied the quantitative impact of PAL attendance on student achievement in the two courses – Vector Spaces and Complex Variables. In sections

4.3 through to 4.5, I describe the methodology, participants, methods and research procedures I followed in each phase of the current research.

4.3 Ethnographic study of the student internship

Phase one of the current study was conducted between March 2011 and August 2011 at Middle County University (MCU). As I noted in Section 4.1, phase one focused on students working as partners and change agents in undergraduate mathematics course design. In this phase of the study, staff and students collaborated to redesign two courses Vector Spaces and Complex Variables. The course redesign involved staff and students co-creating learning and teaching resources for the two course units.

I adopted an ethnographic approach to study the staff-student partnership in course design. The ethnographic approach enabled me to experience the natural setting in which the collaborative course design process took place. The ethnographic design enabled me to observe closely the interactions and workings of the staff and the students. It enabled me to take up a close-up view of the staff-student partnership.

4.3.1 *Participants, methods and procedures*

The participants of this phase of the research were made up of five groups. The first group of participants was twenty second-year undergraduate mathematics students who had previously taken and passed Vector Spaces, and were studying Complex Variables for which they had not yet been examined. This group of research participants took part in five focus group discussions. There were four students in each focus group. The four student interns who actively co-created the course content of the redesigned courses constituted one of the five focus groups.

The aim of the focus group discussions was to explore the views of students on the learning and teaching of Vector Spaces and Complex Variables and mathematics more generally. In particular, the focus groups explored changes and additions to the two courses that could enhance the student learning experience; and resources that best help them learn mathematics. The goal of the focus group discussions was to inform the course redesign process.

The second group of participants of the phase one study was the four second-year student interns. As I noted earlier in Chapter 1 (see p. 8), the student interns' role was to collaborate with academic staff to co-create course content for the two courses. The four student interns were recruited as paid summer interns. All second-year undergraduate mathematics students were invited to apply for the four internship positions. The two main criteria for selecting the interns from the candidates applying for the positions were that they should have achieved an average of 60% in their first-year mathematics courses, and should have studied at least one of Vector Spaces and Complex Variables courses in the 2010/2011 academic year.

Vector Spaces is taught during semester one (October – February) of the academic year, and Complex Variables during semester two (February – June). Eight students, out of a cohort of about 100, applied for the internship positions and went through a selection interview conducted by the two course leaders and one additional staff member. The student interns took up their internship positions working part-time, two hours a week, for a maximum of 30 hours between March 2011 and June 2011. During the summer holidays (July – August 2011), the four student interns took up their fulltime summer internship positions, and worked in pairs. One pair worked on Vector Spaces and the other on Complex Variables. Each course leader worked closely with one pair of student interns to plan, design, and produce learning and teaching resources that could potentially enhance future cohorts of students' learning and their engagement with the two courses.

Although the primary role of the student interns was to collaborate with staff to plan, design and create learning and teaching resources, they also volunteered to participate in this research after being informed of the purpose of the research. Hence the student interns constituted an *opportunistic sample* (Creswell, 2008; Trochim, 2006) of the cohort of students from which they were recruited. Researchers already in the research field will need to take advantage of "whatever unfolds as it unfolds" (Patton, 1990, p.179) in the field. A researcher may need to seize the *opportunity* to ask potential participants who present themselves in the field to take part in the research.

The third group of participants was the two course leaders of Vector Spaces and Complex Variables. These were staff who taught Vector Spaces and Complex Variables. The fourth group of participants was six academic staff who made themselves available to provide support and guidance to the four student interns during the internship. Like the student interns, the eight staff (two course leaders and six others) constituted an opportunistic sample of all staff in the mathematics department because they volunteered to work with the student interns and in some sense presented themselves in the research field.

The final group of the participants of the phase one study consisted of 90 first and second-year undergraduate mathematics students who were registered at Middle County University during the 2010/2011 academic year. Of the 90 participants, 56 were first-year students who would eventually become the cohort for whom the two courses were redesigned.

At different stages of the course redesign process, different types of data needed to be collected. Therefore, an appropriate method was required to collect each type of data. Thus, I used a range of methods to collect data during phase one of the research and these included focus group discussions, interviews, email surveys, diaries, reflective reports, and observations.

Wilson (1997) describes a *focus group* as a method “for eliciting respondents’ perceptions, attitudes and opinions” about an issue that concerns them all. With this definition in mind, in March 2011, I conducted a focus group discussion with the four student interns to find out about aspects of learning and teaching of Vector Spaces and Complex Variables that they would like to see changed or improved; the type of mathematics learning and teaching resources that would best engage them (student interns) and their peers; and how best staff could support disengaged students. I acted as the sole moderator during the focus group discussions. The focus group discussions were audio recorded after consent had been sought from the participants (see Appendices A & B for participants’ information and the consent form). The size of the focus group, although small, was not untypical as Wilson (1997) notes that the size of focus groups can range from 4 to 12 participants. A copy of a *schedule of questions* that were used in the focus group discussions is shown in Appendix C.

After the first focus group held in March 2011, each student intern organised their own focus group using a copy of the *schedule of questions* which is shown in Appendix C. Each student intern acted as a moderator during their focus group discussion while I played the role of assistant moderator to ensure that discussions are focused and held in a similar way to the first focus group. The objectives of the additional four focus groups were the same as for the first one: to find out about aspects of learning and teaching of Vector Spaces and Complex Variables that participants would like to see changed or improved; the type of learning and teaching resources that would best engage the participants and their peers in learning mathematics; and how best staff could support disengaged students.

As we shall see in Section 4.3.2, the data gathered from the four focus group discussions were analysed independently by the student interns to inform the course redesign process. For the purposes of this research, I also independently analysed the transcripts of the focus group discussions in order to explore the student perspectives on learning and teaching of Vector Spaces and Complex Variables and mathematics generally.

Of the four focus groups arranged by the student interns, one consisted of only male students and the other only female students. Each of the two remaining focus groups had a mixture of males and females. One of the two mixed gender groups had a student who claimed to be disengaged from at least one of Vector Spaces and Complex Variables. The other mixed gender group had an international student as a participant. Attempts to recruit a focus group of only international students failed and so did an attempt to find a group who may be disengaged from their learning of mathematics. It was not surprising that we could not recruit a focus group of students disengaged from mathematics as these students often become withdrawn and do not seek help (Brown et al. 2005).

A great deal of effort was made by the student interns to have representative groups of second-year students to share their views on learning and teaching of Vector Spaces and Complex Variables and mathematics more generally. The participants of the focus group discussions held by the student interns constituted a *convenience sample* (Creswell, 2008). A convenience sample, as in the case of opportunistic sampling, is not a probabilistic sample but a group about whom qualitative data may be collected. Members of a convenience sample may contact and invite other potential participants who might be willing to take part in a study.

In March 2011, I conducted semi-structured individual *interviews* with each of the four student interns soon after their recruitment. Each interview lasted between 30 mins and 50 mins. The interviews were audio recorded after consent had been sought from the student interns (see Appendices A & B for participants' information and the consent form). The interviews were conducted so that I could explore the motivation behind the interns' desire to collaborate with staff to redesign the two courses. Thus, I wanted to know whether there were factors (e.g. educational reasons or personal interest) which motivated them to get involved in the staff-student partnership in undergraduate mathematics course design. The semi-structured interviews were also used to ascertain the interns' expectations of their role and relationship with staff and each other.

Interviews were considered the most appropriate data collection method because they enabled me to document, *independently* of staff and other interns, the expectations of each student intern. The interviews enabled me to have independent responses from the student interns that I could compare. A copy of the individual interview schedule that I used to interview the student interns is shown in Appendix D.

When the student interns commenced their full-time internship in July 2011, each one was asked to keep a diary of his/her activities; their interactions with staff; their engagement *with* and learning *of* mathematics; and their experiences as course co-creators of course content. Diaries are useful for collecting detailed information about an individual's life, activities, behaviour and events over a period of time (Corti, 1993).

The diaries enabled the student interns to record daily their activities in a Microsoft Word template. Hence they did not have to rely on memory recall of what they did during their working week. The student interns were asked to keep their diaries for four weeks from the start of the internship. In the last two weeks of their six-week internship, I asked the four student interns to write up a self-reflection account of their internship, noting any additional comments they would have made in a diary instead of the self-reflection document.

I carried out field observations of staff and student interns working together, and wrote up fieldnotes about the staff and the student interns' interactions. Also, I wrote up fieldnotes about the nature of the collaboration, staff and student interns' practices during the co-creation of course content, and their narratives about teaching and learning mathematics.

I interviewed the two course leaders before the student interns began their full-time internship positions in order to explore their expectations of the collaborative course design process. Appendix E is a copy of the schedule of questions used during the interviews. Four of the six other staff members who supported the student interns during their internship were also interviewed via email about their expectations of the collaborative course redesign process. Appendix F is a copy of the email interview questionnaire. After the internship, all eight staff members were interviewed about their experiences of the partnership and of working with the student interns. Appendix G is a copy of the schedule of questions used during the interviews.

The student interns worked in a shared open plan office, from 9 am to 5 pm, Monday to Friday. I immersed myself amongst the staff and student interns while they were co-creating content for Vector Spaces and Complex Variables. Staff came to the office during the working hours to interact with the interns, discuss their work, provide feedback on the resources they were producing and to answer any queries they may have. These questions were wide ranging, but often focused on the mathematics content of the resources that the interns were producing, the nature of the resources or format in which they were to be produced, and the teaching and learning of mathematics generally.

Data on the two courses, Vector Spaces and Complex Variables, as taught in the previous academic year were also collected in the form of online documentation. Documentation relating to the redesigned Vector Spaces and Complex Variables courses was also collected during the 2011/2012 academic year. A comparison was made in order to explore any differences and similarities in the design of learning and teaching resources in respect of the two academic years. The documentation provided information on aspects of the redesigned courses that could be attributed to the role played by the student interns to bring about change. The documentation provided further information to help me to ascertain if the student perspectives on learning and teaching were incorporated into the newly redesigned courses, and if not, explore the reasons with the interns and the course leaders.

In May 2011, I surveyed first and second-year students (the fifth group of participants). The survey was conducted to ascertain the *extent* to which undergraduate mathematics students would be willing to collaborate with staff to redesign aspects of their courses and their expectations of a Peer Learning Support (PLS) scheme if one were to be set up to support their learning. Appendix H is a copy of the questionnaire which was distributed to students. Of the 90 respondents, 56 (out of approx. 100) first-year students and 34 (out of approx. 100) second-year students responded to the survey

4.3.2 *Data analysis*

Audio files of interviews and focus group discussions were transcribed. Interview transcripts were shared with all interviewees so that they could provide feedback on the accuracy of the transcriptions. The qualitative data obtained from individual interview transcripts, focus group discussion transcripts, fieldnotes, diaries, self-reflection and evaluation reports, and documentation were all analysed using *thematic* analysis (Braun & Clarke, 2006; Bryman, 2008; Creswell, 2008; Robson, 2011). I followed the thematic analysis steps outlined by Creswell (2008) and these are shown in Figure 4.1.

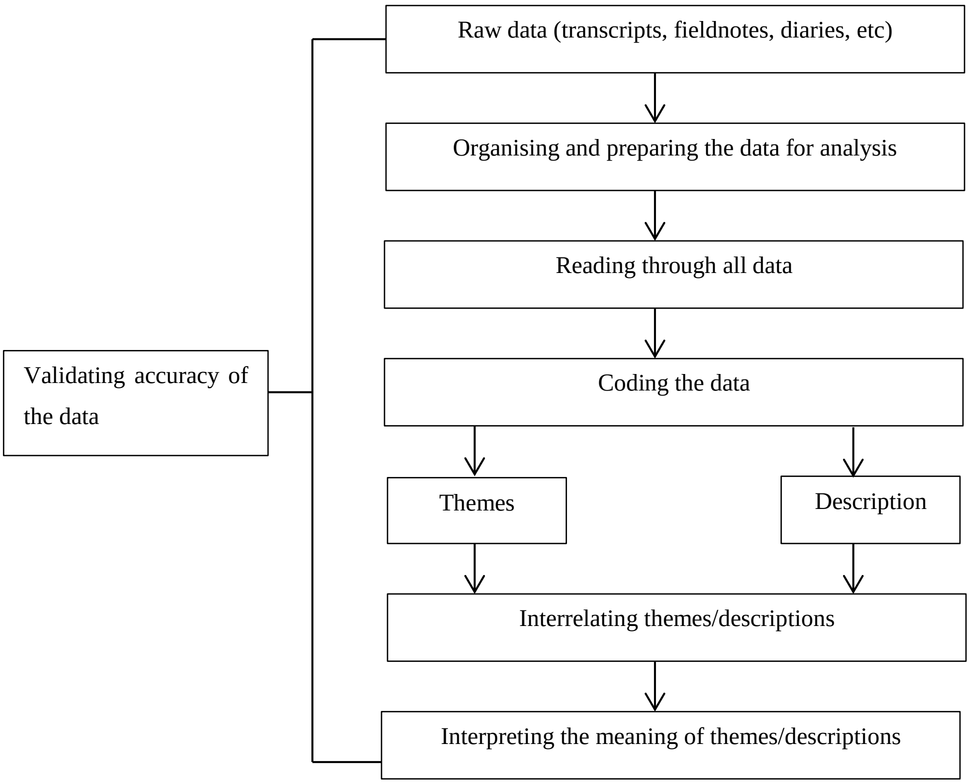


Figure 4.1. A qualitative data analysis flow chart (adapted from Creswell, 2009, p.185).

I started with what Creswell calls "preliminary exploratory analysis". This involved me reading through textual data to get a general sense of the meaning of the data. I read through the individual interview transcripts, focus group transcripts, diaries, fieldnotes, and self-reflection reports several times. The fieldnotes were read at the end of each day when the student interns had left the office so that issues that needed clarification could be shared and discussed the following day. The focus group and interview audio files were listened to several times so that I could familiarise myself with the content and to verify any gaps that may exist in the transcripts so that they could be filled.

Textual data from the interview transcripts, diaries, fieldnotes, and self-reflection accounts were imported into NVivo 11. I chose to use NVivo 11 to carry out the data analysis because of the large amount of qualitative data I had collected in the field. Using the memo feature of NVivo 11, I wrote memos of emerging ideas and meanings of the data that sprung to mind as I read through them. After reviewing the memos, I drew up a list of codes comprising predetermined and emerging codes for use in the detailed data analysis. Some predetermined codes were derived from the constructs of CoP which I discussed in Chapter 3.

I coded segments of textual data that reflected the predetermined codes and if they provided evidence in support of the answers to the research questions. I also coded some segments of textual data with an emerging code if the text provided evidence that helped answer the research questions. Some segments of textual data were also coded with emerging codes even though the codes and related themes did not necessarily answer my immediate research questions. Further details of the data analysis and the emerging codes and themes are presented in Chapter 5 (see Sections 5.2-5.4) and Chapter 6 (see Sections 6.2-6.6).

The survey of the 56 first-year and 34 second-year students was analysed to generate frequency counts for each of the mutually exclusive choices of responses to the closed questions (see Appendix H for the questions). The results of this analysis are presented in Chapter 5 (see Section 5.4.2, p.134)

4.4 Ethnographic study of PAL sessions

Phase two of the research focused on PAL as a staff-student partnership in course delivery. I was interested in the characteristics of second-year undergraduate mathematics PAL sessions and the learning experiences of PAL participants and PAL leaders. As in the case of the phase one study, I employed an ethnographic approach to study the characteristics of PAL sessions and the qualitative impact of PAL attendance on PAL participants and PAL leaders.

4.4.1 *Participants, methods and procedures*

I conducted the phase two study between May 2011 and May 2012. The academic year at Middle County University runs over two semesters of 15 weeks each. The first semester runs from October to February and the second semester from February to June. Examinations take place from week 13 to week 15 in each semester.

The three groups of participants of this study included the 56 first-year students and 34 second-year students who responded to the survey described in Section 4.3.1 (see p.96). Recall that one of the objectives of this survey was to ascertain undergraduate mathematics students' expectations of a Peer Learning Support (PLS) scheme. Appendix H is a copy of the survey questionnaire with two closed questions and three open ended questions on PLS that sought students' views on the kind of scheme with which they would be prepared to engage.

The second group of participants were 12 second-year undergraduate mathematics students. Ten attended PAL sessions in semester one and/or two. One participant did not attend any PAL session in either semester one or two. Another attended two sessions and stopped attending any further sessions. These participants were part of the 56 prospective second-year students who were surveyed about their expectations of a PLS scheme in May 2011.

The third group of participants were 12 third-year students who were recruited as PAL leaders to facilitate PAL sessions in semester one and/or two during the academic year 2011/2012. The PAL sessions focused on the content of Vector Spaces and Complex Variables. In semester two, only 10 out of the 12 facilitated PAL sessions. Of the two who did not facilitate PAL sessions in semester two, one had not studied Complex Variables and felt he could not lead PAL sessions on the course. The other chose not to continue for personal reasons.

In May 2012, the 10 PAL participants were interviewed about their experiences of PAL sessions for Vector Spaces and/or Complex Variables. These participants were students who responded to invitations to be interviewed about their views and perceptions of the PAL scheme and the sessions they attended. The PAL participant who attended only two sessions and stopped attending any further sessions sent an email explaining her experiences of the PAL sessions and the reasons for ceasing attendance. The student who did not participate in any PAL sessions was also interviewed about reasons for *non-participation*. Appendices I and J are copies of the interview schedules used. In May 2012, eight out of the twelve PAL leaders were also interviewed about their experiences of PAL sessions. Appendix K is a copy of the interview schedule I used. The PAL leader interviews were also audio recorded and transcribed verbatim for analysis after informed consent had been sought from participants (Appendix A and B are copies of the Participant Information and Informed Consent Forms).

I observed some PAL sessions in semesters one and two. Appendix L is a copy of the observation form used. The purpose of the observations was to triangulate the accounts of the PAL participants and PAL leaders. In semester one, I observed six PAL sessions in week eight and week ten. Also in semester two, I observed six PAL sessions in week eight and week ten. In the sessions I observed, I took detailed fieldnotes of the mathematics topic that was discussed, questions that were asked, directions that were given to the PAL participants by the PAL leaders, the mathematics problems that were solved or discussed, and solutions that were presented by the PAL participants on the board. I noted social interactions and discussions which were relevant to the research questions. I recorded instances of peer-to-peer support and feedback provided by PAL participants to each other when working in pairs or groups. I noted instances when feedback was given to students who presented their solutions to mathematics problems on the board. The strategies that PAL leaders used to encourage discussions and active participation were also noted.

I obtained consent from the PAL leaders and PAL participants of two PAL groups and video recorded one each of their sessions in week nine and week ten of semester two (see Appendices A and B for the ethical documentation). Fieldnotes were taken during these sessions as in all other sessions. The purpose of the video recordings, then, was to help me check the accuracy of the fieldnotes recording and hence providing some measure of validity check.

4.4.2 *Data analysis*

The textual data from the interview transcripts, PAL session observation fieldnotes and documentation were uploaded into NVivo 11 and analysed through *thematic* *analysis* (Braun & Clarke, 2006; Bryman, 2008; Creswell, 2008; Robson, 2011). Again, I followed the thematic analysis steps outlined by Creswell (2008) as shown in Figure 4.1.

I read through the fieldnotes textual data and I wrote memos of emerging ideas and meanings of the data that sprung to mind. I then drew up a list of codes comprising predetermined and emerging codes for use in the detailed data analysis. As noted in Section 4.3.2, some predetermined codes were derived from the constructs of CoP which I discussed in Chapter 3. I coded segments of textual data that reflected the predetermined codes and if they provided evidence that supported the answers to the research questions. I also coded segments of textual data with emerging codes derived from the transcripts. Codes were categorised into hierarchical themes and further details of these are presented in Chapter 6.

4.5 Study on the impact of PAL attendance on student achievement

4.5.1 *Correlational study of student involvement in course delivery*

The phase three study also focused on staff-student partnership in course delivery via PAL. The aim was to investigate the impact of PAL attendance on student achievement in Vector Spaces and Complex Variables. I employed a quasi-experimental design to investigate the relationship between PAL attendance and achievement in Vector Spaces and Complex Variables. In Chapter 3 (see p.85), I outlined the theoretical framework relating the variables that were studied in the phase three study.

4.5.2 *Participants, methods and procedures*

The participants of the phase three study were 85 students who were registered on Vector Spaces and 127 students who were registered on Complex Variables. Of the 85 Vector Spaces students, 57 attended at least one PAL session and of the 127 Complex Variables students, 66 attended at least one PAL sessions.

I asked for and received from academic records basic demographic data on the participants and their overall course marks for Vector Spaces and Complex Variables.

The use of this data was subject to a long standing institutional ethical approval held by the research centre where I conducted the research. The overall course marks in percentages are classified into grades[5], consistent with the departmental practice of reporting student achievement to the learning and teaching committee. Moreover, the grade classification is approximately equivalent to the national classifications of English undergraduate degrees.

Data on students' achievements in prerequisite courses for Vector Spaces and Complex Variables was also obtained. For example, Vector Spaces has a pass in an introductory *Linear Algebra* course as a prerequisite and Complex Variables has a pass in both *Calculus* and *Geometry, Vectors and Complex Numbers (GVCN)* as pre-requisite courses. These pre-requisite courses are first-year (level one) courses. The PAL participants would have studied these pre-requisite courses.

The PAL leaders kept attendance registers for their sessions. So, I was able to collect data on PAL attendance of each of the 85 Vector Spaces students. Similarly, I was able to collect data on PAL attendance of each of the 127 Complex Variables students. The attendance of students at six randomly selected lectures for each of the two courses was monitored and recorded.

Eight weeks after the start of each course, an independent course feedback through a survey was obtained from students taking each course. Appendix M is a copy of the questionnaire used in the survey. I surveyed the students enrolled on each course about their views *of* and satisfaction *with* the redesigned courses and the PAL sessions specifically.

4.5.3 *Data analysis*

I carried out several statistical procedures details of which I provided in Chapter 7. Here, I outline five general analytical steps to inform the ready about how the impact of PAL attendance on student achievement was carried. First, descriptive statistics of

[5] Below 30% =D, 30%-39%=D, 40%-49%, 50%-59%=C, 60-69%=B,70%-100%=A

the demographic data (gender, student status as home/ international student, type of degree programme, and participation in PAL) were obtained. Second, I conducted Chi-square tests to determine if there was any association between PAL participation and gender; and between PAL participation and student status as home/international student. Third, I conducted a Chi-square test to determine if there was any association between PAL participation and Vector Spaces course grade.

Fourth, an independent *t*-test was conducted to determine if there were any statistically significant differences in the mean examination marks (in percentages) in the pre-requisite courses between PAL participants and non-PAL participants. Finally, a correlational and multiple regression analyses of PAL attendance and students course marks in Vector Spaces and pre-requisite courses was conducted. A similar analysis was carried out in respect of Complex Variables.

The independent end of course feedback survey was analysed separately for Vector Spaces and Complex Variables but in similar ways. Demographic data and Likert scale items data were subjected to frequency analysis and the percentages of the responses to each question in the questionnaire (see Appendix M) were obtained. I indicated previously in this Section, further details of the statistical procedures are provided in Chapter 7.

4.6 Validity, reliability, transferability and generalizability

The rigour of a quantitative based research study is judged by the validity and reliability of the measurement instruments used and the findings reported from the study. Strauss and Corbin (1990) suggest that parallel criteria to the validity and reliability of quantitative research are more appropriate to qualitative research design. Lincoln and Guba (1985) and Guba and Lincoln (1994) propose trustworthiness and authenticity as two primary criteria for assessing a qualitative study. Trustworthiness is made up of four criteria: credibility (truth-value); transferability (applicability); dependability (consistency); and confirmability (neutrality).

In the current study, the trustworthiness of the qualitative studies conducted in phase one and two studies was ensured through an audit trail of the data collection and analysis procedure. The memos and journal I kept helped me to review my qualitative analysis to ensure consistency and saturation of data coding. In addition, multiple forms of data were collected to explore the staff-student partnership from different angles. For example, data on the process in which staff and students co-created resources for Vector Spaces and Complex Variables during the summer internship were collected from the student interns via diaries and self-reflection reports. In these, the interns recorded their activities, their thoughts and feelings about the process. These were supplemented by interviews with staff on their experiences of the course design process.

In addition, transcripts of pre-internship and the post internship interviews were reviewed by some staff and student interns to ensure the accuracy of the transcriptions and authentication of their narratives as a true reflection of what they had said during the interview. Five staff members did review their transcripts and all four student interns also reviewed their transcripts for accuracy.

The focus group members also had the opportunity to review the transcripts of the focus groups discussions that informed the course design process. There were no additions or alterations to the original transcripts of the focus groups. Similarly, the interview transcripts of PAL participants and PAL leaders were reviewed by more than half of each group.

In relation to PAL observations, the credibility of the data is strengthened by the multiple number of observations that were carried out. The accuracy of the PAL observation fieldnotes was assessed through cross checking with video recordings of two of the sessions that were observed. A sample of interview transcripts were scrutinised, read, coded and tentative themes generated by three colleagues who were independent of the research project. The coding and the themes from the three colleagues, who acted as critical friends, matched my own coding of the same sample of transcripts.

To minimise any influence that I might have on the partnership process, I engaged in 'bracketing' myself from influencing the research process (Ahern, 1999). Bracketing is a qualitative technique in which the researcher attempts to set aside preconceived notions and assumptions about the subjects, what they will say, and why they will say it.

The initial questions that were framed to be used during the focus group discussions, the pre-internship interviews and the post interview questions were all reviewed by an experienced researcher and modifications were suggested to ensure that questions were not ambiguous and that they were clear. The revised questionnaires were then used during the live interviews.

The questionnaire which was used during phase one and phase two studies was also piloted before their eventual use in the studies. The independent end-of-course feedback questionnaire was based on items from the National Student Survey (NSS). The reliability and construct validity of the NSS Likert type questionnaire is already established and the most recent evaluation of a similar questionnaire had a Cronbach alpha of 0.73 (HEFCE, 2016).

4.7 Ethics

In conducting this research, I followed the ethical guidelines set out by the British Educational Research Association (BERA) (BERA, 2004), supplemented by similar publications produced by the Scottish Educational Research Association (SERA, 2005) and the American Education Research Association (AERA, 2000). Institutional ethical approval was sought for and the conditions for carrying out the research as laid down in the standing ethical approval notice these conditions were accepted and followed. The conditions included compliance with the UK Data Protection Act 1998.

A participant information sheet (see Appendices A and B) explaining the purpose of the research was provided to participants in each of the three phases of the study. Participants were informed of their right to withdraw from the research process at any time should they wish to do so. Both staff and students were assured of anonymity and confidentiality of the data gathered from them for the study. For example, students' names were not used in this thesis where findings were reported. Where extracts from students' interview transcripts, diaries and self-reflection reports were used as evidence to illustrate an argument, pseudonyms are used. Similarly, staff names are not used in this thesis. Where staff are quoted, pseudonyms are used to protect their anonymity. Staff and students were informed about security measures that had been put in place to ensure that digitally recorded data would be password protected to prevent unauthorised access to audio files and transcripts.

PAL attendance and lecture attendance data were collected with student consent after appropriate explanation had been given to the students regarding why attendance was monitored. The Vector Spaces and Complex Variables course leaders had no access to either the PAL attendance data and lecture attendance data.

In respect of the courses, again all students were invited to and welcomed to apply to collaborate as student interns. However, as only four students were needed for the internship positions, not all student could participate in the internship. However, the selection process was fair and no groups of students were privileged over others with regard to the selection. Another ethical issue that the study addressed through the implementation of the PAL scheme is that all students were provided with the opportunity to volunteer as PAL leaders. Also, all students had the opportunity to attend the PAL sessions and hence no student was denied of the potential outcomes of the collaborations through PAL.

4.8 **Summary**

In this chapter, I have described the philosophical assumptions that underlie the current study, the research design, the participants, the methods and procedures of data collection. An eclectic set of data were collected during the research process and these are summarised in Table 4.2. In addition to the data summarized in Table 4.2, I collected documentary evidence of: a) some of the learning resources produced by the student interns, b) meetings held during the internship and the PAL implementation, and c) recruitment and training of PAL leaders. In this Chapter, I have also described briefly how the data were analysed generally. An account of how each piece of data had been analysed is provided as appropriate in the relevant sections in Chapters 5-7.

Table 4.2 Data Sets

No.	Description of Data	*N*	Code[6]
1	Pre-internship interviews with course leaders	2	PRE-CL01, PRE-CL02
2	An email survey of six other academic staff	6	PRE-L01, PRE-L02,…, PRE-L6
3	Interviews with four interns	4	S01, S02, …S04
4	A focus group with the interns	4	FGS01, FGS02, …, FGS04
5	Four focus groups with second-year students (each size 4)	16	FGS05, FGS06, …, FGS020
6	A survey of first and second-year mathematics students	90	In-Survey-2011
7	Report by student interns to staff before their fulltime internship	1	INT-REP
8	Researcher fieldnotes on the internship (six weeks)	6	FN1, FN2, , …FN6
9	Interns' diaries (four weeks) and reflective report (two weeks)	6	D11-D14, D21-D24, ..., R1-R4
10	Post-internship interviews with course leaders	2	POST-CL01, POST-CL02
11	Post-internship interviews with six other staff	6	POST-L01, POST-L02, …, PRE-L6
12	PAL session observation fieldnotes	12	POF1, POF2, POF2, …, POF12
13	Interviews with PAL participants	10	PS01, PS02, PS03, .., PS010
14	Video recordings of PAL sessions	2	VID1, VID2
15	Interviews with PAL leaders	8	PL01, PL02, PL03,…, PL08
16	An interview with a non-PAL Learner	1	PS011
17	Email correspondence with a PAL participant	1	PS012
18	Vector Spaces lecture attendance	81	VSLA
19	Complex Variables lecture attendance	122	CVLA
20	Vector Spaces PAL attendance	81	VSPA
21	Complex Variables PAL attendance	122	CVPA
22	Vector Spaces achievement data	81	VSAD
23	First year achievement data for Vector Spaces students[7]	81	VSFYAD
24	Complex Variables achievement data	122	CVAD
25	First year achievement data for Complex Variables students[8]	122	CVFYD
26	Independent Vector Spaces end of course feedback	45	VS-FB2011
27	Independent Complex Variables end of course feedback	85	CV-FB2012

[6] These codes are for access to and retrieval of data files from storage and may not necessarily be used in subsequent chapters.

[7] Student course marks in each of Linear Algebra and Calculus

[8] Student course marks in each of Calculus and Geometry, Vectors & Complex Numbers

CHAPTER 5 STUDENTS' AS PARTNERS IN COURSE DESIGN

5.1 Introduction

> *"Through dialogue, the teacher-of-the-students and the students-of-the-teacher cease to exist and a new term emerges: teacher-student with students-teachers." (Freire, 1970)*

In Chapter 1, I stated that phase one of this current study focused on a staff-student partnership in which an internship opportunity was created for four second-year undergraduate mathematics students to work with mathematics staff to co-redesign two undergraduate courses. The interns worked with staff at Middle County University (MCU) to redesign Vector Spaces and Complex Variables with the view to enhance the learning experience and improve the achievement outcomes for future cohorts of students who take the two courses. The interns had previously studied Vector Spaces and Complex Variables. In this chapter, first I describe the data collected in the phase one study; second, I describe how the data were analysed; and third I present the findings that emerged from the analysis of the data.

The internship was divided into two periods. The first period ran from March 2011 until the end of June 2011. During this period, the interns worked part-time as partners and change agents gathering evidence to inform the course redesign process. They consulted informally with their peers who also studied the two courses, and collected data on their peers' views about learning and teaching of Vector Spaces and Complex Variables. The second period of the internship ran from 4th July to 5th August 2011, a period of six weeks. In this period, which was during the summer vacation, the interns worked full-time co-creating mathematics learning and teaching resources for Vector Spaces and Complex Variables.

During the six-week period, the student interns worked in an open plan office which had a library stocked with undergraduate mathematics textbooks. I shared the open plan office with the student interns. Consequently, I had the opportunity to ethnographically observe the student interns and staff work together to co-create learning and teaching resources. I immersed myself amongst the staff and the student interns, observing and documenting the course redesign process, the products of the process, and the outcomes for both the student interns and staff. I listened to the interns' conversations and interactions with each other and with staff and documented the mathematics with which they engaged. I documented their negotiation of the mathematical content of the resources they were producing; and their negotiation of mathematical notations and meaning of mathematical concepts.

I described the methodological details of this ethnographic study in Chapter 4 (see Section 4.3). In Chapter 3, I also discussed in detail the theoretical framework and the model of variables underpinning the whole research, and I listed the constructs of the Communities of Practice (CoP) theory that were used to explore the qualitative data collected during the phase one study. My goal in this chapter is to report the findings of this ethnographic study. As a preamble, in Section 5.2 I briefly review the constructs of the CoP theory used to analyse the qualitative data collected in this phase of the study. In Section 5.3, I discuss findings relating to issues on learning and teaching of Vector Spaces and Complex Variables that informed the course redesign process. In Section 5.4, I discuss the nature and the process of the staff-student partnership in which students acted as co-creators of course redesign and course content; the impact of the partnership on the *identity* of the student interns and of staff; and the sustainability of such partnerships within a department of mathematical sciences. I then summarise the chapter in Section 5.5.

5.2 **Preamble to the chapter**

In a CoP, members "are engaged in actions whose meaning they negotiate with one another" (Wenger, 1998, p.73) and through these actions, members of the community build relationships and engage in practices which enable them to find solutions to shared problems. Members of a CoP find solutions to their shared problems through their mutual engagement which is fostered through ongoing interactions and relationships. Joint enterprise describes the common goal that binds members of a CoP. The joint enterprise is defined by members of the community as a negotiated response to a shared problem that requires a solution. Through their mutual engagement, members of a CoP do things together to achieve their common goal – the joint enterprise. As with all relationships, tensions and conflicts may arise and these may need to be overcome by members of the community in order for them to focus on the community's joint enterprise. Members of the community may engage in routines, use words and language, tools, artefacts, do things in certain ways, use gestures, share stories, gossip, and over time all these become part of their shared repertoire. Members of a CoP may express their identities through the language they use, the stories they tell, and the artefacts they use or produce during their daily engagement.

Members of a CoP may also adhere to the community's practices and discourse to direct their focus on the joint enterprise. *Alignment* is members' adherence to the practices of the community. Individuals may belong to multiple CoP and may cross boundaries of those communities of which they are members. Those members – referred to as *brokers* – who cross boundaries of communities may share the practice of one community with members of other communities of which they have become members.

The staff-student partnership in course design which is the focus of the current study brought two though not entirely unrelated CoP together – undergraduate mathematics students and researcher mathematicians. In making this assumption, I drew upon the work of Solomon (2007) and Biza, Jaworski and Hemmi (2014) who have viewed undergraduate mathematics students and researcher mathematicians as separate CoP. To explore the nature and the process of the staff-student partnership and its impact on the partners, I selected some of the constructs of the CoP theory and deployed them as a lens to analyse the qualitative data collected in the phase one study. The constructs I deployed were: *joint enterprise*, *mutual engagement*, *shared repertoire*, *brokering, modes of belonging and identity* (Wenger, 1991). Through these constructs, I have been able to show that staff-student partnership in course design can result in an emergent CoP in which members – staff and student partners – have the opportunity to learn and develop personally and professionally as I will describe in Section 5.4.

In the next section, I discuss the issues that informed the redesign of the two courses and gave a focus for the Community of Practice that emerged.

5.3 Issues informing the course design

The findings in this section are based on the analysis of the transcripts of five focus group discussions. As I have detailed in Chapter 4, twenty second-year undergraduate mathematics students (including the student interns) took part in the focus group discussions. The participants of the focus groups are identified in this Chapter as S01, S02… S19, S20.

A thematic analysis (Braun & Clarke, 2006) of the five focus group transcripts was conducted. During the analysis, I read the transcripts of the focus groups discussions several times and segments of text in the transcripts (words, phrases, sentences and/or paragraphs) were scrutinized and coded with a descriptive phrase. For example, when participants referred to "gappy notes" as a learning resource that helps them to engage with mathematics lectures, this was coded as "gappy notes". When participants reported that the approach of some staff to answering their questions relating to mathematics problems makes them feel "stupid" sometimes, this was coded as "relationship". Appendix U is an example of the focus group transcripts.

Many codes were generated. These codes were then scrutinized and some identical codes with different tag names were merged. I discussed the remaining codes with my peers and colleagues and after reaching a consensus on relevant final codes and their related textual segments, irrelevant codes were discarded. Related codes were categorized into themes. Three themes that emerged were: *Teaching Approach, Learning Resources and Environment,* and *Assessment*. The three themes are broad categorizations of multiple student perspectives on the learning and teaching of Vector Spaces and Complex Variables. Table 5.1 shows the themes, related codes and the frequency of each (see Appendices CC for the coding NVivo Coding Frame). The findings shown in Table 5.1 were triangulated by those contained in the student interns' own report[9] based on their analysis of those transcripts.

Table 5.1 Themes that Emerged from the Analysis of the Focus Group Data

CODING	**# of references**	**# of distinct students**
TEACHING APPROACH[1]		
Pedagogy	16	6 (20) [2]
Relationship	8	4 (20)
Total	24	N/A
LEARNING RESOURCES AND ENVIRONMENT		
Learning material	62	17 (20)
Lectures and tutorials	40	17 (20)
Total	101	N/A
ASSESSMENT		
Formative assessment	3	2 (20)
Summative assessment	20	7 (20)
Total	23	N/A

[1] The high-level headings in capitals are the themes. Below each high-level theme are the related codes.

[2] Numbers in brackets are the numbers of focus group participants.

The student interns' findings based on their independent analysis of the focus group transcripts are similar to the themes in Table 5.1. Thus, the congruence between the two independent findings, mine and those of the student interns', gave me confidence in the reliability of the themes in Table 5.1 which I discuss in Section 5.3.1.

The issues that I discuss from the point of view of the focus group participants are important because they highlight the implicit "didactic contract" that exists between them and those who teach them mathematics. The issues represent a range of student views on how teaching was orchestrated by staff teaching Vector Spaces and Complex Variables and mathematics more generally. These issues are not dissimilar to those that have been reported on the students' experiences of learning university mathematics (e.g. Brown et al. 2005; Seymour & Hewitt, 1997; Solomon, 2008).

[9] Appendix T shows the actual report. Also, see item 7 (INT-REP) in Table 4.2.

However, they needed negotiation amongst the staff and the student partners within the constraints of institutional policies and academic quality guidelines. The staff and the student interns considered these issues as they redesigned the two courses. I discuss the issues on the learning and teaching of Vector Spaces in the next section.

5.3.1 *Teaching approach*

Teaching approach emerged as an issue for consideration by the course redesign team. Twenty-four references were made by the focus group participants to the theme: teaching approach. The notion of teaching approach centres on both the *pedagogy* adopted by staff and on their *relationship* with students. Table 5.1 shows that 16 and 8 references were made by participants to pedagogy and relationship respectively. Participants were asked to discuss the learning and teaching approaches that result in their engagement or disengagement with the courses and the subject – Mathematics. Three references to pedagogy from participants were:

> *The main problem I had was [that] in tutorials, [when] you have been working through a problem and you get stuck or you don't know how to start it and you ask a lecturer and he comes over and says 'it's obvious how can you not do it?' Well that is no good to anyone. (S05, focus groups)*

> *It did put you off going [to tutorials] as well. Going to the tutorials... I admit, I didn't go to half of them because I thought he is not going to help. The whole point of tutorial is the interaction so if you don't understand something, anything, you are in a comfortable environment to sort it [sic]. We did not have that. (S06, focus groups)*

> *It makes you feel like intimidated, like scared to ask if you think he is going to treat you that way then you don't want to say anything and think that oh I am the only one that think that and he would talk to you that way. (S08, focus groups)*

The comments indicate that certain approaches to teaching may cultivate negative attitudes towards the subject. The significance of these statements is that they show that course design may need to be complemented by effective pedagogy and good staff-student relationship in and out of class if the effects of a good course design were to be realised. These student comments may not be unique to mathematics students or indeed one institution. Nonetheless these comments suggest that course design is only one of perhaps many factors that can affect student engagement with their course unit.

Good teaching approach is a complex phenomenon that involves the interplay of pedagogical content knowledge, active learning and teaching strategies, effective communication, and teacher attitudes and beliefs. Thus, the level of student engagement with their learning of mathematics may be affected by factors other than *course design*. For example, the very nature of mathematical abstraction and tertiary mathematics pedagogy may be the source of students' difficulty. Insecure prerequisite subject knowledge could also pose challenges for some students. The implication of the three students' comments is that course design or redesign alone is not a sufficient condition for students' success. Some focus group participants also commented on staff approachability, staff willingness to teach them, and staff desire to see them succeed. Participants believed that when staff are approachable, enthusiastic, and show that they care about their (students') success, then they are more likely to engage with and persist with difficult and advanced mathematics.

5.3.2 *Learning resources and environment*

One hundred and one references were made by the focus group participants to the theme *learning resources and environments.* Of the 101 references, 62 related to learning material and 40 to lectures and tutorials. Participants of the focus groups identified several learning resources that helped them to engage with Vector Spaces and Complex Variables and mathematics courses generally. In terms of the theory of CoP, in the wider undergraduate mathematics community, lecture notes and problem examples are important *artefacts*. They are the main components of undergraduate mathematics course design. The participants of the focus groups agreed that the following resources help them to engage more with the subject: "gappy notes" – PDF lecture notes with spaces for student self-completion during live lectures; screencasts or video resources; glossary of specialised vocabulary used on the courses; carefully evaluated online resources relevant to their courses; and extension tasks for the more able students. Accordingly, the participants of the focus groups called for these resources to be considered when additional resources are co-created for Vector Spaces and Complex Variables.

An issue that emerged from the analysis of the focus group discussions was that the mathematical content presented during live lectures was sometimes different from that in the printed copies of lecture notes provided in advance to students. This difference, it would appear from the students' comments, caused difficulties for some students as they were unable to reconcile the differences in the two sets of notes. The following comments from two focus group participants illustrate this viewpoint:

> *Our notes are different to what they [sic] teach so you don't know how to write it down. (S17, focus group)*

> *I think may be the set out of the lecture notes ... we can have a bit of input into that. Because sometimes the way lecturers work through the lecture notes compared to the way they write them is really different and that can be a bit confusing. (S18, focus group)*

It may be argued that these students were unable to reconcile their notes with those provided in live lecture because they lacked the appropriate study skills to enable them to do so. However, from the students' perspective, these comments suggest that when there is a *mismatch* between the notes presented in *live* lectures and printed notes provided in advance of lectures, some students may have difficulties in trying to understand the material. I use the term mismatch deliberately here.

Mismatch between live lecture notes and printed copies (e.g. a PDF document) provided in advance refers to any marked differences in terms of the sequence of mathematics topics, examples and use of notations. It was not certain that the student perspectives on lecture notes expressed by S17 and S18 were representative of the undergraduate second-year mathematics student population. If they were, then I would argue that mathematics course designers may need to consider this student perspective when designing courses, taking into account institutional policy and academic standards. It is also important to point out that students' views on learning and teaching may not always be pedagogically sophisticated or be informed by mathematics education research. Nonetheless, co-creators of course content and course design may need to consider students' perspectives on learning and teaching if they subscribe to democratic pedagogy which aims to involve students actively in shaping their own and their peers' learning.

The focus groups also agreed that the way solutions to mathematics problems and examples are presented in lectures sometimes affects their engagement with the material. S19 describes this very well:

> *A lot of the time, in the notes, [they] go from A to D and they don't go through steps from A to B. And when you go through your notes you [ask] how the hell does he go from there to there? (S19, focus group)*

To address the problems associated with missing steps in the solutions to mathematics problems, the focus group participants suggested that screencasts (or video tutorials) that demonstrate how to solve some types of mathematics problems could help students engage with the mathematical content anywhere and at any pace of their choosing. For example, two participants commented:

> *S11: Videos of the approach to [solving] the questions. Where do I start?*
>
> *S09: Yeah!*

Also, two focus groups agreed that a glossary of vocabulary and definitions could help students understand and engage with the mathematical content:

> *There is a lot of vocabulary, new words. It would actually be handy to have a sheet that literally says these are the words [the lecturer] is going to use and their definitions. (S11, focus group)*

University mathematics teachers need not provide this glossary themselves. Rather, I will argue that the notion of staff-student partnership suggests that students can be invited to co-create this resource themselves even in large classes.

When describing aspects of the learning environment that help them learn, typical responses from participants in the focus groups were:

> *Tutorials are good. [The lecturer] works a question with you and gives you a similar one to do on your own and then you see what line you are missing and what you don't understand. (S05, focus group)*

> *The tutorial I think is really good. [The lecturer] does a problem at the start. He does a problem that we can all do. (S08, focus group)*

The comments made by S05 and S08 also indicate a *pedagogical practice* that is valued by some members of the undergraduate mathematics CoP. S05 and S08 were not only providing evaluative comments on the type of tutorials they find helpful, but they were also "amplifying the student voice" (Cook-Sather, 2012) on the kind of tutorial practices that help them to engage with mathematics.

References to lectures and tutorials by the focus groups indicate that there are certain pedagogical practices that, in the view of participants, *reduced* their levels of engagement with mathematics. For example, participants commented on the dissimilarity between examples of mathematics given *during* live lectures and set *as* assignments/homework:

> *One of the problems I had as well was that the examples we did in tutorials were nothing like the examples we did in lectures. So I followed everything we did in lectures; I never struggled in lectures. I understood everything he was talking about but then you come to tutorials and you look at a question and you don't know where to start. (S05, focus group)*

It seems that the comment above reflects the previous mathematical identity of S05. In school mathematics, the teacher does examples and students then practise similar examples in class. This is then followed by similar problems set as exercises. This practice is clearly not always available in undergraduate mathematics education where students must learn to engage with novel and non-routine problems. This difference in school and tertiary mathematics teaching practices reveals itself in the narratives of the participants who often commented that the examples done in lectures are not always like those set for tutorials or homework.

Another student offered a similar perspective concerning the examples provided in lectures:

> *We normally did other problems related but not necessarily similar to what the problem sheet had. So maybe sticking more to the actual examples that we are supposed to know how to do. It might be better for students to understand the content. (S18, focus group)*

Comments on the quality, variety, and range of problem examples appeared often in the narratives of the focus group participants. As members of the undergraduate mathematics community, mathematics problems and examples are artefacts or tools with which they expect to engage regularly to assess their mathematical competency. These artefacts take on particular significance. When the students are unable to engage with these artefacts, that could affect their lecture and tutorial attendance. This argument is evidenced by the following comment made by one of the focus group participants:

> *If there are no extra examples there is no point in going to the lecture because you've got nothing to write. What is written on the board is exactly the same as what is in the booklet and I just find myself not listening whereas as if it is something different you have got to follow it. (S10, focus group)*

There seem to be a contradiction when the comments made by S10 and S18 are compared. The two comments suggest differences in the approach to teaching of Vector Spaces and Complex Variables by the two course leaders, L01 and L02 respectively. However, S10 and S18 were referring to two different things vis-à-vis the presentation of topics and examples. In the case of S18, the lecturer presents the *same* examples of problems as presented in printed copies of lecture notes. Thus, S18 was suggesting that examples given in the live lectures should be different to those in the printed notes so that students have the opportunity to practise what is in the printed notes themselves. In the case of S10, the student appears to suggest that the topics which are presented in PDF lecture notes are not necessarily always discussed in the lectures. Thus, S10 was suggesting that as students, they were unsure of the aspects of the notes with which they needed to engage.

The comments discussed in the preceding paragraph are important as they indicate how student engagement with mathematics can be affected. Novel and non-routine problems may be provided by staff to help students grapple with the content of the mathematics. When students are able to solve such problems, they gain deep understanding and increased confidence. However, undergraduate mathematics students may follow different trajectories in their learning and hence differentiated mathematics problems may need to be provided to facilitate students' movement from the *marginal participation* into full and confident membership of the undergraduate mathematics Community of Practice. Some students gain confidence by being able to solve routine problems. Following that, they then move on to engage with novel and non-routine problems. Formative and summative assessments in undergraduate mathematics may involve both routine and novel problems. Both types of assessments take on significant meaning in the undergraduate mathematics community. The analysis of the data showed several references made to assessment during the focus group discussion and I next discuss some of the issues on assessment that came to the fore.

5.3.3 *Assessment*

Twenty-three references were made by the focus group participants to the theme assessment. Three references were made to formative assessment and twenty to summative assessment. Two out of the five focus groups agreed that in general students take assessment seriously if it bears credit towards their degree. In relation to this students' view on assessment, some participants suggested that the weight of each assessment component should be commensurate with the effort and time that are required to complete the assessment. A participant from one of the focus groups offers this view point:

> *The amount of work you have to put in for an eighty percent exam is pretty similar to the amount of the work you have to put in to write a piece of coursework up which is worth ten percent.... if it is going to be worth that level then there should not be that much content. (S10, focus group)*

Some of the focus groups also suggested that if material is non-examinable (i.e. not required or not needed for an examination) then this needs to be made known to students. Specifically, they suggested that if there are formulas that need not be memorised because they would be provided in the examination, they would like to be informed about this. Similarly, they suggested that if there are theorems that are non-examinable they would like to be informed so that they could focus on the content that they need to learn for the examination. These views, expressed by some of the focus group participants, suggest perhaps that they have preference for instrumental learning and for them, examinations success is their main goal rather than deep learning. However, the students' views are congruent with open book examinations which permit access to reference texts that may contain information that need not be remembered for the examination. As documentary evidence gathered during my observations indicate that some of the mathematics courses at MCU conduct open book examinations, the students' views discussed above is therefore not alien.

The evidence presented above indicates that undergraduate mathematics students do have their own perspectives on learning and teaching. I see these student perspectives as reflecting the lived experiences of the twenty undergraduate mathematics students. While the 20 focus group participants represented about 20% of the cohort of second-year undergraduate mathematics students, their voice on the teaching and learning of Vector Spaces and Complex Variables and mathematics generally are worthy of consideration. As Cook-Sather et al. (2014) argue, such *student voice* needs to be considered and acted upon as appropriate in a collaborative course design that seeks to engage students as partners in learning and teaching.

So far, the findings presented have focused on *issues* of learning and teaching which informed the collaborative course redesign process. In the next section, I refocus this chapter on the work of the student interns and staff in co-creating resources for learning and teaching of Vector Spaces and Complex Variables.

5.4 Students as co-creators of course design and course content

The findings I present in this section are based on the analysis of four datasets. The first dataset was the transcripts of the focus group discussions which I referred to in Section 5.3. I have also stated in Section 5.3 that there were twenty participants in the five focus groups one of which was constituted by the student interns. One question that was discussed by the focus group participants was: to what extent do students have a role to play in course design? I believed that the responses to this question are best reported in this section so they were analyzed together with the rest of the data described below.

The second dataset was a survey of first and second-year undergraduate mathematics students which was conducted in May 2011. The survey was conducted in order to ascertain the *extent* to which first and second-year undergraduate mathematics students are willing to collaborate with staff to co-create aspects of their courses either for themselves or for future cohorts of students. I surveyed first-year students because they constituted the cohort for whom the two courses, Vector Spaces and Complex Variables, were being redesigned. The second-year students were included in the survey because they constituted the cohort from which the four student interns were selected to participate in the staff-student partnership in course design. The survey data were subjected to a frequency analysis which resulted in proportional counts.

The third dataset comprised transcripts of the student interns' pre-internship interviews, their summer internship diaries and self-reflection reports. This dataset also included transcripts of pre-internship interviews with the two course leaders and responses from four other staff to a pre-internship email survey. In addition, the data included transcripts of post-internship interviews with the two course leaders and six other staff who provided support to the student interns by interacting with them and answering their queries regarding the mathematical content on which they worked. Of the six other staff members, four responded to the pre-internship email survey questions and they were also interviewed after the internship. The remaining two other staff did not respond to the pre-internship email survey but were interviewed after the internship (see Appendices V - AA for examples of these data and Chapter 4 Section 4.3.1 for details).

The fourth dataset was fieldnotes written during the six-week internship when I observed the staff and the student interns' co-creating resources for the two courses.

In these fieldnotes I recorded: the interns working together in pairs or with staff; staff and student interns discussing learning and teaching of mathematics; staff and student interns negotiating the meaning of mathematical terminologies and symbolism; staff and interns discussing and negotiating the content of the resources that were being co-created for Vector Spaces and Complex Variables. (see Appendices BB for an example of the fieldnotes).

Again, all this eclectic set of qualitative data were analysed using a thematic analysis approach (Braun & Clarke, 2006). The data sources were all coded in a single NVivo file. When reading the textual data, I coded text which showed that the staff and the student interns were interacting as “relationship and interaction”. I coded textual segments that indicated that staff and student interns were negotiating mathematics content or discussing mathematics terminology as “negotiation of content and meaning”. When staff talked about the interns’ increased mathematical understanding and attributed it to the internship – this was coded as “mathematical understanding”. Identical codes with different tag names were merged.

The list of codes was scrutinised and those which related to one of the selected constructs of the CoP were categorised into a theme with the same name as the construct. Some categories which cannot be explained by the CoP theory were also grouped under appropriately named abstract themes, for example *sustainability.* Table 5.2 shows six themes that emerged from the analysis of the data excluding the fieldnotes. The six themes were: *mutual engagement*, *joint enterprise*, *shared repertoire*, *modes of belonging*, *identity transformation*, and *sustainability* Similar themes emerged from the analysis of the fieldnotes (Appendix BB) and these triangulate those reported in Table 5.2 (see Appendices CC-DD for the coding NVivo Coding Frame and the full set of codes).

5.4.1 *Mutual engagement*

Table 5.2 shows that the student interns and staff made 90 references to the theme mutual engagement. The student interns and staff made 70 and 20 references respectively.

Table 5.2 Themes from the Analysis of Qualitative Data on the Internship[10]

	# of student' comments	**# of distinct student interns' making comments**	**# of other students making comments**	**# of staff comments**	**# of distinct staff making comments**
MUTUAL ENGAGEMENT[1]					
Relationship and interactions	22	4	-	7	5
Student voice	17	4	-	12	2
Support and feedback	23	4	-	1	1
Negotiation of content and meaning	6	3	-	-	-
Conflict	2	2	-	-	-
Total[2]	70	N/A	-	20	N/A
JOINT ENTERPRISE					
Motivation to partner	38	4	-	7	3
Roles and responsibilities	5	4	11	8	2
Total	43	N/A	N/A	15	N/A
SHARED REPERTOIRE					
Stories	20	3	-	-	-
Reflection	6	2	-	-	-
Products or outputs	24	4	9	-	-
Total	50	N/A	N/A	-	N/A
MODES OF BELONGING					
Engagement	1	1	-	2	2
Alignment	22	4	-	1	1
Imagination	14	3	-	-	-
Total	37	N/A	-	3	N/A
IDENTITY TRANSFORMATION					
Interns' understanding and confidence	38	4	-	11	6
Interns' personal development	53	4	-	27	8
Pedagogical and affective outcomes for staff	-	-	-	20	6
Total	91	N/A	N/A	58	N/A
SUSTAINABILITY					
Inclusivity	8	3	-	38	8
Successful collaboration	11	4	-	6	4
Total	19	N/A	N/A	44	N/A

[1] The high-level headings in capitals are the themes. Below each high-level theme are the related codes.

[2]Totals are not provided for the columns: "# of distinct interns making comments", # of distinct other students making comments" and "# of distinct staff making comments" because participants could make a reference to one or more categories of each major or sub-theme.

[10] Data based on interviews with staff, email survey of staff, interviews with student, student interns' diaries and self-reflection report, and focus groups discussion.

As the student interns worked with staff full-time between 1 July and 5 August, the staff-student partnership evolved into a new community constituted by two CoP – undergraduate mathematics students and researcher mathematicians. Thus, the members of this new community were staff, the four student interns, and to an extent, the focus group members. The practice of the student interns within the new community included, among other things, turning up at the office to discuss and produce learning and teaching resources that could enhance the student learning experience of Vector Spaces and Complex Variables. The practice of both the student interns and staff also included negotiation of: 1) the mathematical content for inclusion into the learning material being created, 2) the type of learning resources being produced, and 3) mathematical notation, symbolism and terminologies.

The four student interns worked in pairs. One pair worked on Vector Spaces and the other Complex Variables. Although each pair of the student interns interacted often with their respective course leader, they also engaged with the other six staff members. During the first week of the summer internship, each pair of the student interns negotiated with their respective course leader the mathematical content that needed to be reshaped, redesigned or presented using different media. For example, as S03 notes in his diary (See Appendix W for the diary), the course leader for Complex Variables provided a list of topics that students had found difficult in the immediate past examination.

The student intern pair assigned to Complex Variables worked through the list to identify topics that they could present in new formats. Similarly, the pair of student interns assigned to Vector Spaces negotiated with their course leader the content and material to be reshaped for Vector Spaces. Unlike the student intern pairs assigned to Complex Variable, the pair who were assigned to Vector Spaces did not have a list of difficult topics with which to work. Rather, they drew on the findings of the focus group discussions and their own experiences of learning Vector Spaces to produce learning material in a new format. Examples of reformatted learning material and other resources produced are shown and discussed in Section 5.4.3 (see pp.141 -143).

Table 5.2 also shows that the interns made 22 references to *relationship and interaction* amongst, and between, the staff and the student interns. Staff also made seven references. These interactions characterise the mutual engagement of the staff and the student partners. The interaction between the staff and the student interns extended beyond the confines of the open plan office in which they worked. The student interns had a one-hour break each working day. During the break, the student interns met in the office of one member of staff (identified as L03). The staff, L03, provided refreshments and snacks and thereby fostered mutual engagement through what Wenger (1998, p.74) refers to as *community maintenance*. Other staff regularly joined the student interns during the break which became a forum for discourse on mathematics learning and teaching. This forum was also a source of mathematics learning for the student interns.

During the break the student interns continued to articulate the *student voice* on learning and teaching of Vector Spaces and Complex Variables and mathematics generally. Table 5.2 also shows that the student interns made 17 and 23 references respectively to the *student voice* and *support and feedback*. Similarly, staff made 12 references to the student voice. They also made one reference to support and feedback.

The student interns received support and feedback on the artefacts they produced. This was made possible through their mutual engagement with staff. Also, given the number of staff who were involved in the partnership, support and feedback was readily available to the student interns. The mathematical accuracy of the resources the student interns produced was important since one of the aims of the course redesign process was to make examples of the resources available not only for students at MCU taking the two courses, Vector Spaces and Complex Variables, but also for other HEIs to use as exemplary material. Hence, notwithstanding the autonomy the student interns had in their role as co-creators of course content, they felt it was essential that staff reviewed the content of the resources they produced. Clearly staff too had a stake in the course design process. They had a stake in the process because they were responsible for the mathematical integrity of the resources, and by implication their own professional integrity depended on the quality of the resources being produced.

Where feedback from staff was constructive, it was often well received and led to revision of the resources as indicated by the following quotes from the diaries of two participants.

> *[L01] has reviewed all of the materials that I have produced and provided feedback for each of them, so I now have to amend these." (S01, Diary)*

> *Got feedback which I found helpful and constructive. (S04, Diary)*

In summary, the staff and the student interns' mutual engagement facilitated the support and feedback that were given to the student interns; and enabled the student interns to share the *student voice* and perspectives on learning and teaching with staff.

The student interns, as members of two CoP, were in a position in which they could engage in *boundary practices* across communities. For example, the student interns played the role of *brokers* by soliciting the *student voice* through focus groups and other informal communication channels. They sought the views of their peers to effect change in the learning and teaching of Vector Spaces and Complex Variables. These views were shared informally through regular discussions with staff and formally in the form of reports to staff at meetings of the departmental learning and teaching committee. In doing so, the student interns engaged in negotiation and reconciliation of multiple perspectives on learning and teaching.

It is acknowledged that the student interns' perspectives on teaching was most likely to be based on their tacit knowledge rather than formal pedagogical knowledge as may be acquired by trained teachers. Nonetheless, the student interns' views and those of their peers in the focus groups were based on their lived experiences of being students and experiencing different pedagogical approaches from different lecturers. It is reasonable to suppose that those students' views on teaching will be informed by what works for them and their peers. These perspectives should not be ignored by those who profess the ideals of democratic education.

Staff practices were modestly impacted upon (and I shall return to this in Section 5.4.5) through the student interns' *brokering* and negotiation of multiple perspectives on learning and teaching. For example, the Vector Spaces lecture notes were restructured. Previously, the lecture notes did not have separate end of chapter summaries and related problems, examples and exercises. Similarly, solutions to Vector Spaces problems which had previously been handwritten were typeset in LaTeX and differentiated at three levels of mathematical challenge and difficulty with the view to meeting the learning needs of students of all abilities.

However, not all the changes in staff practices were well received by the students for whom the course was redesigned. For example, L01, the Vector Spaces lecturer, changed practice from the two-hour traditional lecture and one-hour tutorials to the two-hour traditional lecture and one-hour "interactive lecture". The "interactive lecture" was an attempt by L01 to encourage independent problem solving during tutorials followed by discussions. This is an example of a pedagogical change which, it had been hoped, would have engaged students. The "interactive lecture" was not well received by students as illustrated by this extract from a post-internship interview with the staff member:

> *As you know, I did drop the interactive lectures, because it was not successful and I could certainly not persuade anybody to do that [the interactive lectures]. (`L01, Post internship staff interview)*

Three weeks after the introduction of the "interactive lecture", L01 reverted to the two-hour traditional lectures and one-hour tutorials per week. Based on this evidence, I argue that it is possible that the students for whom the Vector Spaces course was redesigned might have rejected the novel pedagogy to maintain the established *didactic contract* between them and L01. This is important because it indicates that change in pedagogical practice should be negotiated with students who would need to be fully informed of the potentialities of the novel pedagogy for their understanding of mathematics.

The course leader for Complex Variables, L02, also changed practice. L02 and his two student partners restructured the course lecture notes and designed "gappy notes" to facilitate students' "interactive engagement" with the notes during live lectures. Previously, the Complex Variable course had one summative assessment of 100% marks. The L02 introduced a 10% continuous assessment component for the course in response to the student perspectives on assessment as reported by the student interns (see Appendix T) based on the focus group discussions. In contrast to Vector Spaces, there was no pedagogical change in Complex Variables lecture delivery.

As members of the wider undergraduate mathematics Community of Practice, undergraduate mathematics students and staff would be expected to have a joint enterprise: an enhanced and enjoyable learning and teaching experience. However, this is not always the case, as we shall see. Next, I discuss whether staff and undergraduate mathematics students share in the joint enterprise of the undergraduate mathematics Community of Practice. More specifically, I also discuss the joint enterprise of the partnership CoP.

5.4.2 *Joint enterprise*

Table 5.2 shows that the student interns and thee focus group participants made 26 references to joint enterprise in their datasets. Staff also made15 references to joint enterprise. These references indicate that there was some evidence of a shared joint enterprise between the student interns and staff. This is not surprising given that the student interns self-selected to partner with staff to co-create resources for the two courses. However, undergraduate mathematics staff and students may not necessarily share in the same joint enterprise – an enhanced and enjoyable learning and teaching experience.

The survey I conducted in May 2011 (Section 5.4 see p.127.) had 56 (out of approx. 100) responses from first-year students and 34 (out of approx. 100) responses from second-year students. Of the 56 first-year students, 30% reported that they would welcome an opportunity to work with staff in a collaborative course design process. Of the 34 second-year students, 35% also reported that they would welcome an opportunity to work with staff in a collaborative course design process. As these proportions were less than 50%, I decided to explore in the focus group discussions students' views on the notion of staff and students working together to plan and design some aspects of their learning experiences or those of their peers in other cohorts.

As I indicated in Section 5.3, the focus group participants were identified as S01, S02, S03, S04…. S18, S19, S20. During the focus group discussions participants were asked: "do students have a role to play in the undergraduate mathematics course design process and, if so, in what ways?" The majority of the focus group participants, 17 out of 20, believed that students have a role to play in the mathematics course design process. Some participants suggested that students could contribute to the planning of learning and teaching by providing not only the traditional end of course feedback, but also by creating resources for learning and teaching.

Two focus groups were, coincidentally, each made up of only one gender: all males or females. The two groups had different positions and views on the role of students in shaping their own learning and that of future cohorts of students. Although I did not set out to look for gender differences in the discussions of the focus groups, I believe it is important to highlight the differences in the views of these two groups as portrayed in the narratives of their data. The female only focus group unanimously agreed that students have a role to play in the actual design of resources for learning and teaching in addition to providing traditional end of course feedback. The following comments from the female only focus group illustrate this viewpoint:

> *I think [it] is important we do get the chance to work with the staff. (S05, focus group)*

> *If we don't speak up to say if we have got an issue with something, then how are they supposed to know what it is that they are getting wrong? (S08, focus group)*

> *They [staff] can deliver the lecture as well as they like, but without our feedback they won't know they are getting it right. So in that sense we need to... even if it doesn't benefit us it is going to benefit the year after us. We should be involved with them [staff] in the sense of giving them feedback. (S06, focus group)*

Thus, the female students were positive about the notion of student involvement in collaborative course design in undergraduate mathematics. In contrast, a male only focus group insisted on maintaining the *traditional roles* of undergraduate mathematics students and university mathematics teachers. When the male only focus group was asked whether students have a role to play in the course design process, here is a dialogue that ensued between two participants:

> *S13: Not much. I think we have enough on our plate as it is.*
>
> *S14: I think is our job to learn and it is their [lecturers] job to teach.*
>
> *S13: You don't pay your tuition to come and…*
>
> *S14: …teach yourself.*
>
> *S13: Yeah. Teach yourself and design your own courses*
>
> *S14: …because you don't know what you have to learn*

These two students clearly believed that pedagogical planning is the role of staff who teach those courses. They believed that the students' role should be limited to the end of course feedback. When asked to explain why they think the way they do, S13 suggested that:

> *I think with the amount of lectures I've got each week, I have got fifteen hours plus doing everything else I've not got enough time to come and talk to the teachers to tell them how they should do things, they should have the experience to do it. (S13, focus group)*

In contrast to this view point, a participant in one of two mixed gender focus groups provided a rationale in support of the need for student involvement in the course design process as follows:

> *You probably have got more input into a course you have already taken. You have ideas when it comes to exams and how you actually found the course. Whereas when you are designing a new course you wouldn't necessarily know how you are going to find it until you've taken it. (S18, focus group)*

These responses provide evidence to support the believe that staff and students may not necessarily share in the same *joint enterprise*. These findings also provide evidence in support of the warnings that some students may resist the invitation to participate in a collaborative course design process (see e.g. Bovill, Cook-Sather and Felten, 2011).

Analysis of the transcripts of the semi-structured individual interviews I conducted with the student interns before they started their internship showed differences in their *motivation* for wanting to become partners in the mathematics course redesign process. When asked about their reasons for wanting to collaborate with staff in course design, two of the student interns responded as follows:

> *I was really interested in just being able to help improve stuff for the people that come [after] us, to change the experience of the lectures. (S02, focus group)*

> *To work alongside staff in the department …[and whom] is good to know on one to one basis. I think it is quite a responsibility. [The] idea of how to form a course [and] work alongside other students will be really quite good. (S04, focus group)*

The comments made by S02 and S04 above show that some students may wish to participate in a staff-student partnership because they want to contribute to improving the learning of their peers. Others may hope to be drawn into a community in which they could learn about and understand academic practice in undergraduate mathematics education. For example, S03 stated that he wanted to gain about how departments work:

> *[I want the] experience of working in university and maths education department which I am looking into as a career and just so to get some real experience to see how it works. (S03, interns' interviews)*

Understanding the different motivations that the student interns brought to the staff student partnership is important because these motivations may also give insights into the extent to which the student interns identify with the joint enterprise of community – enhanced and enjoyable learning and teaching experience.

Staff-student partnership in undergraduate mathematics course design provides opportunities for students to gain insights into the workings of academia. For some students, such an opportunity might lead them to go on to postgraduate study in mathematics and perhaps become mathematics academics. For S03, the prospect of him being able to work as an intern within a tertiary mathematics department was seen as beneficial to his career goals. S03 saw the internship as an opportunity to engage in some form of '*academic apprenticeship*' albeit for a limited period. Thus, in this sense, the internship enabled S03 to participate in the practices of academia through *legitimate peripheral participation*.

Some of the student interns chose to enter into partnership with staff for altruistic reasons. For example, S02, having done less well on the Complex Variables course, was keen to make a difference to other students' learning by helping to produce learning material that takes into account the student perspective on learning and teaching mathematics. S02 wanted to help improve things for others.

So far we have seen that each intern had a "personal interest" in the joint enterprise of the new community of which they became part. The shared personal interest in the joint enterprise, whatever the motivation, is a demonstration of the student interns' sense of responsibility and commitment to the *community maintenance* (Wenger, p.74) of the undergraduate CoP.

As I noted in Chapter 4 and earlier in this section, I interviewed L01 and L02 *before* and *after* the internship. The purpose of the pre-internship interview was to explore L01 and L02's expectations of the internship and its outcomes. The post-internship interview was aimed at exploring staff experiences of the collaborative course design process particularly the nature and impact of the internship on them and the student interns. During the staff pre-internship interview, I asked the question: at the recruitment interview, how motivated were the student interns to get involved in the course design process? In response to the question, L01 stated:

> *They are enthusiastic and young. It's very good. We should take … on board [what they have got to say]. (L01, Pre-internship interview)*

The above quotation shows that L01 was receptive to the notion of student involvement in undergraduate mathematics course design. It illustrates that he was willing to listen and to take seriously the student perspectives on learning and teaching. In contrast, in response to the same question, L02 stated:

> *They all said they were motivated to be involved. I think the only way we will find out really is when they actually come along and do it." (L02, Pre-internship interview)*

It appears L02 was uncertain about what the student interns can actually do in terms of the production of resources for learning and teaching. Nonetheless, L02 volunteered his course *for* the collaborative course design process. So, at some level he was receptive to the student involvement in the course design process. If there was any resistance to the notion of students being actively involved in the course design process, then it was not apparent from the narratives of the staff. Although the staff and the student interns brought different motivating factors to the partnership, they were bound together by the joint enterprise – enhanced and enjoyable learning and teaching experience.

As members of multiple CoP, the staff and the student interns of this study would have developed a shared repertoire through their mutual engagement within the partnership community as well as their memberships in their pre-existing CoP. Next, I discuss how the data reveal the shared repertoire of the student interns and staff.

5.4.3 *Shared repertoire*

Table 5.2 shows that the student interns and the focus group participants made 50 references to shared repertoire. None of the staff explicitly made references to shared repertoire. However, the course specifications are themselves artefacts with which researcher mathematicians and university mathematics teachers will be familiar. To give context to the mathematical content of the learning and teaching resources produced by the student interns for Vector Spaces and Complex Variables, it is helpful to describe the *course specifications* – the course syllabus. The facts in the specifications, particularly the prerequisite courses, are relevant to my discussion of the sample of the resources produced by the student interns in this section. They are also relevant to the mathematical content which students discussed in Peer Assisted Learning (PAL) sessions. These sessions will be the focus of parts of Chapter 6.

Vector Spaces is an advanced Linear Algebra course which is available to any student meeting the pre-requisite with priority given to those for whom the course is listed in their degree programme regulations. The pre-requisite of the Vector Spaces course is a first-year introductory Linear Algebra course. The aim of the Vector Spaces course is to create an awareness of the power and range of abstract mathematical concepts and to develop further the concept of a vector space. Among the learning outcomes are that students will be able to develop: knowledge and understanding of vector space theory in an axiomatic way; demonstrate an appreciation of the wide application of the results to different areas of mathematics; transferable skills including effective time management; independent working; construction of clear and logical arguments, and abstract thinking. The mathematical *content* taught to students includes: rings, modules, fields and vector spaces; subspaces, direct sums, bases and dimension; quotient spaces; linear maps; image, kernel, rank and nullity; eigenspaces, matrix of a linear map, and transformation to another basis; determinants; inner product spaces and Cauchy-Schwarz inequality; Norms; orthonormal bases and the Gram Schmidt process; orthogonal projections, adjoint of a linear map; self-adjoint operators and their normal form; quadratic forms, unitary and orthogonal transformations and other normal forms. Complex Variables also has a similar course specification structure.

Complex Variables is available to students meeting pre-requisites but only if listed in their degree programme regulations. The prerequisites of Complex Variables are two first-year course units: Calculus and another unit named Geometry, Vectors and Complex Numbers. The aim of the Complex Variables course is to introduce students to the classical results in the theory of analytic functions of a complex variable. The intended learning outcomes of the course are that students should be able to develop knowledge and understanding of: the properties of complex-valued functions and the relationship with their real-valued counterparts; some of the theorems in the theory of analytic functions; the residue theorem; and the theory of conformal mappings. Students completing the course are expected to develop transferable skills including: effective time management; construct logical arguments; break down complex calculations into their logical units. The mathematical *content* taught to students includes: Cauchy-Riemann equations and analytic functions of a complex variable; contour integration, Cauchy's theorem and integral formula; Taylor and Laurent series; theory of residues and conformal transformations.

Examples of learning and teaching resources that the student interns co-produced during the internship are shown in Figures 5.1-5.6. Figures 5.1-5.2 are screenshots of Vector Spaces screencasts created for student use out of class. Figure 5.3 is an example of handouts created to be used by PAL leaders in Vector Spaces PAL sessions. Similarly, Figures 5.4-5.5 are also screenshots of Complex Variables screencasts. Figure 5.6 is an example of handouts created to be used by PAL leaders in Complex Variables PAL sessions.

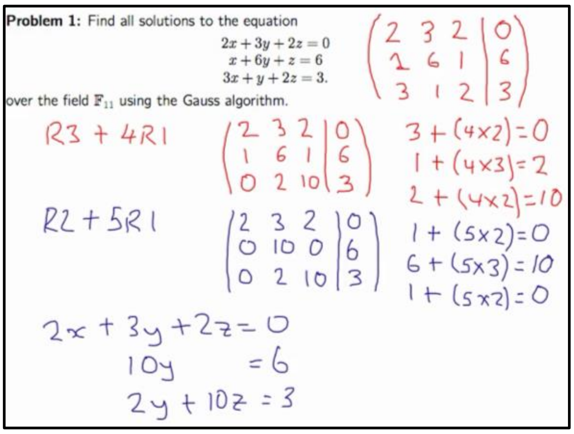


Figure 5.1 A screenshot of a Vector Spaces screencast I

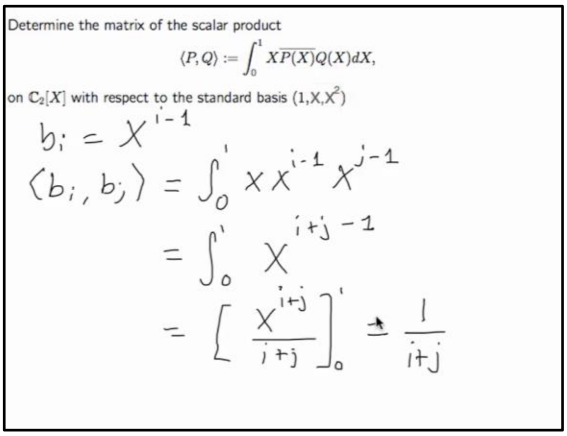


Figure 5.2. A screenshot of a Vector Spaces screencast II

Vector Spaces

Orthogonal Projections

1 Orthogonality

1.1 Basic concepts in $\mathbb{R}^n$

If we consider two vectors $u, v \in \mathbb{R}^n$, we say that u and v are orthogonal, or perpendicular, in $\mathbb{R}^n$ if $u \cdot v = 0$. This is making use of the standard inner product on $\mathbb{R}^n$, namely

$$\langle u, v \rangle = u_1 \cdot v_1 + u_2 \cdot v_2 + \cdots + u_n \cdot v_n.$$

Similarly, we can say that a vector u is orthogonal to a subspace V, if it is orthogonal to every vector $v \in V$. This can be simplified by considering a basis of V. As the vectors in a basis span V, every vector $v \in V$ can be written as a linear combination of the vectors in the basis. As u is orthogonal to both of the vectors in the basis, u is therefore orthogonal to V if it is orthogonal to the basis vectors of V.

We can represent this graphically, by considering a vector $u = \begin{pmatrix} 0 \\ 0 \\ 4 \end{pmatrix} \in \mathbb{R}^3$ and a plane T which lies within $\mathbb{R}^3$. A plane is a 2-dimensional object, and so can be spanned by two basis vectors, such as

$$v_1 = \begin{pmatrix} 4 \\ -1 \\ 0 \end{pmatrix} \quad \text{and } v_2 = \begin{pmatrix} 3 \\ 2 \\ 0 \end{pmatrix}.$$

For u to be orthogonal to T, it must be orthogonal to both v_1 and v_2 (see Figure ??). By direct calculation,

$$\langle u, v_1 \rangle = (0 \cdot 4) + (0 \cdot -1) + (4 \cdot 0) = 0 \quad \text{and}$$
$$\langle u, v_2 \rangle = (0 \cdot 3) + (0 \cdot 2) + (4 \cdot 0) = 0$$

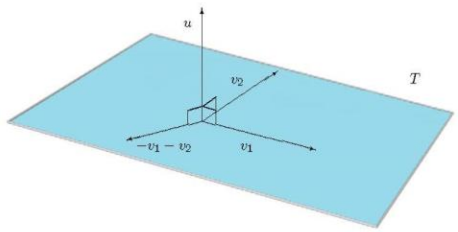


Figure 1: An example of a vector u being orthogonal to a plane V, as it is orthogonal to the basis vectors v_1 and v_2. Note that u is also orthogonal to the linear combination $w \in W$, for example $w = -(v_1 + v_2)$.

1.2 Generalisation to vector spaces

These concepts can be generalised to any subspace of a vector space that has an inner product, which we will refer to as an inner product space. This means that, for a subspace W of an inner product space V with inner product $\langle \cdot, \cdot \rangle$, a vector u is orthogonal to V if, for a basis $\{w_1, w_2, \ldots, w_n\}$ of W,

$$\langle u, w_1 \rangle = 0, \langle u, w_2 \rangle = 0, \ldots, \langle u, w_n \rangle = 0.$$

This follows the same principle as in Figure ??; it is orthogonal to each of the basis vectors, and therefore as they span the inner product space, it is orthogonal to every vector within W. This graphical intuition is limited however, as graphically representing a function such as "$1 + 2x$" in $\mathbb{R}_2[x]$ is not easily achievable.

Figure 5.3. Supplementary handout for Vector Spaces PAL sessions

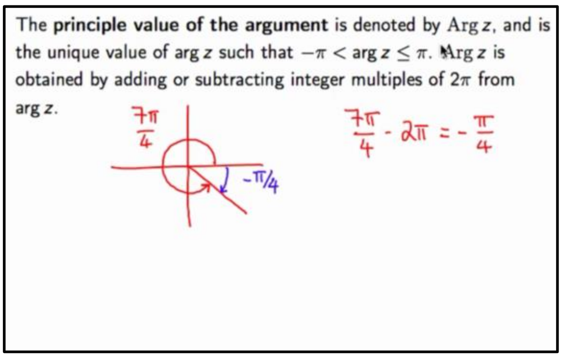


Figure 5.4. A screenshot of a Complex Variables screencast I

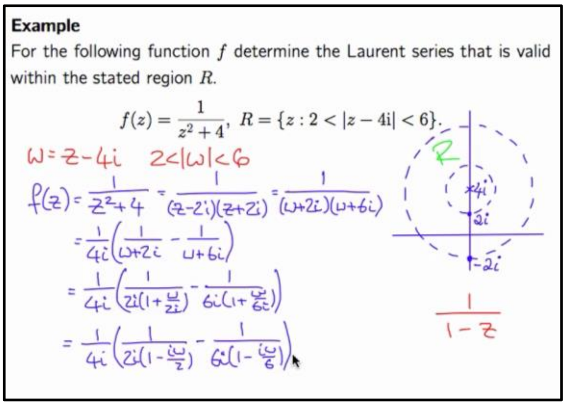
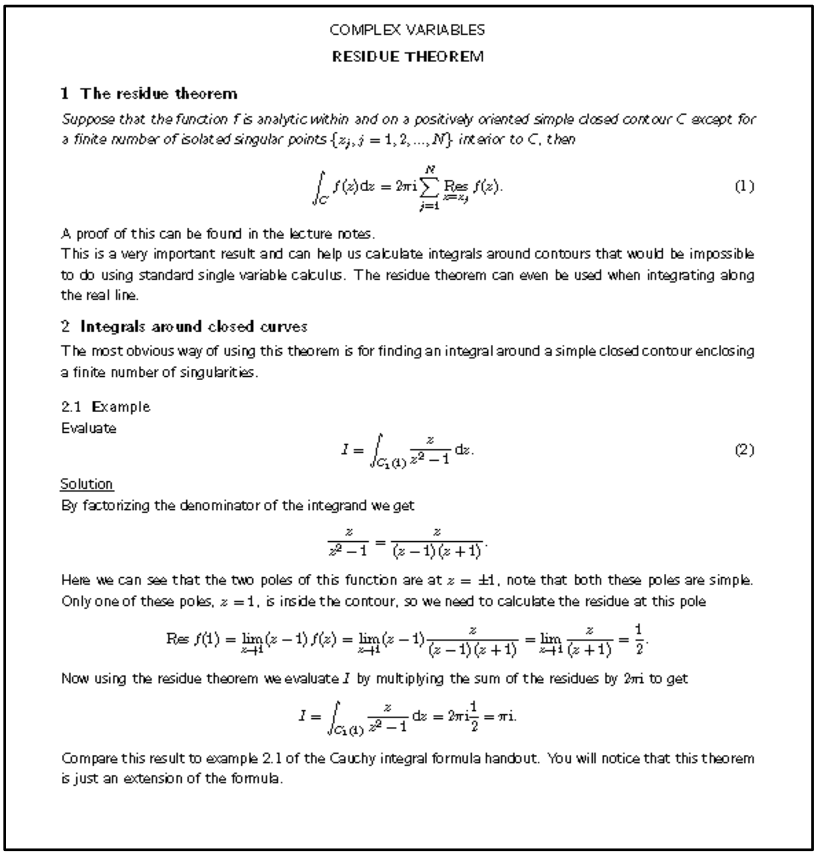


Figure 5.5. A screenshot of a Complex Variables screencast II



COMPLEX VARIABLES

RESIDUE THEOREM

1 The residue theorem

Suppose that the function f is analytic within and on a positively oriented simple closed contour C except for a finite number of isolated singular points $\{z_j, j = 1, 2, ..., N\}$ interior to C, then

$$\int_C f(z)\,\mathrm{d}z = 2\pi\mathrm{i}\sum_{j=1}^{N} \operatorname*{Res}_{z=z_j} f(z). \qquad (1)$$

A proof of this can be found in the lecture notes.
This is a very important result and can help us calculate integrals around contours that would be impossible to do using standard single variable calculus. The residue theorem can even be used when integrating along the real line.

2 Integrals around closed curves

The most obvious way of using this theorem is for finding an integral around a simple closed contour enclosing a finite number of singularities.

2.1 Example

Evaluate

$$I = \int_{C_1(1)} \frac{z}{z^2-1}\,\mathrm{d}z. \qquad (2)$$

Solution

By factorizing the denominator of the integrand we get

$$\frac{z}{z^2-1} = \frac{z}{(z-1)(z+1)}.$$

Here we can see that the two poles of this function are at $z = \pm 1$, note that both these poles are simple. Only one of these poles, $z = 1$, is inside the contour, so we need to calculate the residue at this pole

$$\operatorname{Res} f(1) = \lim_{z\to 1}(z-1)f(z) = \lim_{z\to 1}(z-1)\frac{z}{(z-1)(z+1)} = \lim_{z\to 1}\frac{z}{(z+1)} = \frac{1}{2}.$$

Now using the residue theorem we evaluate I by multiplying the sum of the residues by $2\pi\mathrm{i}$ to get

$$I = \int_{C_1(1)} \frac{z}{z^2-1}\,\mathrm{d}z = 2\pi\mathrm{i}\frac{1}{2} = \pi\mathrm{i}.$$

Compare this result to example 2.1 of the Cauchy integral formula handout. You will notice that this theorem is just an extension of the formula.

Figure 5.6. Supplementary handout for Complex Variable PAL sessions

The screencast examples (Figures 5.1-5.2, Figures 5.4-5.5) illustrate what the student interns were able to produce – artefacts which the staff teaching the two courses had never created (i.e. used technology in teaching these courses or developed e-learning resources). The mathematical content of these resources is based on topics which students had previously found difficult. These co-created resources exemplify the shared repertoire of students of Vector Spaces and Complex Variables and more specifically the student interns.

While the above examples of artefacts produced by the student interns may not be novel, they take on particular significance for the undergraduate mathematics community at MCU. The student interns created these artefacts based on the evidence gathered via the focus group discussions. For example, the focus group participants at MCU suggested that screencasts help them to further engage with mathematics content at their own pace and specifically for content with proofs or problems with multi-step solutions.

Students' preferences for screencasts were also attributed to the functionalities which enable pause and replay and allow access to mathematics content on portable mobile devices. The focus groups reported that screencasts enabled them to engage with mathematics wherever they may be and when they want. Figures 5.3 and 5.6 might also look like any typical mathematics text. However, these handouts were created for a specific audience at MCU. These were created primarily for PAL leaders to use in sessions, when appropriate. While they may not be revolutionary, they were negotiated and agreed upon to be produced by the student interns to help future PAL leaders who might want a structured plan to follow to facilitate sessions.

The student interns brought to bear on the partnership some technological expertise and developed other expertise during the internship. As I noted earlier in this Section, hitherto, the two courses have not had any screencasts or videos resources produced and incorporated into the learning and teaching process even though such resources had been the norm on other courses that the students had taken. In some sense the student interns shared their technological expertise and knowledge within the evolved

CoP of which they had become members. The learning resources produced represent a shared repertoire because they emerged in the discourses of the student interns with their peers. Although the resources were created for a specific audience, it was envisaged that other students and staff might find them useful.

So far, the nature of the partnership as CoP characterised by mutual engagement, joint enterprise and shared repertoire has been discussed with illustrative comments from staff and students. The student interns' active involvement in the course design process meant that they took on other identities and referred to a *sense of belonging* in their narratives of their experiences of the staff-student partnership. In the next section, I discuss how the student interns and staff accounts of their experiences illuminate the student interns' sense of belonging.

5.4.4 *Modes of belonging*

According to Wenger (1998), there are three modes of belonging to a Community of Practice and these are *engagement, imagination,* and *alignment* (p. 173). Wenger further suggests that "to make sense of formation of identity…it is necessary to consider modes of belonging" (p. 173). Therefore, to understand the nature of the staff-student partnership in course redesign, it was informative to explore the student interns' identities before, during and after the internship. I had conjectured that the data on the staff-student partnership in course design might reveal the student interns' modes of belonging to the community that emerged during the internship. The analysis of the data revealed that the student interns had a double identity of being students and mathematicians albeit without the credentials as is the case for the staff. Table 5.2 shows that the student interns made 37 references to modes of belonging and staff made three such references.

The student interns' saw themselves as mathematicians in relative terms. They compared themselves to both staff and those without post-secondary mathematics qualifications. Depending on whom they compared themselves, they either saw themselves as mathematicians or not. The following comments from S02 and S03 illustrate how they saw themselves in relation to being "mathematicians":

> *I don't see myself as an expert at all...Probably in the middle because I have gone [sic] so far I am probably a mathematician because I have an in interest in [it]. That makes me kind of not like an expert in it, but I have obviously done a lot [of maths] for 13 years. (S02, Pre-internship Interview transcript)*

> *I have not done much in maths. At A level I thought I knew everything. Came here, I knew nothing. Compared to PhD students or professors, I am a novice completely. It depends on where you are... (S03, Pre-internship interview transcript)*

These comments made by S02 and S03 show that the student interns viewed staff as the source of authority and knowledge of the content of the mathematics on which they worked. The implications of these views of themselves is that during the internship they would have looked up to the staff as the experts to judge the quality and the integrity of what they produced. These views of themselves as novice mathematicians did not affect their dispositions to make decisions for themselves. As expected, they sought feedback from staff on the resources they created and they did so in the spirit of collegiality and respect for staff as was accorded them by staff. Still this did not diminish the authority and power that staff still had. Therefore, I will argue that student involvement in course design does not take away the responsibility and authority of staff who are still accountable for the outcomes of their course design and teaching.

Staff also positioned the student interns as both novices and experts of mathematics. The two course leaders, L01 and L02, commented:

> *They have certainly not gone far with it [maths]. They have successfully completed the course. They are much further than the students [future cohort of Vector Spaces students]. So they are both experts and novices and that it's their strength that we should use. (L01, pre-internship interviews)*

> *They are definitely not experts. I don't think they are novices either. So well I suppose they are experts if you compare them to the general population. In terms of being trained to be mathematician, I think they are long way from being experts. (L02, pre-internship interviews)*

The comments made by L01 and L02 suggest that the student interns did not come to the partnership with little or nothing to offer in terms of mathematics and its learning. However, the partnership offered them the opportunity to become part of a community with which they can identify.

Table 5.2 shows that the student interns made only one reference to *engagement* in the course design process in their dataset while staff made two references. The student interns' practice in the evolved community is evidenced by the fact that they attended work and focused daily on creating resources, liaised with staff, obtained feedback on the resources they produced and were socialized and enculturated albeit in a limited time frame. The student interns' engagement in the course design process is also evidenced in their reports on feeling: a sense of belonging to the evolved community, being valued and taken seriously by staff. Their engagement in the course design process led to an enhanced relationship between themselves and staff. The enhanced relationship was further strengthened through their daily interactions with staff in their open plan office and during the afternoon breaks. The enhanced relationship enabled the student interns and staff to discuss their views on what constitutes good mathematics teaching as this quotation from the diary of one student intern demonstrates:

> *Spent time at tea today building more relations with lecturers informally which was good, and we had a chance to put our views across about lectures, [university] and tutorials which was interesting. (S02, Diaries)*

The internship afforded the student interns the opportunity to articulate informally the student voice on learning and teaching to staff and to see their views taken seriously and acted upon within the constraints of university policy, structures and governance

Prior to the internship, three of the interns had not had any contacts with the staff outside lectures and tutorials. For these three students, S02, S03 and S04, there was a renewed and enhanced relationship with staff as evidenced by the following three extracts from their diaries:

> *Meeting up with some of the staff for tea and biscuits was a good opportunity to get to know people a bit more, and made me feel much more involved and valued as a member of the project. (S02, Diaries)*

> *Its good to be able to comfortably talk to lecturers about interesting points in mathematics; it's also interesting to hear what they do as mathematicians and how they work together or alone. (S03, Diaries)*

> *I feel L01 is more approachable now. (S04, Diaries)*

These statements indicate a renewed and an enhanced relationship between staff and the student interns. The renewed and enhanced relationship was made possible through the student interns' socialisation into the evolved Community of Practice to which both staff and the student interns belonged.

Table 5.2 also shows that the student interns made 22 references to *alignment* while staff made one such reference. A consequence of the student interns' socialisation was that they began to *align* with staff practice, norms and "language" which they had previously described as being disengaging. For example, when it was suggested to S04 while he was producing a screencast that he should provide scaffolding in his explanation of the concept of "eigenvalue" and how to find an eigenvalue in a problem, he recounted: "*if a student does not know this by now then I can't help him*". This was surprising because there was a consensus among the four student interns during their focus group discussion that such language is unhelpful and disengaging. It was surprising to hear S04 speak using language that the student interns have unanimously described as unhelpful to the mathematical learning of students.

It is possible that they began to align with staff practice because they became aware of the challenges involved in designing and creating learning and teaching experiences that could engage all students. They also began to empathise with staff perspective on the delivery of their courses. For example, S03 noted in a self- reflection report:

> *Though at the time of the focus groups the [we] would have agreed with most of what the students said., after careful consideration and discussion with lecturers some*

> *suggestions were deemed unfeasible. The first suggested topic on our report was about interactivity in lectures. Though at the time it seemed like a good idea to have an energetic enthusiastic lecturer making each student feel part of the discussion we know this is impossible. (S03, Self-reflection report)*

In some sense S03 and the other student interns were critical not only of staff teaching practice but also their peers' perspectives on teaching. Similarly, during the internship, the student interns aligned with staff views on assessment and not their peers' views on assessments as described in section 5.3.3. Writing in a self-reflection report, S01 noted:

> *Another suggestion by students was to change the balance of the assessments, particularly in Vector Spaces with the class test and exam. Students felt that the class test was very difficult, and that this was not proportionate to the percentage of the module that it accounted for (10%). We raised this point with [L01] and he explained his reasoning for this…in his experience, students do not take the module seriously and often leave their revision until the last couple of weeks, so they often struggle with the module. Therefore, if he provides a difficult test for them early on, they will realise they have to work hard. (S01, Self-reflection report)*

This evidence suggests a teaching practice which assesses students using difficult tests with the hope that students may be awakened to work harder. However, while the view expressed by L01 is his own, the interns did not challenge this staff perspective thereby maintaining the status quo of teaching practice. It is plausible that the student interns did not challenge the staff about his perspective on teaching due to: 1) the *power differential* between the student interns and the staff and 2) the *authority* the staff have which derives partly from his knowledge of mathematics. In spite of the power differential and staff authority, the student interns were able to *generate* their own learning and teaching material for Vector Spaces and Complex Variables that took into account some of the issues on learning and teaching which I described and discussed in Section 5.2.

The reasons given by the student interns for wanting to partner with staff in the course redesign process did not only illustrate the way they perceived the *joint enterprise* of the course design process but also characterised their *imagination* of their roles in the partnership. Some of the student interns imagined the potential of their role to give them ideas about future careers in academia. Others imagined the relationships they might build with staff and with each other. Furthermore, some of the student interns imagined the ways in which their involvement in the course design process might offer them *responsibility* to enhance the learning experience of future cohorts of students who study Vector Spaces and Complex Variables. The following two quotations presented earlier in Section 5.4.2 sum up the interns' imagination of their roles and membership of the new community which they joined:

> *[To get] experience of working in university and maths education department which I am looking into as a career and just so to get some real experience in that to see how it works (S03, Pre-internship interview)*

> *You get to work alongside staff in the department which is good to know on one to one basis. I think it is quite a responsibility. To get ideas of how to create a module and to work alongside other students will be really quite good. (S04, pre-internship interview)*

These comments highlight the difficulty in addressing the issue of *inclusivity* in staff-student partnerships. Students who are most likely to be involved in working with staff as partners in course design are those who are able to imagine the potential outcomes of such partnerships for their peers and their own future careers.

The few students who elect to partner with staff and are selected, typically through recommendations or interviews, get the opportunity to work in an authentic environment where they engage with and apply the mathematics they have been learning. As in all authentic roles, one would expect, all things being equal, that those who enact the roles will develop some knowledge and skills relevant to the role. The individual knowledge and skills developed may then lead to identity formation. In the next section, I discuss student interns' identity formation arising from the role they enacted. This is then followed in the same section by how staff viewed themselves because of their experience of the partnership.

5.4.5 *Identity transformation*

I use the term *identity transformation* to refer to changes in one's views about themselves, their capabilities and their very being. The student interns' views about themselves and their relationship with mathematics before and during the internship give an indication of change in their identity with respect to their understanding of mathematics and their developing skills as prospective mathematics graduates. Table 5.2 shows that the student interns and staff made 91 and 58 references respectively to identity transformation across their datasets. The sub-themes of this identity transformation were mathematical understanding and confidence, personal development, pedagogical and affective outcomes for staff.

5.4.5.1 Mathematical understanding and confidence

When students engage in collaborative course design in undergraduate mathematics, they can potentially develop a deep understanding of the content of the course they help design. Table 5.2 shows that the interns made 38 references to their learning and understanding of mathematics. Similarly, staff made 11 references to the student interns' learning and understanding of mathematics.

When the student interns commenced their full-time internship, they had previously studied and passed the two courses. The student interns were successful students in terms of their academic performance. Yet, for some, their behaviour was congruent with lack of confidence and insecure subject knowledge. The internship provided the interns with further opportunities to work with staff on the content of Vector Spaces and Complex Variables. Thus, they were afforded the opportunity to work with more competent others in what Green (2005) calls "*spaces of influence*" in a Community of Practice. At the start of the internship, the student interns demonstrated a level of *mathematical competence* that enabled them to create resources for the courses on which they worked. Nonetheless they talked about their lack of understanding in some aspects of the content on which they worked. They also viewed themselves as students and positioned themselves as such in relation to the academic mathematicians. Their view of themselves as students did not change but their view of their level of *mathematical competence* relative to when they started their internship and their mathematical work and study practices changed during the internship.

The internship and the course redesign process thus provided opportunities for the student interns to develop a deep understanding of the mathematical content of the course they helped to redesign. Consequently, they gained increased confidence in their abilities which they articulated in their diaries as demonstrated by the following three extracts:

> *My knowledge of Vector Spaces is also improving, as I discovered an application for a theorem that I had not previously realized was possible. (S01, Diaries)*

> *I found that as I was creating videos my understanding of the topics is becoming much deeper and I hope these skills will be transferable to other courses I take in the future. (S02, Diaries)*

> *"Despite all the frustration I feel my knowledge of the eigenvalue equation has improved a lot. (S04, Diaries)*

These comments are significant because, S01 for example, commented that he had less than secure knowledge and understanding of Vector Spaces at the beginning of the internship. Reconciling his comment above with his previous view of himself suggests that indeed he had gained a much better understanding of Vector Spaces.

By the third week, I observed S01 on three occasions attempting to find a solution to a Vector Spaces problem on a board using a *geometric approach* and then eventually using his solution to produce a supplementary help sheet on Orthogonal Projection (see Figure 5.3, p. 142). S01 notes in his diary that his solution to the problem on Orthogonal Projection is different from the way the course leader (L01) had previously solved the same problem in lectures. While S01 had used a "geometric approach" to solving the problem, he claimed that L01 had used an "algebraic approach". In some sense, S01 was contributing a different *representation* of a mathematical concept, and thus making "multiple representation" of a mathematical concept readily available on the course. By adopting an approach to solving the problem which was different from that of the course leader, L01, S01 demonstrated a deep understanding of the topic. The impact of the internship experience on the mathematical understanding of the S01 is further supported by this extract from his self-reflection report:

> *I have had to use the blackboard several times to work through a problem, so that I understand it completely and can convey my understanding through the solutions. This has helped me understand the topics within the course better though, which I believe is very helpful. (S01, Self-reflection report)*

When students are engaged in staff-student partnerships, they have the opportunity to develop personal confidence. The student interns in the current study reported *increased confidence* in their abilities to explain and discuss concepts related to Vector Spaces and Complex Variables with their respective course leaders. For example, S02 noted in her self-reflection report

> *Most importantly my confidence, in my mathematical ability and myself, has grown so much since being a student intern, especially through working directly in partnership with lecturers. (S02, Self-reflection report)*

As professional teachers, staff were able to assess the student interns based on their interactions with them and the discourses they had during the afternoon breaks as exemplified by the following comments from four staff:

> *So, in both situations, there was a fair amount of time and effort that needed to go into solidifying the students' understanding of the subjects that they were developing materials for, which I think is a good outcome, because it means that they have come to a new level of understanding of what it means to learn mathematics. (L03, Staff post internship interview)*

> *They got a better insight into mathematics. I think it was also a very good exercise in how you can present things. Yeah. So, it's about trying to communicate what you've learned. (L04, Staff post internship interview)*

> *They have learned what mathematics is about. They have actually thought about the mathematics in a bit of context, which I'm pushing for … in Linear Algebra. (L06, Staff post internship interview)*

> *They got a much better understanding and they matured, both I think in terms of their working practices, and in terms of their mathematical understanding. (L08, Staff post internship interview)*

The significance of these comments is that students who partner with staff may develop a deep understanding of the subject, learn to communicate mathematics better and learn how staff work with mathematics in context. Staff-student partnerships thus offer those who opt to go into teaching or academia the opportunity to reflect on their potential career. However, whatever careers mathematics graduates embark on, they will require certain attributes to be successful. Some of these attributes are embedded as learning outcomes in the mathematics course specifications. Nonetheless, staff-student partnership in course design offers a space for the student partners' personal development beyond the confines of the classroom.

5.4.5.2 Personal development

Table 5.2 shows that the student interns and staff made 53 and 27 references to personal development respectively. The collaborative course design made it necessary for the student interns to engage with academic text in ways which hitherto they had not done. At a library inside the open plan office where the student interns worked, I observed the four student interns browse through a stock of mathematics texts to research problem examples that they could possibly adapt for use in the learning resources they were developing. Finding and selecting appropriate texts and examples require decision making, reading and note taking, and devising solutions for a number of mathematics problems. These activities and skills were sustained throughout the internship and may have been a contributing factor to the interns' personal development.

Extracts from the diaries and self-reflection and evaluation reports of three student interns show that they believed that their study skills had been impacted upon:

> *Looking through different books and internet sources to do extra research on certain areas, then filtering through all this information to find the pieces relevant and pitched at a suitable level for the course to include in handouts. (S02, Diaries)*

> *"My approach to learning will be very different after this internship. I will now get books out, ask lecturers questions and ensure a deeper understanding of my Mathematics. Using all these resources have meant I have been able to understand most of the topics. I will now use all these resources to enable me to learn all of my third year mathematics instead of just relying on the notes provided by the lecturer. It is actually quite interesting when you understand it all rather than just revise for an exam!" (S04, Diaries)*

Through their involvement in the course design process, the way the student interns viewed the use of textbooks and other learning resources changed. During the internship, S03 went to the university library and borrowed textbooks for his third-year courses, something that hitherto S03 has not done for his previous courses. Similarly, other student interns planned to use the library to borrow library books as a resource for learning mathematics and to get a different perspective and deep understanding of the mathematics they will study during their remaining years at the university.

The student interns also reported on their *improved communication skills* which they attributed to their presentations to staff and interactions and negotiations with each other. Analysis of their diaries and their self-reflection reports sheds light on their belief that their communication skills had improved as a result of their involvement in the collaborative course design process. For example, S01 notes in his diary:

> *I feel that my communication skills are now much better than they were, both written and oral. I have been required to give presentations to the SYMBoL [Project] team, which has helped me to develop my public speaking skills. This has also been developed during the tea meetings with the lecturers (S02, Self-reflection report)*

Group work is used in mathematics classrooms for its effectiveness in helping students understand mathematics and to develop interpersonal skills. The staff-student partnership in course design incidentally allowed small group work which did not only develop the interns' understanding of mathematics but also their team skills. For example, S01 and S04 noted in their diaries:

> *My teamwork skills are now more developed, as I have worked with [S02] on several problems during this internship, and we have worked towards a solution as part of a team. (S01, Self-reflection report)*

> *I have learned to work as part of a team and realised my views may not echo the team's views and what the team believe is more important. It is still important to put your own view across but you need to realize when you are the minority. (S04, Self-reflection report)*

Mathematics course design, and indeed course design in other disciplines, now requires the deployment of new technologies for delivery as well as for creating the course content such as lecture notes. One of the most common and efficient technologies for processing mathematics text is LaTeX. Despite its efficiency, LaTeX requires a lot of effort and dedication to learn to use. Until recently the most common technological tool used to create screencasts has been Camtasia. Staff-student partnership in mathematics course design may offer student partners the opportunity to learn, use, and apply technology in an authentic mathematics space where, over time, they may become proficient.

I observed that S02 and S04 seemed less confident when using technology than S01 and S03. However, there was evidence in the data that indicate, S02 and S04, reported increased confidence in their use of LaTeX and Camtasia as evidenced by the following comments extracted from their self-reflection reports:

> *My computer skills have particularly improved. I was very weak a in t LaTeX before and had never used Camtasia. I now feel very confident at using these programs. (S04, Diaries)*

The student interns had been introduced to LaTeX in a different course during the first semester of 2010/11 academic year. However, at the start of their full-time internship, they had not had the opportunity to work with the software in any significant way on any project.

Some of these skills, it could be argued, could have been acquired in other internship opportunities in industry and commerce as on some sandwich courses. Nonetheless, as collaborators in course design, the student interns were afforded opportunities not just to develop these skills, but to develop them within the context of advanced undergraduate mathematics. In this context, then, they also consolidated their understanding and knowledge of mathematics. The emergent Community of Practice to which the interns belonged, at least during their internship, provided them with the opportunity to put their basic skills to use and to learn new skills. Their skills and proficiency would have developed because they drew upon each other's strength in the use of LaTeX and Camtasia for support. They learned from each other and when necessary they consulted staff. My fieldnotes show that they had not only learnt to process text, equations, and formulae but also they had learnt to create presentations using Beamer [11]for the first time.

Staff also believed that the student interns gained, in addition to the deeper understanding of mathematics, skills and attributes that will serve them well beyond their graduation. The post-internship staff interview transcripts contained staff narratives that indicated the skills staff believed the interns would have acquired. For example, L07 and L08 argued that:

> *They[the student interns] would have gained new study skills. Well, it would certainly be a useful experience if they want to go into teaching at any level. (L07, Staff post internship interview)*

> *I think they are far more comfortable with the concept of presenting. What they were presenting within the project was just mathematical concepts. But I think it would also be true of non-mathematical concepts. Their writing-up skills improved a lot. And also their self-confidence, I think, improved a lot as well. So, there are a lot of additional, more fringe items that really came on very strongly during that period as well. (L08, Staff post internship interview)*

[11] Beamer is a flexible LATEX class for making slides and presentations as an alternative to PowerPoint.

These comments are important because mathematics graduates are expected to acquire not only knowledge of the content of the discipline but also to develop skills required for world of work.

In addition to transferable skills identified above, staff-student partnerships in course design appear to offer the student partners the opportunity to develop as professionals in a generic sense for all and any type of career and not just mathematics careers. Commenting on the personal development of the student interns in the post internship interview, L08 acknowledged a change in the professional identity of the student interns:

> *…how much they changed over that time period. I think even when they started; they brought a very professional attitude to it. But even so, they really matured a lot over that summer more than you might have expected for what was a very short time period. You might have expected them to grow a little bit over that period. (L08, Staff post internship interview)*

It is important to point out that not every student can succeed as co-creators of course design. In fact, the student interns may not necessarily be typical of the cohort from which they were selected. They did possess certain attributes which perhaps made them successful as student partners and for them to be easily assimilated into the Community of Practice within which they worked. The following extracts from the self-reflection reports of S01 and S02 suggest the attributes the potential student partners should have:

> *You just need to have enough enthusiasm and drive to want to learn more and the ability to persevere when something may appear to be way over your head. (S02, Self-reflection report)*

> *Throughout the internship I have needed to really persevere at times when I have struggled to get to grips with new programs or difficult problems. I have got much better at this over the 6 weeks so I would say my perseverance has improved. (S04, Self-reflection report)*

S04 had to persevere, especially during the first week, when he had to learn how to create screencast videos using Camtasia. In my observations, I noted the frustration that beset S04 as Camtasia would not work properly and the appropriate resolution for the Tablet PC could not be set. Yet, like the other interns, S04 resolved his difficulties through the mutual engagement of the staff and all the student interns

5.4.5.3 Pedagogical and affective outcomes for staff

Staff views of themselves as members of the partnership and of teaching also changed. Thus, I will argue that there was staff identify transformation, albeit limited. Table 5.2 shows that staff made 20 references to the sub-theme *pedagogical and affective outcomes for staff*. For example, L01 describes the outcomes of the partnership for him as follows:

> *I've also benefited professionally in the sense of being a lecturer, because they did work through the lecture notes. (L01, Staff post-internship interview)*

L01's acknowledgement that the student interns were able to restructure the Vector Spaces lecture notes demonstrates his changing awareness and recognition of the small but important contribution made by the student interns. A similar comment from L02

> *It was obviously fruitful for me, because it focused my attention on certain parts of the lecture notes that had deficiencies, shall we say, and I was able to improve them. So, there definitely was a direct benefit, even if the resources turned out to be not very good for whatever reason, which I'm not saying they will do. (L02, Staff post-internship interview)*

Other staff also considered changing their approach to course design as a consequence of gaining an awareness of the student perspective on learning and teaching as the following comments illustrate:

> *I also had discussions with the students about teaching and communicating mathematics. I got a bit of their view about the assignments that I have, and I'm trying to keep that in mind in setting the assessments for the coming semester. (L06, Staff post-internship interview)*

I think it did give me a good sense of first of all what the students find valuable that they have on LEARN[12]. I think that's influenced to some degree what I've put up on Learn this year, although I've also realised that it takes a lot of effort to produce these resources. (L03, Staff post-internship interview)

Throughout the partnership process, staff positioned themselves as mathematics researchers first but recognised the importance of their role as university mathematics teachers. The pedagogical impact of the partnership on staff was framed in terms of their awareness of the student perspectives on learning and teaching; and response to this awareness. Staff, and indeed the student interns considered the issues of learning and teaching discussed in Section 5.3.and responded positively to some of those student perspectives.

An affective impact of the collaboration on staff was also often framed in terms of the socialisation and community building that ensued from the partnership process. This included the development of relationships and the enjoyment of working with the student interns to create resources for learning and teaching. For example, when asked about how they had gained from collaborating with students as co-creators of course design, L01, L02 and L03 commented:

I definitely have benefited socially, because it's always fun to talk to people. I of course have not benefited in terms of research. (L01, Staff post-internship interview)

I enjoyed it. It was fun having the meetings, talking to them and talking to other members of staff about things and discussing different review of sources. (L03, Staff post-internship interview)

I found that it was a very enjoyable and rewarding, but very time-consuming and absorbing, experience. (L05, Staff post-internship interview)

[12] LEARN is the Virtual Learning Environment used at Middle County University.

"Talk" in the first quote refers to the discourses amongst staff and the student interns on mathematics content and teaching. The partnership clearly allowed the space and time for staff and student interns not only to produce course material but also to engage in mutually beneficial discussions. The space and time created by the internship were the catalysts for the outcomes for both staff and the student interns.

Although the data provide evidence of accounts of positive outcomes for staff and the student interns, it is important to state that partnerships are not without challenges. Two important challenges which may impact on the sustainability of such collaboration are worth noting. First, the staff found the process time consuming. In addition to the time taken out by staff to work with the student interns, there was the opportunity cost to research as suggested by one of the staff. These challenges have implications for the sustainability of partnerships within departments. Accordingly, next I discuss sustainability of the staff-student partnership in course design more generally.

5.4.6 *Sustainability*

The sustainability of the staff-student partnership in course design in the department of Mathematical Sciences at MCU were explored. Table 5.2 shows that staff made 44 references to sustainability and the student interns 19 references. The analysis of the transcripts of the post-internship interview with staff revealed that sustainability of staff-student partnership was contingent upon the achievement outcomes for future cohorts of students for whom the two courses were redesigned. When L06 was asked if he would partner with students to redesign any of his courses in future he replied:

> *I think that depends on what the outcome of the project is. If L01 and L02 come back and say, "This is working wonderfully well. Our students are learning much more than they used to," then I'm sure a lot of people will take it up. If it turns out not to be productive, then probably not. (L06, Pre-internship interview)*

Acknowledging that such collaborations between staff and students in course design are not for everyone, L08 recounted:

> *I think there are some staff, for whom it would not be something they would be particularly keen on. And I think in those cases, there's no point in trying to go down*

> *this route, because you're not going to get any benefits from it. (L08, Pre-internship interview)*

Some staff also had reservations as to whether the partnership can be used as a case study for the professional development of new and existing staff. For example, when asked whether the staff-student collaboration can be offered as part of professional development for staff, L01 replied:

> *I think the training sessions of new lecturers are pretty overloaded with material already, anyway, so I would definitely hesitate to put there even more. Whether or not something could be replaced in the training by something else... It's difficult to say, actually. Maybe not, maybe not. (L01, Pre-internship interview)*

Of the six other staff only one had the intention to actively involve students in developing aspects of a course unit. The remaining staff wanted evidence of the effectiveness of the partnership model before adopting the model of partnership for their own course redesign. A comment from L07 illustrates the views of those who wanted more evidence before he could adopt the partnership model to redesign his course.

> *I'm not specifically thinking of doing that with any of my modules. But I might consider it in the future, if I thought it might enhance the teaching of any of my modules. (L07, Post-internship interview)*

> *It's too much effort now. I've got too many other things that I'm trying to do. (L03, Post-internship interview)*

Despite the comment made in the last extract, L03 later secured internal funding and partnered with students to develop resources for learning and teaching statistics in disciplines other than mathematics. A sustainable course design partnership model is one that creates opportunities for other staff and students to co-design course units at department, institutional, or even national levels. This requires that the knowledge and understanding gained from practice are shared amongst staff in and outside the department. Although this chapter does not report on data from other institutions, under the National HE STEM Practice Transfer Adoptions scheme, the partnership model at MCU was shared with other institutions where students had also been involved as co-creators of course content for course units including Analysis, Differential Equations, and Rings, Groups and Fields. This is indicative that the sustainability of staff-student partnership is possible but requires staff to stretch their imagination as to how to involve students. I now summarize this chapter in Section 5.5.

5.5 Summary

In Section 5.3, I have presented evidence from the data that illustrates issues related to the learning and teaching of Vector Spaces and Complex Variables and mathematics in general. The issues that may affect students' attitudes and engagement with mathematics include teaching approaches that may be perceived by students as unhelpful to them; staff and student relationships that may be perceived as disrespectful, and assessment task that are aimed at encouraging learning but may be perceived as unhelpful by students.

In Section 5.4, I presented findings that provide evidence *of* and give insight *into* the nature of the staff-student partnership in undergraduate mathematics course design. The findings suggest that staff-student collaboration leads to an emergent Community of Practice in which staff and student interns mutually engage with a joint enterprise. However, in general, staff and students may not share in the same joint enterprise, some students preferring to maintain the traditional hierarchical roles and responsibilities in learning and teaching of undergraduate mathematics.

The evidence in Section 5.4 also shows that staff and students who engage in course design partnerships experience identity transformation. The staff and student partners develop enhanced relationships. The student partners gain deep mathematical understanding and increased confidence in their mathematical competence. The main gain for staff is in their awareness of the student perspective on learning and teaching and new ways of creating content for their courses. However, the evidence in Section 5.4 also shows that there are challenges in sustaining staff-student partnerships in undergraduate mathematics course design, at least in the short term, unless evidence of their effectiveness can be established in terms of student achievement. In Chapter

6, I present the findings from the analysis of qualitative data collected on PAL during phase two of the research project.

CHAPTER 6 STUDENT AS PARTNERS IN TEACHING

6.1 Introduction

“To teach is to learn twice.” (Joubert, n.d. “Quotes”, bullet 1)

This Chapter reports the findings of the phase two study which investigated the staff-student partnership in the delivery of Vector Spaces and Complex Variables via a Peer Assisted Learning (PAL) scheme. The focus of this study was on the characteristics of PAL sessions and the qualitative impact of participation in PAL sessions on *PAL participants* and *PAL leaders* (see Section 1.6, p.15 for definitions of these terms). In the Sections below, I describe the data that were collected in this phase two study; how the data were analysed; and present the findings that emerged from the analysis of the data.

PAL is a form of “participatory pedagogy” advocated by (Solomon, 2007). PAL was implemented to ameliorate the challenges that some students face in their transition through second-year undergraduate mathematics. As a pedagogical strategy, PAL was implemented to support the learning of Vector Spaces and Complex Variables but was not a replacement for lectures and/or tutorials. PAL was supplemental to the traditional scheduled lectures and tutorials and students played a role in partnership with staff to implement and run PAL sessions.

Section 6.2 below is a preamble to this chapter in which I describe the datasets which were analysed to generate the findings being reported here. In Section 6.3, I describe and discuss how PAL was implemented. I describe students’ *participation* in PAL sessions in terms of their attendance levels in Section 6.4. In Section 6.5, I present six vignettes which offer readers a keyhole through which to see the “inside” of the PAL sessions. These vignettes highlight the characteristics of PAL sessions, and the nature of the mathematics with which the students engaged, the strategies used by the PAL leaders to facilitate sessions, and the mathematical practices in which they engaged.

In Chapter 5, Section 5.2, I briefly discussed the constructs of the CoP theory I drew upon to analyse the qualitative data I collected in the phase one study. In this phase two study, the same constructs of CoP theory were used to analyse the qualitative data collected – PAL observation fieldnotes and transcripts of interviews with PAL participants and PAL leaders. In Section 6.6, I discuss the qualitative impact of participation in PAL on the mathematical understanding and the affective disposition of PAL participants and PAL leaders. I summarise the chapter in section 6.7.

6.2 Preamble to the chapter

The findings in this chapter emerged from the analysis of four datasets. The first dataset was the survey of first and second-year students (see Section 4.3.1, p.98) which also explored undergraduate mathematics students' expectations of a *peer learning support* (PLS) scheme. PLS is a generic term used here to describe all kinds of peer learning support that are offered to students in higher education. PLS may include mentoring and buddy systems aimed at fostering students' adjustment *to* and social integration *into* tertiary education. In the survey, the terms Peer Assisted Learning (PAL) or Supplemental Instruction (SI) were not used so that the survey results were not biased in favour of either of these two forms of PLS. Rather, PLS was explained to students and they were asked to describe the features of a PLS they would like to see implemented; their expectations of the attributes of a PLS leader; and the roles they would expect the PLS leader to play.

The second dataset was fieldnotes I wrote when I observed PAL sessions and a collection of documents used in the sessions (e.g. exercises, worked out examples, attendance register, etc.). To check the accuracy of the observation fieldnotes, video recordings of two separate PAL sessions which were facilitated by different PAL leader groups were made. Each video was approximately one-hour long. Although the videos were not analysed for this study, they enabled the accuracy of a sample of the observation fieldnotes (see Vignettes 6.4 and 6.6 below) to be cross validated through multiple viewings of the videos.

The third dataset included transcripts of interviews with eight PAL leaders and 10 PAL participants. In addition, the third dataset included an email correspondence from a PAL participant who declined to be interviewed, and a transcript of an interview with a non-PAL participant. The interviews explored PAL participants' experiences of PAL sessions in which they participated, their motivation for participating in PAL sessions; their relationship with PAL leaders, and the outcomes of their participation in the PAL sessions for themselves. Only one non-PAL participant volunteered to be interviewed. One possible reason why many non-PAL participants did not volunteer to be interviewed is perhaps that they did not feel they could talk about the PAL scheme in which they have not participated. With respect to the one non-PAL participant who volunteered to be interviewed, the interviews explored the reasons for his non-participation in PAL sessions and his learning experiences during the academic year, 2011/12.

6.3 **PAL implementation for advanced mathematics.**

6.3.1 *Students' expectations of a peer learning support scheme*

The survey results showed that of the 56 first-year (prospective second-year) students who responded to the survey, 70% suggested that they would access a PLS scheme if one was established at MCU. Of the 56 students, 79% suggested that they valued peer support in their learning. Forty-eight percent would prefer a PLS scheme the sessions of which are facilitated by students from the same year group as them. Twenty-five percent indicated that they would prefer a PLS scheme the sessions of which are facilitated by students from the year above them and 14% preferred postgraduate students as PLS leaders. This evidence suggests that the traditional practice in which higher year students facilitate the learning of lower year students might not be the preferred model for all students.

The data also showed that a higher proportion of single honours mathematics students would prefer some form of PLS compared to joint honours students. A Pearson chi square test was conducted to look for association between the degree programme of respondents and the extent to which participants valued PLS. The test showed a statistically significant association between the degree programme type of students and the extent to which they valued PLS, χ^2 (1, 56) =5.543, p=.019. One possible explanation of this finding is that perhaps single honours students find their study more of a challenge and therefore they would welcome additional support Another possible interpretation is that single honours students seeks additional support in order to do even better in their examinations. Although I did not set out to look at gender differences in this study, it is worth pointing out that a Pearson chi-square test did not show a statistical significant association between gender and the extent to which the respondents valued PLS.

The survey also asked the study participants three open-ended questions. The first question asked about students' expectations of the features of a formal mathematics PLS scheme. The second question asked about students' expectations of the attributes of a PLS leader. The third open-ended question asked about the roles students' expected of a PLS leader. The qualitative responses to each question were coded to identify common words or phrases that can be categorised into themes. Three themes that emerged: *expected features of a PLS*, *expected attributes of a PLS leader*, and *expected roles of a mathematics PLS leader*. Table 6.1 shows the number of references made by respondents to each theme and related codes.

Table 6.1 Mathematics Students' Expectations of Peer Learning Support Scheme

Expected features of a PLS	**# of references**	**Expected attributes of a PLS leader**	**# of references**	**Expected role of a PLS leader**	**# of references**
Group work	17	Good	22	Help	42
Peer to peer support	14	Friendly	20	Understand	19
Helpful	9	Patient	17	Answer	9
Timetabled session	9	Helpful	14	Lecture	8
Focus on solving		Approachable	13	Support	7
problem examples	6	Confident	11	Explain	5
Providing support	4	Understanding	10	Guide	5
Problems	3	Enthusiastic	9	Teacher	5
Appointment based	2	Knowledgeable	7	Tutor	5
Offers lectures	2	Have maths skills	6	Check	5
Structured sessions	2	Easy	5	Educator	2
Total references	68	Willing	5	Lead	2
		Able to communicate	4	Provide guidance	2
		With ability	4	Encourage	2
		Confidence	3	*Total references*	115
		Encouraging	2		
		Have empathy	2		
		Have enthusiasm	2		
		Intelligent	2		

Expected features of a PLS	**# of references**	**Expected attributes of a PLS leader**	**# of references**	**Expected role of a PLS leader**	**# of references**
		Interesting	2		
		Non-arrogant	2		
		Non-condescending	2		
		Supportive	2		
		Total references	166		

The top five words or phrases which referenced features of a mathematics PLS scheme are “group work”, “supportive”, “timetabled sessions”, “focus on problem solving”. The least referenced feature of PLS scheme were “appointment based”, “offering lectures” and “structured sessions”. Some respondents expected a PLS scheme would be timetabled and run at regular times for small groups. Other respondents expected a PLS scheme to focus on the content of mathematics. The latter expectation contrasts with the way adapted SI schemes run: that is to integrate *study skills* with content. A few respondents expected a PLS scheme to run like a drop-in centre facilitated by students. Other respondents suggested a PLS scheme which offers appointments for students who might need one-to-one support. Some respondents expected PLS sessions to run via an online forum.

The top five codes referencing attributes of a peer leader are: “good”, “friendly”, “patient” “helpful”, “approachable”, “confident”, “understanding”, “enthusiastic”, “knowledgeable”. The top five codes referencing of the role of a peer leader are to: “help”, “understand”, “lecture” “support”, “explain”, “guide”, “teach”, “tutor”, “knowledgeable”

Some respondents, though not many, expected peer leaders: “to answer *any* question [one] may have about a certain topic of a course”; “to be familiar with *most* of [the] courses and be able to help with *any* problems that [one might have]”; “to help answer *any* questions and help [students] understand topics of difficulty”; “to be available to students *when required”*; “assist and help with *any* examples on problem sheets”. Peer leaders may not be able to meet these expectations all the time. This is because, notwithstanding the form of the PLS scheme, peer leaders are not required to be able to resolve all the difficulties that students may have; but to have the confidence to be able to refer questions back to students in their sessions for them to find solutions for themselves. Some respondents do not expect peer leaders to be teachers but facilitators whose role is to “support” students to find answers for themselves.

Training is often provided to peer leaders but the evidence above suggests that students who wish to access a PLS scheme as learners would, perhaps, also need to be trained and educated about the roles of peer leaders and indeed the roles of the learners themselves as they participate in PLS sessions. For without this training, learners who participate in PLS schemes may have expectations of peer leaders that may not be fulfilled.

6.3.2 *Recruitment of and training for PAL leaders*

The staff-student partnership in the delivery of Vector Spaces and Complex Variables involved the recruitment of prospective third-year undergraduate mathematics students as PAL leaders whose role was to facilitate PAL sessions for second-year students. In May 2011, two academic mathematicians at MCU were assigned to advertise the positions of PAL leaders to all prospective third-year students via flyers posted around the campus and via e-mail. Also, the two mathematics staff members and two academic developers at the university Teaching Centre (TC) jointly held information sessions where students came along to find out more about the role of PAL leaders.

The two academic developers from the TC were also given the task of organising training, based on the 21 principles of PAL (see UKMC, 2015; Bournemouth University, 2010), for the prospective PAL leaders. One half-day training was offered to thirteen prospective third-year students in July 2011. The thirteen students were those who signed up to commit their free time to support second-year students during the 2011/12 academic year. The recruitment criteria for PAL leaders were that they should have taken and passed Vector Spaces and Complex Variables courses before the start of the 2011/12 academic year which was at the beginning of October 2011. There was no selection process for the PAL leaders because everyone who volunteered to be a PAL leader did eventually become a PAL leader. One of the third-year PAL leaders eventually dropped out early in the academic year (November 2011).

The training session provided introduction to PAL and how it was expected to work. In particular, the principle that the role of the PAL leaders was one of a facilitator of group learning rather than that of a mathematics tutor was emphasised. The PAL leaders were unpaid but the potential benefits that could accrue to them as a result of taking up the role as PAL leaders were drawn to their attention. These included academic benefits arising through reworking the second-year courses, but this time as PAL leaders. They were informed about the opportunities arising through training and development in key transferable skills such as communication, team working and leadership. In addition, Middle County University (MCU) operates an ‘Employability Award’ and participation as a PAL leader would earn a substantial number of credits.

In September 2011, a full day’s training was offered to the PAL leaders during the freshers’ week. On this occasion, students were trained on how to co-facilitate their PAL sessions, recognise key features of a successful PAL session, and reflect on successful and unsuccessful learning strategies. They began to explore the design of resources and activities to be used in their sessions. An important element of the training was the modelling of a PAL session. An experienced mathematics lecturer began by giving a mini-lecture to the student leaders and to two mathematics staff members. The material was designed to be unfamiliar to the audience. Thereafter, the two staff members played the role of PAL leaders, working with the group to draw out explanations of what the lecture had been about – without actually tutoring themselves.

Practical issues such as record keeping, accessing additional support and the importance of liaising with the course lecturers were also discussed in the training. Following the training, the PAL leaders were judged to be prepared to facilitate PAL sessions. In the next section, I discuss how the second-year students taking Vector Spaces and Complex Variables were recruited for the first PAL sessions held in October 2011. I also describe and discuss students’ engagement with PAL sessions in terms of their attendance levels.

6.4 Student attendance at PAL sessions

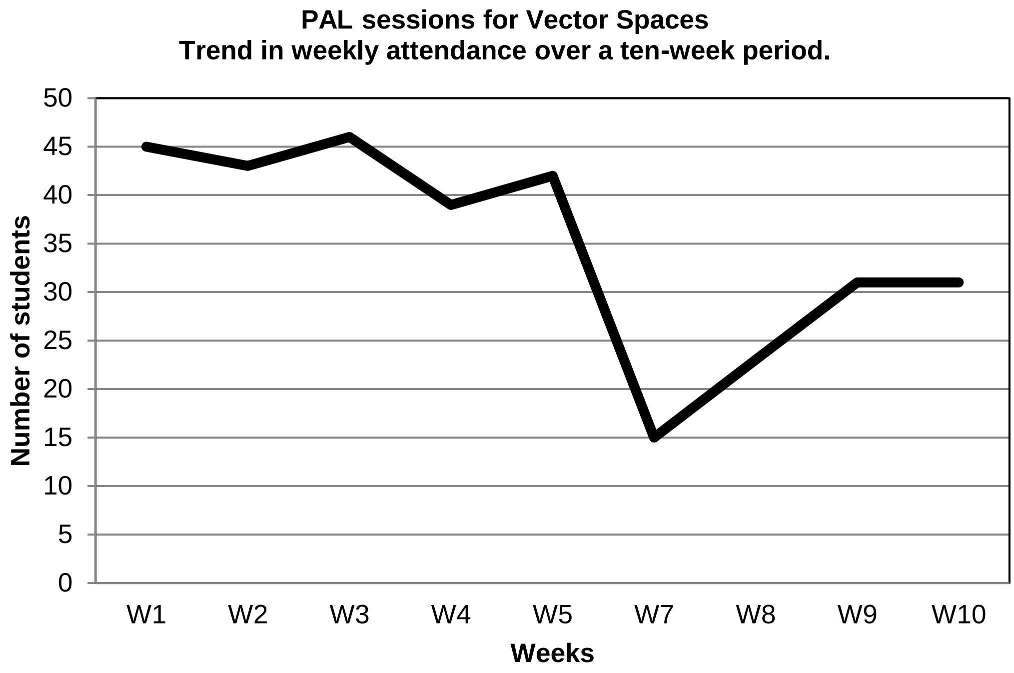


Figure 6.1 Line graph showing weekly Vector Spaces PAL session attendance in Semester 1, 2011/12, cohort size -83.

The PAL sessions were timetabled for Vector Spaces and Complex Variables during semesters one and two respectively. At the start of semester one of the 2011/12 academic year, the PAL leaders had to attend the first Vector Spaces lecture and to ask students to choose their preferred times for attending PAL sessions. The PAL leaders then met and sorted the second-year students into four groups each of which was facilitated by two or three PAL leaders.

Vector Spaces PAL sessions ran for nine weeks during semester one, from week one in October 2011 to week ten in December 2011. Fifty-seven out of 83 students who were taking Vector Spaces attended at least one PAL session. Thus, about a third of the students who studied Vector Spaces did not engage with the PAL scheme. Some students attended every week in which PAL sessions were held. Some students attended a session when they felt they needed support to understand a particular topic. Some students attended regularly. Figure 6.1 also shows the trend in PAL attendance

over a ten-week period. Figure 6.1 shows that more than 30 students attended PAL sessions in most of the nine weeks.
In week six, there were no PAL sessions as the PAL leaders had to meet with staff to discuss how things were progressing and whether there were any issues that needed resolving. The midterm break had been designed into the PAL scheme as this was the first time the PAL scheme had run and no one knew how well it would run. The intention was to run it for five sessions and then take stock and make adjustments if it was not working well. The break was to give the PAL leaders the opportunity to feedback to staff and to reflect on their *practice*. During week seven, a workshop for second-year undergraduate mathematics students had been arranged as part of another course some students had opted to attend. The mid-term break in running the PAL sessions therefore caused considerable difficulties for both PAL participants and PAL leaders when they had to restart in week seven. Figure 6.1 also shows that the number of students attending PAL sessions each week after the break did start to increase after week seven but could not reach the levels it was in the first two weeks.

Although the PAL sessions officially stopped in week 10 in December 2011, at least one PAL group organised a session after Christmas to revise for Vector Spaces examination which took place in February 2012. Eighteen students attended the extra session. In Chapter 7, where I present the results of an investigation into the relationship between PAL attendance and student achievement in Vector Spaces, the relevance of the data presented in this section will become clear. Further details about the demographic characteristics of the PAL participants will also be presented.

I conducted a mini survey of PAL participants who attended sessions in week 9 and week 10. The survey sought to find out how many of the respondents would choose to participate in PAL sessions in semester two when Complex Variables was to be taught. The majority of the respondents (36/40) to the survey intended to continue to participate in PAL sessions in semester two when Complex Variables PAL sessions ran officially for ten weeks. Some PAL leaders voluntarily held additional PAL sessions in week 11 to help prepare the PAL participants for examinations in May 2011. Sixty-one out of 127 students who were taking Complex Variables attended at least one PAL session. Figure 6.2 below shows the trend in attendance over the eleven-week period. Figure 6.2 shows that in semester two, the number of students attending sessions each week was stable compared to semester one.

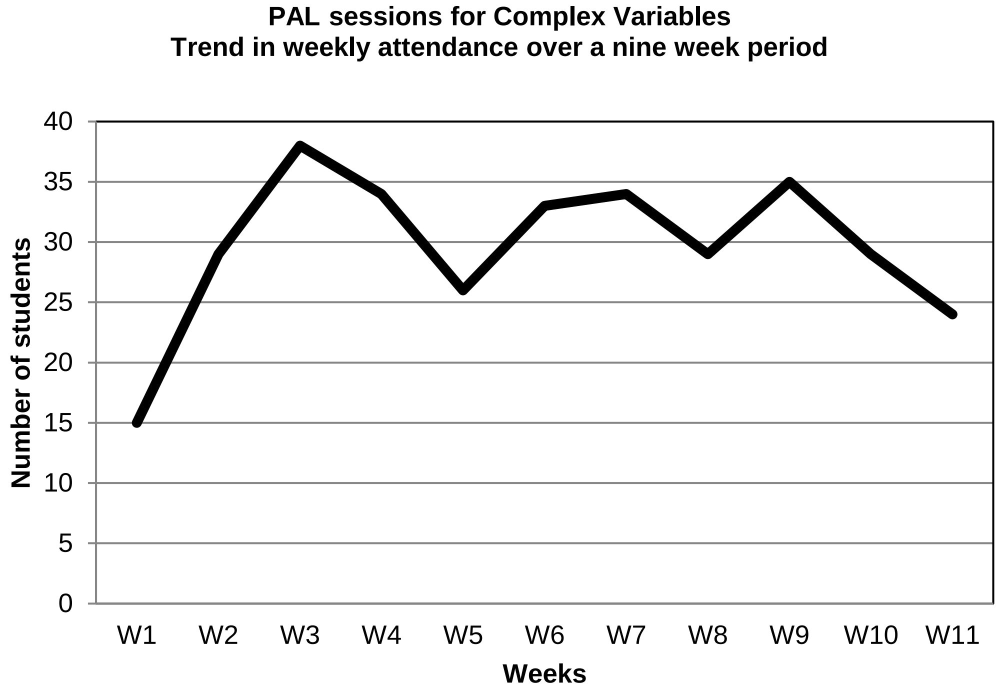


Figure 6.2 Line graph showing weekly Complex Variables PAL session attendance in Semester 2, 2011/12.

The evidence presented thus far suggests that not all students took advantage of the opportunity made available to them to learn collaboratively. About half of the students who studied Complex Variables did not participate in PAL sessions. This proportion of non-PAL participants (52%) is higher than that for Vector Spaces (31%). However, this difference was not statistically significant (z= -5.21, p=0.603).

We shall see in Section 6.6 that some students chose not to participate in PAL sessions for a variety of reasons including 1) issues relating to how the scheme was promoted to the wider second-year undergraduate mathematics community, and 2) the rejection of PAL as a form of participatory pedagogy. In the next section, I describe and discuss the characteristics of six second-year mathematics PAL sessions in which students discussed topics and concepts taught in Vector Spaces and Complex Variables lectures which some students had found difficult and/or challenging.

6.5 Vignettes of PAL sessions

PAL participants were allocated to one of four groups. Each group attended one PAL session in each week when sessions were held. The day on which sessions were held and the time at which they were started for a group were the same in each week. I observed six PAL sessions. Vignettes of these six sessions have been included in this Section. The purpose of the six included vignettes is to give readers of this thesis a snap shot of *how* the PAL sessions ran, *what* was done in sessions, the nature and the type of the mathematics topics on which the students worked.

As Dawson et al. (2014) note, PAL research reports often do not provide data on PAL sessions and when authors provide data on PAL sessions, often it is the ideal sessions to which PAL implementers aspire that is described. This thesis, then, responds to the critique of Dawson et. al. by providing glimpses into real PAL sessions.

These sessions might not appear dissimilar to traditional mathematics tutorials. However, as we shall see in Section 6.6, many of the interviewees who participated in these PAL sessions reported a positive learning experience. The reports of those who participated in sessions indicate that the sessions offered them the kind of social and mathematical practices which foster increased engagement with the subject. Together, these vignettes (see Appendices N through to S for the observation fieldnotes) provide evidence of the characteristics of the PAL sessions for Vector Spaces and Complex Variables. The vignettes also enabled me to characterise PAL sessions for undergraduate second-year mathematics of which there is little research. It is hoped that readers will then be in a position to compare the research participants' narratives of the contrast between traditional mathematics tutorials and the PAL sessions they attended.

6.5.1 *Vector Spaces session: Observation 1*

I chose to include Vignette 6.1 for two reasons. First, the number of students who attended the session as PAL participants was large. This session is often attended by about twenty second-year students taking Vector Spaces. Second, one of the mathematical problems that the PAL participants solved shows that abstract mathematical ideas such as a *field* can indeed be framed in the context of everyday problems that require the application of the abstract mathematical idea. The contextual nature of the problem that students had to solve seemed to have motivated them to engage with the problem.

Vignette 6.1

The PAL session was run at the end of October 2011, two weeks before a formative assessment in Vector Spaces. The topic for this PAL session was "Solving Linear equations over a finite field". Three PAL leaders (PL01, PL02 and PL03) facilitated the session. The attendance register, which was signed by each attending PAL participant, showed that 16 PAL participants (S101, S102, … S116) attended the session – five females and 11 males. PL01 warmly welcomed the PAL participants to the session saying "Hello" to the PAL participants as they entered into the room.

PL01 introduced a starter (opening) mathematics activity, the Granny Buttler problem to the class (see Figure 6.3 for the problem). PL01 told the PAL participants in the session that they will be revising the example on page 6 of the lecture notes. After the introduction, the PAL participants started working on the Granny Butler problem either in pairs or in groups (three or four) although they were not directly instructed to work in groups by the PAL leaders.

One group of female students sat at a table which was surrounded by three groups of male students on three other tables. As the PAL participants were working, PL01 intervenes: "A hint. You can work in F_5[13]". About 15 mins later and after a warning, PL02 went to the board to write up a system of equations required to solve the problem. Suddenly there was a loud uproar from the whole group: We don't want the solution yet. After a few more minutes, PL02 asked one of the PAL participants to state the system of equations for solving the problem (see Appendix M for solution) which she wrote on a board.

PL01 then asked the PAL participants to complete the solution using Gaussian elimination. The rest of this session was focused on students practising past test and examinations papers in preparation for an upcoming examination.

Granny Buttler, who has an odd interest in numbers, likes to show off her three grandchildren and could talk endlessly about them. Two of them are boys and the third is a girl, she tells a maths student, who ended up sitting next to her on a peak time train from Loughborough to London. The Buttler family meeting, which takes place in London every 5 years, is again approaching. Granny has got with her photos of each of her grandchildren taken at each of the previous meetings with their age on the back of the photographs. "Isn't it remarkable that the age of Matthew on this photo and the age of Robert on that photo, add up exactly to twice the age of Lara on this third photo", she says.

Granny well remembers that at one of the meetings, the age of the three children added up to 13 and recalls the unfortunate events following the occurrence of the unlucky number. As the maths student dozes off, Granny Buttler continues to tell remarkable and unbelievable stories about her relatives and the famous family meeting. With London approaching and the student waking up, she holds up three photographs: "If you take the difference of the ages of Matthew and Rob and add-on these you get exactly Lara's age", she rejoices. The Granny smiles cunningly and says to the student" "If you figure out the age of my grandchildren as written on their oldest photographs, I will pay your ticket." What will the student, who is always short of money, do?

Figure 6.3. The Granny Buttler Problem, a Vector Spaces task used during a PAL session.

[13] F_5 refers to the finite field – a mathematical object discussed in lectures held before the session.

> The PAL participants worked supporting each other and sharing ideas on test items while the PAL leaders circulated amongst them offering help in the form of hints, answering questions or clarifying queries that the PAL participants had with some of the past examination questions.

6.5.2 *Vector Spaces session: Observation 2*

Vignette 6.2 was included in this thesis because students in this session and others I observed claimed to find the Spectral Theorem difficult to understand and apply to solve problems. The Vignette illustrates how complex mathematical ideas and theorems such as the Spectral Theorem may be structured by learning facilitators to aid students' comprehension.

> Vignette 6.2
>
> This PAL session was run a week before Christmas 2011. Two PAL leaders (PL04 and PL05) ran the session. Five PAL participants attended the session (S201, S202, …, S205) – one female and four males. PL04 started the session by ascertaining the part of the lecture notes on which the PAL participants were working in lectures. The PAL participants replied: "Spectral Theorem". PL04 told the group that they will rework the lecture notes on "Spectral Theorem" so that all the learners understand it before the examination. PL04 then asked for a definition of the theorem and suggested that there are three parts of the theorem. PL04 started by discussing the theorem, breaking it up into three "chunks" while PL05 wrote the three "chunks" on the board in a way that they believed was easier for the PAL participants to understand and remember. Suddenly, S201 stated: "I don't know when we are going to use this theorem". To address the concern of S201 about not knowing when the theorem could be used, PL04 explained that the third part of the theorem could come up as a question in the examination. PL04 then presented the PAL participants with a potential examination problem that required a solution using the third part of the theorem.

Part 1

V is a finite dimensional real or complex Hibert space.

Let $f \in \text{End}\,(V)$ be a self-adjoint map

Endomorphism (See Chapter 4 of the lecture notes)

$$f: V \to V$$

Then there exists an orthonormal basis of V consisting of eigenvectors of f

Every self-adjoint map is a diagnosable if $e_{1,}\, e_2 \ldots e_n$ is orthonormal basis consisting of eigenvectors then we can express

$$f = \sum_{i=1}^{n} \lambda_i \langle e_i, . \rangle e_i$$

Figure 6.4. PAL leaders' presentation of part of the Spectral Theorem – 1.

Part 2

Let V be a finite dimensional real or complex Hilbert space and let $f \in \text{End}\,(V)$ be a self-adjoint map.

Let P_λ = orthogonal projection onto the λ eigenspace.

Then:

$$f = \sum_{\lambda} \lambda P_\lambda$$

Figure 6.5. PAL leaders' presentation of part of the Spectral Theorem – 2.

Part 3

Let $A \in$ Mat (n, ℝ) be a symmetric matrix. Then there is an orthonormal [sic] matrix C such that $C^{T}AC$ is a diagonal matrix. Then there is a unitary matrix C such that: $C^{*}AC$ is a diagonal matrix.

Figure 6.6. PAL leaders' presentation of part of the Spectral Theorem – 3.

Through the use of different questioning styles, PL04 inspired S201 to respond to a question even though most of the group were focussed on copying the "chunked" parts of the theorem and asking no questions. Questions posed by PL04 were often answered by the same two PAL participants. Others remained silent. It is not clear from the passivity of other PAL participants whether they learned and understood the concepts underpinning the Spectral Theorem. This is because the PAL leaders' presentation was mainly PAL leader centred rather than PAL participant centred. Although the PAL participants asked no questions, they were attentive and appeared to be listening well. This session was akin to a lecture.

In this session, there was less focus on practising past tests and exams papers than in Vignette 6.1. The PAL leaders led from the front of the classroom as might be observed in a formal lecture. The PAL leaders adopted a facilitation approach that was also seen in other sessions that I observed during the week of the observations – breaking up the lecture notes to aid PAL participants' comprehension. The Spectral Theorem was broken up into three small parts. The three "chunked" parts of the Spectral Theorem as presented to the PAL participants by PL04 and PL05 are shown in Figures 6.4 through to 6.6 above.

6.5.3 *Vector Spaces session: Observation 3*

Vignette 6.3 was also included in this thesis because the strategy of support provided to the PAL participants had the potential to contribute to *instrumental* rather than a *deep* understanding of the topic. The Vignette illustrates how a *procedural* and *rule* based approach was used to convey the ideas behind a starter activity that was used in the session.

Vignette 6.3

This PAL session also took place just before Christmas 2011. Three PAL leaders (PL06, PL07, and PL08) facilitated this session which was attended by seven PAL participants (S301, S302, …, S307) – three females and four males. At the start of the session, PL06 told the PAL participants that the topics for discussion are "inner product space" and orthogonality". PL06 also reminded the PAL participants that the topics can be found in Chapters 5 and 6 of the lecture notes. The lecture notes had been provided to the students as PDFs via a Moodle virtual learning environment

(VLE). PL06 asked the PAL participants to work in pairs on a starter activity (see Figure 6.7). After about ten minutes, PL06 asked the students: “Does everyone know how to get the matrix”? There was silence. PL06 then provided a hint: “It is connected to the Inner Product”. A PAL participant, S301, replied: “He [the lecturer, L01] has given us an example but I don’t understand what he has done to the get the answer”. PL06 asked S301 if he could do a similar one as the lecturer has done in the lecture. After about 15 minutes had passed, the PAL participants had not made any progress on the starter activity (see Figure 6.7). PL06 picked up a board marker and passed it to PL08 who went to the board to try to lead the PAL participants through the starter activity. She wrote equations (1) and (2) on the board which she referred to as the *rules* to help finding some of the elements of the matrix of the scalar product (also see Figure 6.8).

$$\langle \mathrm{i}a, b\rangle = -\mathrm{i}\langle a, b\rangle \quad (1)$$

$$\langle a, \mathrm{i}b\rangle = \mathrm{i}\langle a, b\rangle \quad (2)$$

These are rules that the PAL learners need to know in order to find the elements of the matrix of the scalar product of the complex inner product space in Figure 6.7. S301 was asked to go to the board to show how one element of the matrix may be found. S301 went to the board and presented the solution in Figure 6.9. He was pleased with himself after the rest of the class have accepted his solution. There was a big smile on 301’s face. S301 recounted: I loved it when you get it eventually after struggling with the material. While PAL participants worked, a conversation ensued between PL06 and some of the PAL participants about the difficulty of the course and teaching style. PL06 mentored and gave advice to the PAL participants: “Exam papers are lot easier. I will say attend the next few lectures please.” PL07 entered the conversation: “There will come a time where it’s all going to make sense.”

Vector Spaces

Orthogonality and Orthonormality

Let V be a complex inner product space with the inner product

$$\langle P, Q \rangle := \int_0^1 x^2 \overline{P(x)} Q(x) \mathrm{d}x.$$

(a) Determine the matrix of the scalar product on $\mathbb{C}_2[x]$ with respect to the basis $(\mathrm{i}, \mathrm{i}x, x^2)$.

(b) Find an orthonormal basis of $\mathbb{C}_2[x]$ using the Gram-Schmidt procedure.

(c) Determine a basis in the orthogonal complement of $\{1, x\}$.

Figure 6.7. A starter activity used in PAL session described in observation 3.

The PAL participants needed to be able to recall the "*rules*" for finding the elements of the matrix of a scalar product on the complex inner product space if they were to be able to solve the problem in the starter activity shown in Figure 6.7. Vignette 6.3 demonstrates that students (learners and leaders) were adopting a procedural approach to problem solving.

PAL participants may not be able to solve future problems if they are unlike the ones for which they learned the procedural approach. Therefore, even though the PAL participants who were in the session were content with their competency in solving the problem, it is unclear whether they learned and gained a deeper understanding of how to find the matrix of the scalar product on $\mathbb{C}_2[x]$ with respect to a given basis.

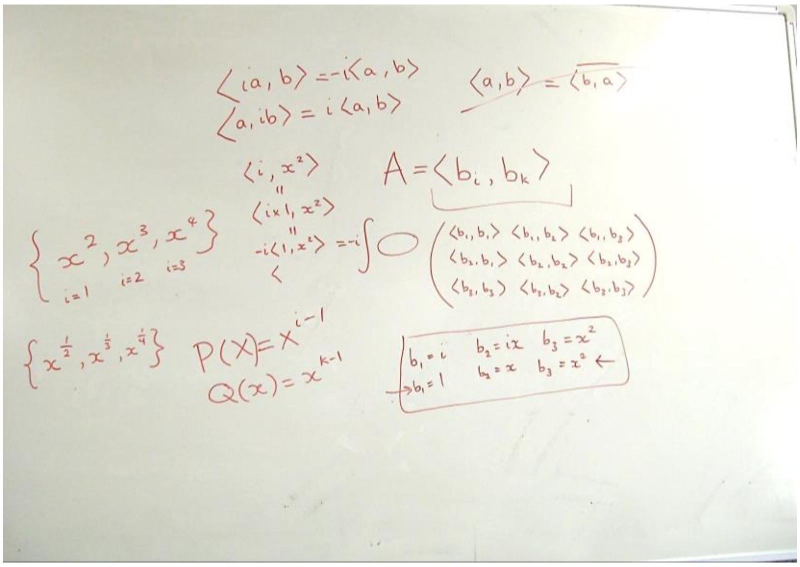


Figure 6.8. Rules for finding the matrix of a scalar product presented by PAL leaders.

the rules	<i*a*, *b*>=-i<*a*, *b*>
and	<*a*, i*b*>=i<*a*, *b*>
and so	$<b_2,b_2>$ = <i*x*, i*x*>

$$= \int_0^1 x^2 \times x \times x \, dx$$

$$= \int_0^1 x^4 \, dx$$

$$= \left[\frac{x^5}{5}\right]_0^1 = \frac{1}{5}$$

Figure 6.9. A presentation by S301 showing how to find an element of the matrix.

By providing the “rules”, PL07 seemed to have provided some sort of *scaffolding* necessary for the PAL participants to make progress on the activity which otherwise could have been challenging for them. In this session, I observed instances where PAL leaders shared their own experience of learning the content of Vector Spaces with PAL participants and in some sense provided *encouragement* and *reassurance* to the PAL participants to persevere in their learning of Vector Spaces.

6.5.4 *Complex Variables session: Observation 4*

Vignette 6.4 was included in this thesis because it illustrates an example of collegiality between PAL leaders and the support they provided to each other in sessions. The PAL participants I observed in this session found the *integration along contours* difficult, as did those students I observed in the sessions on which Vignettes 6.5 and 6.6 are based.

Vignette 6.4

This session took place in May 2012 just before the semester two examinations. Two PAL leaders (PL01 and PL02) facilitated the session and 17 PAL participants (S401, S402, …, S417) attended the session) – six females and eleven males. The topic for this session was integration along contours. At the start of the session, PL01 stated: “We will go through problem sheet 4 Q1b. We will put an extra example on the board. You will need the theorem on page 44”. After allowing the PAL participants sufficient time to grapple with Q1b on problem sheet 4, PL01 asked one of the PAL participants

$$I = \int_{c1} \frac{z}{z^2 - 1}\,dz = \int_{c1} \frac{z}{(z+1)(z-1)}\,dz$$

So I=2πi Res $f(z)$, simple poles at $z = 1, z = -1$ but only $z = 1$ is in C_1

$$I = 2\pi \mathrm{i} \lim_{z\to 1} \frac{(z-1)z}{(z+1)(z-1)} = 2\pi \mathrm{i}\frac{1}{2} = \pi \mathrm{i}$$

Figure 6.10. The solution to a complex variable problem presented by S402.

$$\int_0^{2\pi} \frac{1}{5 - 4\cos\theta}\,\mathrm{d}\,\theta,\ \text{Let } z = e^{\mathrm{i}\theta}$$

$\mathrm{d}z = \mathrm{i}e^{\mathrm{i}\theta}\mathrm{d}\theta,\ 4\cos\theta = 2e^{\mathrm{i}\theta} + 2e^{-\mathrm{i}\theta} = 2z + \frac{2}{z}$

$$I = \int \frac{1}{5 - 2z - \frac{2}{z}}\,[\text{sic}] = \mathrm{i}\int \frac{1}{2z^2 - 5z + 2}\,\mathrm{d}z$$

$$I = \mathrm{i}\int_{C_{1(0)}} f(z)\,\mathrm{d}z\ when\ f(z) = \frac{1}{(z-2)(2z-1)}$$

which has singularities[sic] at $z = 2$ and $\frac{1}{2}$ but only $z = \frac{1}{2}$ lies within $C_{1(0)}$

So by the Residue Theorem,

$$I = \int \mathrm{i}(2\pi\mathrm{i})\mathrm{Res}_{z=\frac{1}{2}} \frac{z - \frac{1}{2}}{(z-2)(2z-1)}$$

$$I = \mathrm{i}(2\pi\mathrm{i})\mathrm{Res}_{z=\frac{1}{2}} \frac{z - \frac{1}{2}}{(z-2)2(z-\frac{1}{2})}$$

$$I = -2\pi\mathrm{Res}_{z=\frac{1}{2}}\ \frac{1}{2(z-2)}$$

$$I = -2\pi\left(-\frac{1}{3}\right) = \frac{2\pi}{3}$$

Figure 6.11. Part of a solution to a complex variable problem presented by S401.

to come to the board to present and explain his solution to the rest of the class. A PAL participant, S0401, went up to the board to present his solution. Figure 6.10 above was *an* attempted solution to Q1b which was being discussed and critiqued by fellow PAL participants and therefore *not necessarily* the final *correct solution* which the PAL participants and PAL leaders agreed. After presenting part of the solution as shown in Figure 6.10, PL01 consulted PL02 and quietly asked: “What is the difference between *pole* and *singularity*?” PL01 returned to the front of the class and told the rest of the class: “I am going to change “Singularities” (as in Figure 6.11

above) to "Poles". He did not offer any explanation as to why he had made that change.

Following the intervention by PL01, S401 continued and finished the presentation of his solution as shown in Figure 6.10. After allowing the class time to reflect and after providing feedback on S401's solution, PL01 instructed the class: "Now you can try the extra question"

$$\text{Evaluate } I = \int_{C_1} \frac{z}{z^2-1} dz.$$

The PAL participants again worked either in pairs or individually on the above task. While the PAL participants worked, the PL01 and PL02 circulated amongst them and provided hints when necessary. A PAL participant, S402, was then invited to go to the board to present his solution to the rest of the class. His solution is shown in Figure 6.11.

6.5.5 *Complex Variables session: Observation 5*

Vignette 6.5 is based on a PAL session also held in May 2012 just before semester two examinations. Two PAL participants attended the session and it was led by only one PAL leader. This was uncharacteristically a very small group compared to all the other eleven sessions I observed. I included this session because it higlights how the PAL leader's practice could be affected by the number of Participants in attendance. The topic was also claimed to be difficult for most PAL participants I observed. It also shows that students would like to know the application of even abstract mathematical ideas and concepts in order to motivate them to engage with the ideas.

Vignette 6.5

This PAL session was held in the first week of May before the end of the Complex Variables course. Only two PAL participants attended the session, one male and one female and they are referred to as S501 and S502. PL04 led this session alone. PL04 ascertained from the PAL participants the chapter in the lecture notes on which the PAL participants were working in lectures and from the learners' response PL04 decided on Laurent series as the topic for the session. PL04 told the learners: "I have to remind myself what Laurent series is. We will go through the definition first. Then we will go through question 5. Can someone give me a formal definition of Laurent series?" S501 responded: "Is more like Taylor series". PL04 added: "It is analytic at point (0, 0). If it is analytic around a point…., it has been a year since I have done this". PL04 wrote the definition of Laurent series on the board as shown in Appendix R but the discussion stalled, as he was not certain of the definition. PL04 asked the PAL participants if they should continue with the discussion of the definition of Laurent series or work through some examples. S501 and S502 responded in unison: "examples please". PL04 wrote $f(z) = \frac{1}{z+5}$ on the board and asked: "Where will that point be analytic? It has a radius L where L tends to ∞". PL04 directed the learners to page 34 where they could find a result to help them answer the question he posed. The result on page 34 of the lecture notes was:

$$\frac{1}{1-z} = \begin{cases} \displaystyle\sum_{\mathrm{n}=0}^{\infty} z^{\mathrm{n}}, & |z| < 1, \\ \displaystyle -\sum_{\mathrm{n}=1}^{\infty} \frac{1}{z^{\mathrm{n}}}, & |z| > 1. \end{cases}$$

PL04 then wrote on the board $f(z) = \frac{1}{z+5} = \frac{1}{5(1-\frac{-z}{5})} = \frac{1}{5}\left(\frac{1}{1-\left(\frac{-z}{5}\right)}\right)$.

PL04 asked the PAL participants: "What can you say about this, using the same function[14]?" He wrote the following down following a period of silence.

$$f(z) = \begin{cases} \displaystyle\frac{1}{5}\sum_{\mathrm{n}=0}^{\infty} \left(-\frac{z}{5}\right)^{\mathrm{n}}, & |-\frac{z}{5}| < 1, \quad \text{[sic]} \\ \displaystyle -\frac{1}{5}\sum_{\mathrm{n}=1}^{\infty} \frac{1}{\left(-\frac{z}{5}\right)^{\mathrm{n}}}, & |z| > 5. \end{cases}$$

S501 challenged PL04 by asking: "What is the point of doing this?"

[14] That is, using the same function (the result on page 34 of the lecture notes) to find the expansion of $f(z) = \frac{1}{z+5}$.

PL04 replied: "These results are used to get a geometric series of an analytic function". For example, $f(z)=\frac{1}{5}\sum_{n=0}^{\infty}\left(-\frac{z}{5}\right)^{n}=\sum_{n=0}^{\infty}\frac{(-1)^{n}}{5^{n+1}}z^{n}$.

PL04 asked: "Where is this valid?"

S501 replied and wrote on the board: $|z|<5, f(1)=\sum_{n=0}^{\infty}\frac{(-1)^{n}}{5^{n+1}}$

PL04 asked: "What is Laurent series actually used for?" After allowing the PAL participants time to respond, PL04 told them: "You could ask the lecturer. I will say it is on the exam!"

PL04 used "questioning and answering" as facilitation strategy throughout the session. PL04 led from the front and often wrote the PAL participants' responses to his questions on the board. Thus, the session was PAL leader centred rather than PAL participant centred. This approach to facilitating the session is consistent with the PAL session described in Vignette 6.3 which was led by the same PAL leader.

6.5.6 *Complex Variables session: Observation 6*

I included Vignette 6.6 in this thesis because it was one of two sessions in which three PAL leaders facilitated the session. The other session is presented as Vignette 6.3. Of the three PAL leaders who facilitated the session upon which Vignette 6.6 is based, two also facilitated the session described in Vignette 6.3. The third PAL leader in Vignette 6.3 was different from that in Vignette 6.6. Therefore, it is interesting to compare Vignette 6.6 with the data presented in Vignette 6.3 for changes in PAL leader dynamics, if any.

Vignette 6.6

Three PAL leaders ran this session (PL06, PL09, and PL10) and twelve PAL participants attended (S601, S602, S607…S612) the PAL session. The session was held approximately two weeks (end of May 2012) before the end of the Complex Variables course. The topic for this session was series, poles and residues. PL09 announces to the class: “I am going to put a question on the board” and wrote this question on the board.

Obtain the series expansion for $f(z) = \dfrac{1}{z^2 + 4}$,

valid in the region $|z - z_0| > 4$

PL09 reminded the learners of an example on page 41 of the lecture notes that may help them to attempt to answer the question above. After a while, PL06 asked for a volunteer to present the solution to the above question on the board. There was silence in the session. PL06 persisted and posed the question: “Who wants to be brave and come to the board?”

$$f(z) = \frac{1}{z^2 + 4} = \frac{1}{(z - 2\mathrm{i})(z + 2\mathrm{i})}$$

Let $w = z - 2\mathrm{i}$, $\quad \dfrac{1}{w(w + 4\mathrm{i})} = \dfrac{1}{4w(1 - \frac{w}{4\mathrm{i}})}$ [sic]$= \dfrac{1}{4w}\left(-\sum_{\mathrm{n}=1}^{\infty}\left(-\dfrac{4\mathrm{i}}{w}\right)^{\mathrm{n}}\right)$

$$= -\sum_{n=1}^{\infty}\frac{(4\mathrm{i})^{n-1}}{(-1)^n w^{n+1}} = -\sum_{n=1}^{\infty}\frac{(4)^{n-1}}{\mathrm{i}^{n+1} w^{n+1}} =$$

$$= -\sum_{n=1}^{\infty}\frac{(4)^{n-1}}{\mathrm{i}^{n+1}(z - 2\mathrm{i})^{n+1}} = \sum_{n=2}^{\infty}\frac{(4)^{n-2}}{(1)^n (z - 2\mathrm{i})^n}$$

Figure 6.12. A solution to a complex variable problem presented by S602.

S602 volunteered and was cheered on by the other PAL participants. S602 went to the board to present the solution in Figure 6.12. During the presentation, PL06 intervened and drew a picture to represent the given function (see Appendix S for the visual representation of the function). S601 then asked: “When do you have to draw the circle?” PL06 replied: “To make it easier to see what is going on”.

Once again the PAL leaders were observed encouraging PAL participants to take ownership of their own learning by inviting them to the board to present the solutions of their work for evaluation by other PAL participants. The solution presented by S602 in Figure 6.13 had an arithmetical error in the second line, $\frac{1}{w(w+4\mathrm{i})} = \frac{1}{4w\left(1-\frac{w}{4\mathrm{i}}\right)}$ [sic]. Of course, this arithmetical error had an effect on each of the subsequent equations. A possible remedy for this error would have been:

$$\frac{1}{w(w+4\mathrm{i})} = \frac{1}{4w\mathrm{i}\left(1-\left(-\frac{w}{4\mathrm{i}}\right)\right)} = \frac{1}{4w\mathrm{i}\left(1-\frac{w\mathrm{i}}{4}\right)}$$

$$f(z) = \frac{1}{z^2+4} = \frac{1}{(z-2\mathrm{i})(z+2\mathrm{i})}$$

$$\text{Let } w = z - 2\mathrm{i}, \quad = \frac{1}{w(w+4\mathrm{i})} = \frac{1}{4\mathrm{i}w(1-\frac{\mathrm{i}w}{4})}$$

The modified geometric series can be written as

$$\frac{1}{4\mathrm{i}w\left(1-\frac{\mathrm{i}w}{4}\right)} = \begin{cases} \frac{1}{4\mathrm{i}w}\sum_{\mathrm{n}=0}^{\infty}\left(\frac{\mathrm{i}w}{4w}\right)^{\mathrm{n}}, & |w| < 4 \\ -\frac{1}{4\mathrm{i}w}\sum_{\mathrm{n}=1}^{\infty}\frac{1}{\left(\frac{\mathrm{i}w}{4}\right)^{n}} = \frac{1}{4\mathrm{i}w}\sum_{\mathrm{n}=1}^{\infty}\left(\frac{4}{\mathrm{i}w}\right)^{\mathrm{n}}, & |w| > 4 \end{cases}$$

$f(z) = -\sum_{n=1}^{\infty}\frac{4^{n-1}}{(\mathrm{i}w)^{n+1}} = -\sum_{n=2}^{\infty}\frac{4^{n-2}}{(\mathrm{i}w)^{n}}$.

Substituting back in, $w = z - 2\mathrm{i}$, we get the Laurent series valid within the region $|z-2\mathrm{i}|>4$

$$f(z) = -\sum_{n=1}^{\infty}\frac{4^{n-2}}{(\mathrm{i}(z-2\mathrm{i}))^{n}}.$$

Figure 6.13. Correct expansion of the function *f*(*z*)

The PAL participants in Vignette 6.6 focused on solving mathematics problems similar to those set in problem sheets for traditional tutorials. Signposting PAL participants to the *parts of the lecture notes relevant to a mathematics problem* appeared to be used as a *scaffold* to support learners in this session as well as all others sessions I observed.

Remarkably, while eventually the class queried the solution of S602 and asked for a revision, they did not show disrespect to the student but allowed her room to present and maintain the flow of her mathematical argumentation. This allowance of space for the development of the learners' mathematical thought enabled the PAL participants to *trust* their peers and feel comfortable to engage with mathematics. The students in the session were actively engaged in the session. They asked and responded to questions posed by the PAL leaders. Comments from S602, S604, S605 and S606 were all meant to be supportive or provide a dialogue as shown in Appendix R. Following this error, the student did not commit any more errors and her approach would have yielded the correct results. The correct series expansion of $f(z)$ is shown in Figure 6.13.

6.5.7 *Characteristics of PAL sessions advanced mathematics*

As I have indicated in Chapter 1, Vector Spaces and Complex Variables are described as advanced mathematics courses in the context of this thesis. These courses are taken by students who have competed the pre-requisite first-year courses. When students start the study of Vector Spaces and Complex Variables the content and formality of these courses would be unfamiliar to them.

These six Vignettes highlight some characteristics of the PAL sessions at MCU. These characteristics of the PAL sessions may be contrasted with the "ideal" PAL sessions espoused by the International Centre for Supplemental Instructions which I discussed in Section 2.3.3 (see p.39). In Chapter 8, I will discuss the characteristics of the PAL sessions in relation to the ideal sessions but here I note that the characteristics of the PAL sessions are: a) leaders' proclamation of discussion topics at the start of sessions, b) references to specific sessions in lecture notes, c) peer review and feedback on learners' solutions to problems, d) paired and group work, e) regular use of the board by PAL participants not just by the session facilitators, and f) provision of additional examples to those provided by the course leaders, and g) tests and exam paper practice.

As indicated in Vignette 6.1, I observed PAL participants working on non-routine mathematics activity and the main collaborative work was small group work. PAL participants who sat around the same table discussed problems and shared ideas. Again, even though gender differences were not my main focus in this research, it was interesting to observe that in this session – Vignette 6.1 – and others, there were no mixed gender groups working together. In Vignette 6.1, a group of five females sat around one table although there were spaces available on tables with male students. It may well be that these females were friends and wanted to sit together. However, there was not attempt by the PAL leaders to assign individual PAL participants into working groups which would have disrupted the "clinging" together of the same gender of students in the sessions.

A key aspect of the PAL leaders' practice across all the sessions I observed was provision of hints, signposting learners to the relevant pages in lecture notes that related to the problems the learners were solving. These strategies provided scaffolding to learners and helped them make progress. While the PAL participants worked on past exam and test items, the PAL leaders shared their experiences of learning Vector Spaces and sitting exam with some of the PAL participants. In sharing their experiences, the PAL leaders acted as role models, providing reassurance and encouragement to the PAL participants to persevere with their learning of mathematics even when they found some content difficult. Therefore, in this session, at least, the PAL leaders' practices were in *alignment* with what is often described as traditional university mathematics teaching practice: transmission model.

In section 6.6, I further explore the characteristics of PAL sessions for advanced university mathematics through the lens of the CoP theory which was applied to PAL leaders and PAL participants' interviews, and PAL observation fieldnotes. The analysis of the fieldnotes yielded themes that were comparable to those that emerged from the analysis of the interview transcripts (see details in Section 6.6). Codes that were applied to the observation fieldnotes included but were not limited to "informality of sessions", "topics students found difficult and wanted discussed", "interactions between peers", "type of facilitation strategies used by leaders" "mathematical practice", and "representation of mathematics concepts and objects". The codes and themes based on the analysis of the fieldnotes are shown in Appendix Y.

6.6 **Undergraduate mathematics peer learning community**

6.6.1 *About the PAL participants, PAL leaders and the interviews*

In Sections 6.5 I highlighted some of the characteristics of the PAL sessions I observed. The findings presented in Section 6.5 are supplemented by the ways in which the PAL participants and PAL leaders describe the PAL sessions in the transcripts of the interviews I held with them. Like the analysis of the qualitative data collected for the phase one study (see Chapter 5, pp. 126-163), the interview transcripts of PAL participants and PAL leaders (see Section 6.2) were also analysed through the lens of the CoP theory.

Ten PAL participants who were interviewed are referred to as PS01, PS02, … PS10 in the sections below. The only interviewee who did not attend any PAL sessions is referred to as PS11 (see Appendix EE for example of a PAL participant's interview transcript). The PAL participant who attended two sessions and stopped is referred to as PS12. I have not included the interview transcript of PS11 or the email of PS12 in order to preserve their anonymity. Of the twelve PAL leaders referred to as PL01, PL02…PL12, only eight were interviewed. Four PAL leaders were unavailable to be interviewed as they had departmental commitments and these were PL05, PL07, PL09 and PL10 (see Appendix FF for an example of the PAL leader's interview transcript).

Using NVivo 11, I conducted a thematic analysis (Braun & Clarke, 2006) of the interview transcripts of the PAL participants, the single interview with a non-PAL participant, the email correspondence from the PAL participant who stopped attending sessions, and the eight interview transcripts of PAL leaders. During the coding of the textual data, when the PAL participants talked about their interaction with each other in or out of sessions, this was coded as “interaction”. When PAL leaders talked about sharing their experiences of studying or being examined in Vector Spaces or Complex Variables, this was coded as “shared experiences”. When PAL participants or PAL leaders expressed views of themselves in relation to learning Vector Spaces, Complex Variables or mathematics generally, this was coded as “views on learning mathematics”. When PAL participants or PAL leaders compared PAL sessions and traditional tutorials in terms of the learning environment being informal or formal, this was coded as “formality of the learning environment”.

Following the first round of coding, similar codes with different tag names were merged into a single code. Related codes were categorised into themes and named as one of the constructs of the CoP theory I used as a lens in this study. Four themes emerged from the analysis of the interview transcripts and these are: *mutual engagement*, *joint enterprise*, *shared repertoire* and *identity transformation*. The themes and related sub-themes are shown in Tables 6.2 and 6.3. Other categories of related codes which could not be described by a construct of CoP theory and/or did not answer the research questions were also labelled with an appropriately named abstract theme (e.g. *further development of PAL, s*ee Appendices GG-HH for the NVivo Coding Frame and the full set of codes).). In the Sections below, I present and discuss the four themes with quotes as supporting evidence.

6.6.2 *Mutual engagement*

As I have noted previously in Chapter 3, undergraduate mathematics students constitute a CoP. The PAL participants and PAL leaders, being part of the undergraduate mathematics students, have shared identities. Hence, it is not unreasonable to suppose that as a group, PAL participants and PAL leaders also constitute a CoP characterised by mutual engagement, joint enterprise, and shared repertoire. As we have seen previously in Section 6.4, not every student who studied Vector Spaces and/or Complex Variables participated in the peer learning community which is was purposefully created to support students. Therefore, the second-year students who studied Vector Spaces and/or Complex Variables displayed identities of participation and non-participation in the peer learning community.

Table 6.2 Themes Based on Learners' Interview Transcripts and an Email

Themes	**# of references to the themes**	**# of unique learners making references**
MUTUAL ENGAGEMENT[1]		
Engagement with PAL	28	9 (12)[2]
Peer learning community	40	9 (11)
Mathematical practice	88	11 (11)
Role Modelling	21	8 (11)
Total	177	N/A
JOINT ENTERPRISE		
Academic success	11	5 (11)
Other academic reasons	19	8 (11)
Total	30	N/A
SHARED REPERTOIRE		
Formality of tutorial and PAL sessions	19	10 (11)
Small group discussions	12	8 (11)
Peer to peer support	10	6 (11)
Use of co-created resources	3	2 (11)
Views on mathematics	3	2 (11)
Total	45	N/A
IDENTITY TRANSFORMATION		
Deep understanding of maths content	60	9 (11)
Mathematical and personal confidence	26	8 (11)
Personal Development	30	8 (11)
Enjoyment of sessions	11	5 (11)
Total	127	N/A

[1]The high-level headings in capitals are the themes. Below each high-level theme are the related codes.

[2] Numbers in brackets are either numbers of PAL participants (11) only or number of PAL participants and a non-PAL participant (12).

Table 6.2 shows the number of references made to the themes and sub-themes that emerged from the analysis of the PAL participants' and non-PAL participants' interview transcripts. In the same table, the unique numbers of PAL participants and non-PAL participants making references to each theme and sub-theme are also shown.

Table 6.3 Themes Based on the PAL Leaders' Interview Transcripts

Themes	**# of references to themes**	**# of unique PAL leaders' making references**
MUTUAL ENGAGEMENT[1]		
Peer learning community	11	8 (8)[2]
Mathematical practice	49	8 (8)
Brokering	13	8 (8)
Role Modelling	24	8 (8)
Total	97	N/A
SHARED REPERTOIRE		
Formality of tutorial and PAL sessions	15	6 8)
Small group discussions	2	1 8)
Peer to peer support	5	2 (8)
PAL leader handbook	5	5 (8)
Total	27	N/A
IDENTITY TRANSFORMATION		
Deep understanding of mathematics	8	6 (8)
Mathematical and personal confidence	4	4 (8)
Personal Development	24	7 (8)
Enjoyment of leaders' role	11	8 (8)
Total	46	N/A

[1]The high-level headings in capitals are the themes. Below each high-level theme are the related codes.

[2] Numbers in brackets are numbers of PAL leaders (8).

Tables 6.2 and 6.3 show that 177 references were made by the PAL participants and non-PAL participants to the theme "mutual engagement" while the PAL leaders made 97 references to mutual engagement. References to mutual engagement were comments or statements that related to *engagement with PAL sessions, peer learning community, mathematical practice and role modelling, and brokering*. The comments characterise the PAL scheme as a partnership in which students shared in the responsibility of learning and teaching. The comments also characterise the PAL sessions as a learning community in which space was created for students to engage with mathematics in ways that suited the learning style preferences of the majority of the PAL participants.

6.6.2.1 Engagement with PAL

Engagement with PAL entail participation or non-participation with PAL sessions. Some students participated in the PAL sessions which were ran for the two courses, Vector Spaces and Complex Variables. Others did not. About two weeks before the end of each course, 45 out of 85 students who studied Vector Spaces and 85 out of 127 students who studied Complex Variables responded to an independent end of course survey (See Appendix M for a copy of survey instrument). The main results of the survey are reported in Section 7.5. One aim of the survey was to determine the respondents' views about PAL sessions and the extent to which PAL participants were satisfied with the PAL sessions they attended. A copy of the survey instrument is shown in Appendix M.

Open ended comments made by some respondents to the survey suggest that some students did not participate in PAL sessions for reasons including: timetabling restrictions, location of sessions, and other logistical reasons (e.g. not being aware that a PAL scheme existed for the courses).

Table 6.2 shows that 28 references were made by the both PAL participants and non-PAL participants to the sub-theme *Engagement with PAL*. PS11, who did not attend any sessions but volunteered to be interviewed, was asked about his non-participation and he commented:

> *I got the idea that it [PAL] was more of a drop-in rather than ... tutorial-based [sessions]. Well…the idea that I had was completely different to what [PAL] was. So, in that respect, then, I'd say it could have been explained exactly what's going to happen in each one. (PS11, Non-PAL participant interview).*

This comment by PS11 suggests that schemes such as PAL which are aimed at providing additional support to undergraduate mathematics students need to be clearly explained to students so that they know the interplay between the PAL sessions and other course related activities. PS12, who attended two sessions and stopped attending, gave reasons for discontinuing attendance that reflected partly her expectations of a PAL scheme and her perception of the PAL leaders' role. For example, PS12 commented:

> *"I found the tutorials from some lecturers are more useful than the PAL group because the lecturers would teach us how to do the questions together properly and give us time to do so, whereas I went to the PAL group sessions twice the leaders give us some tasks to do with a partner or on your own made it seems like a competition with the others". (PS12, PAL participants' email correspondence)*

The extract above reveals the tension between the novel pedagogy and the enduring transmissive mode of university mathematics pedagogy (William, 2015). Clearly PS12 was unhappy with the two sessions she attended. I will argue that the extract above suggests that PS12 had preference for the traditional transmissive mode of teaching. The staff interviews, discussed in Chapter 5, asked about how they teach and their responses were coded as "pedagogy" (see Appendix V). The majority of the staff reported that they teach in "traditional way". This reflects William's observations, as part of the Transmaths project, of university mathematics teaching. If indeed PS12 preferred the traditional university teaching, then it is plausible to suppose that she would have had an implicitly established didactic contract which could not be honoured in PAL sessions. The reason is that PAL sessions strive to develop a sense of independence in students. This is achieved by PAL leaders who are encouraged to run sessions which aim for participatory and collective action through student discussions, collaboration, and interdependence.

Competition in the PAL sessions, and indeed any class, could potentially motivate some students. The paradox, in this instance, is that the very shared repertoire which was aimed at motivating students within PAL sessions was one aspect of PS12's source of frustration. This evidence suggests that PAL is not a panacea. Most PAL sessions that were attached to Vector Spaces and Complex Variables were well attended. However, there were occasions where sessions had been scheduled in the morning at 9 am and only one participant or a few participants (as in the case of Vignette 6.6) attended.

6.6.2.2 Peer learning community

Tables 6.2 and 6.3 shows that 40 references were made by the PAL participants to the sub-theme *peer learning community* while PAL leaders made 11 references. The PAL participants and PAL leaders belonged to the same Community of Practice which is the “undergraduate mathematics” students generally. The PAL scheme fostered a *learning community* which extended opportunities for learning beyond lectures and tutorials. Within this learning community, the students’ mutual engagement and interactions enabled them to maintain their levels of engagement with mathematical activities. As with any community, the student members of the learning community had practices and customers in which they engaged when dealing solving mathematics problems. Some of these practices are discussed next.

6.6.2.3 Mathematical practices

The practices of this learning community, among other things, included session attendance and interaction with each other Through their interactions in sessions, the PAL participants and PAL leaders engaged in *mathematical practices* the purpose of which was to aid the comprehension of the learning material. Tables 6.2 and 6.3 show that 62 references were made by the PAL participants to the sub-theme *mathematical practices* while PAL leaders made 50 references. Mathematical practices of the peer learning community were wide ranging. The 11 students who participated in PAL sessions as learners reported on mathematical practices that included PAL leaders’ *facilitation strategies, problem solving, board use*, the *scaffold* provided by the PAL leaders when learners were engaged in problem solving, and *peer review and feedback*. For clarity, the frequencies of each of these practices are not shown in either Table 6.1 or 6.2. Rather, they have been summarised below (numbers in brackets are numbers of research subjects who were either PAL participants or PAL leaders):

Theme	**# of references to theme**	**# of distinct PAL participants making references**
MATHEMATICAL PRACTICE		
Facilitation strategies	22	7 (11)
Focus on problem solving practice	8	3 (11)
Use of board for presentations	8	6 (11)
Provision of scaffolding	5	4 (11)
Peer review and feedback	5	3 (11)
Group work and discussions	14	7 (11)
Total	62	N/A

Theme	**# of references to theme**	**# of distinct PAL leaders making references**
MATHEMATICAL PRACTICE		
Facilitation strategies	-	4 (8)
Focus on problem solving practice	2	3 (8)
Use of board for presentations	-	8 (8)
Provision of scaffolding	1	4 (8)
Peer review and feedback	-	3 (8)
Group work and discussions	-	4 (8)
Reflections on facilitation practice	47	8 (8)
Total	50	N/A

The mathematics practices are better illustrated by examples of the narratives of some of the PAL participants. For example, in their narratives of how PAL leaders worked with them, PAL participants described *example generation* by the PAL leaders as a strategy that allows them to have access to more problems on which to practise. Two PAL participants interviewed described the PAL leaders' strategy as follows:

> *They'll make up a question. Say if I didn't understand something, then they'd set it into an easy example and then develop that. (PS01, PAL participant interviews).*

> *They usually […] write a question on the board at the start, get you to do it and then give you a bit of help when you're struggling with it. And then they'll work through it. (PS10, PAL participant interviews)*

These comments also illustrate that example generation was a practice of the PAL leaders. The solutions to these examples which were collectively created by the PAL participants became models for future problems of the same kind. This practice is akin to school mathematics practice which many of the PAL participants would have been familiar. While the kind of mathematics practice described above may be viewed as having contributed to instrumental learning, for some of the PAL participants this practice seemed to build their confidence and enable them to grapple with non-routine problems with less fear.

Another facilitation strategy of the PAL leaders in the learning community was the use of rewards which were given to PAL participants for timely completion of tasks. The use of rewards in sessions was not advocated as part of the PAL implementation strategy. Rather the PAL leaders voluntarily obtained the prizes (e. g. typically confectionaries) and used them as they saw fit in the sessions they held. PS09 comments further on the practices and strategies used by the PAL leaders to facilitate learning in sessions:

> *They normally get particular questions from the problem sheet that they want you to do on the board, and they put ones that aren't on the problem sheet on a different board. They get everybody to work their way through them, and whenever the first person gets it, normally there's a prize for someone during the day. The first person who gets it normally goes and writes it up on the board and they've got to explain what they're doing. That means as well that everybody's competing because they want to come first and because they've then got to explain it, it means that you understand the stuff even more. (PS09, PAL participants' interviews).*

The rewards had the dual effect of fostering competition and motivating most students to participate fully in sessions but as I shall explain in Section 6.7, at least for one student, this caused anxiety. The irony is that PAL aims to engender cooperative and supportive learning environment but it would seem that the use of rewards may have both positive and negative consequences to which staff and student collaborators need to be sensitive.

Much of the PAL leaders' efforts were aimed at empowering the PAL participants to practise mathematics through collaborative working relationships and discussion with peers; students taking responsibility for their own learning. As successful students who had previously taken the two courses, the PAL leaders were better positioned to offer encouragement and sometimes guidance to the PAL participants. Tables 6.2 and 6.3 shows that 21 references were made by the PAL participants to the sub-theme *role modelling* while PAL leaders made 24 references. PAL leaders were *respected* and derived some *authority* from their roles as facilitators. For example, in the narratives of the PAL participants' interview transcripts, the PAL leaders described instances when the PAL leaders shared their learning experiences with them and described how the PAL leaders understood the challenges they were facing because they had previously completed the courses which they facilitated. The following two comments from two PAL participants exemplify the way in which the PAL participants perceived the PAL leaders as role models:

> *I think because they've been through the same problems we've had, they understand where we've gone, but they did really well last year, as well, so we know that we could still do well. There is hope. (PS02, PAL participant)*

> *Yeah. I don't think they've ever done anything that would make them anything other than a good role model. ... if we can talk to them and say, "look, did you do any modules which you really wish you hadn't?" If, last year, someone had said to me, "don't take Numerical Methods because it is so hard," I would have been so happy. (PS06, PAL participant)*

These comments are important in that they demonstrate that learning mathematics is more than a focus on content. It is also about knowing which content one wishes to engage in and why. It would appear from the above comments that the PAL leaders played a role in reassuring students that they will succeed if they engage with the content of the courses even if they are difficult. PS02’s comment on hope suggest the PAL leaders fostered mathematics resilience amongst PAL participants by creating a sense of hope and optimism even when the content of the course became difficult. They also played a role in advising PAL participants to make appropriate selection and combination of optional courses to suit ability and interests. The roles played by the PAL leaders included brokering and this is discussed next.

6.6.2.4 Brokering

As I have previously stated in Chapter 2, PAL was a partnership between PAL participants, PAL leaders, and staff who teach the two courses to which PAL was attached. Tables 6.3 shows that 13 references were made by the PAL leaders to the sub-theme *brokering*. Surprisingly the PAL participants made no references to brokering. However, PAL participants often channelled some of their concerns about the learning and teaching of the courses through the PAL leaders to the course lecturers.

Thus, the PAL leaders did not only facilitate sessions, but also acted as *brokers* between the PAL learning community and the course lectures who are themselves members of the CoP of the academic mathematicians. By doing so, the PAL leaders acted as *change agents* who influenced the practices of staff to some extent. This influence enabled the two course leaders to effect some changes in their teaching practice. For example, during Semester one, the PAL leaders had weekly meetings with the Vector Spaces course leader and these lasted for an hour. At these meetings, the PAL leaders were able to communicate any concerns that PAL participants had with lectures, lecture notes, and assignments. This then enabled the course leaders to address the concern in the next lecture or tutorials.

6.6.3 *Joint enterprise*

Tables 6.2 and 6.3 show that 30 references were made by the PAL participants to the theme joint *enterprise* while PAL leaders made no references to joint enterprise. This difference between PAL participants and PAL leaders was surprising. The joint enterprise of the PAL participants was to learn and understand the courses to which the PAL scheme was attached. Although PAL leaders made no references to the joint enterprise, the PAL leaders implicitly shared in the joint enterprise of the PAL participants and hence that of the PAL learning community. If this were not the case, then one would wonder why the PAL leaders would devote their time to voluntarily facilitate PAL sessions for their peers. The staff, the PAL participants and the PAL leaders all had a stake in the success of the students who were taking Vector Spaces and Complex Variables. In this respect, and as members of the undergraduate mathematics community, the PAL participants and PAL leaders have a common interest which is student success in the Vector Spaces and Complex Variables examination, albeit from different positions and possibly perspectives.

The majority of the PAL participants interviewed chose to attend PAL sessions because they found Vector Spaces and Complex Variables difficult and they believed that attending the PAL sessions would help them understand and improve their grades. Comments made by PS04 and PS06 illustrate some of the range of reasons given by students who participated in the PAL sessions:

> *I didn't understand any of it [Vector Spaces] in lectures. So when I came to the support session, that helped with that, yeah. (PS04, PAL participants interviews)*

> *Well, the series stuff that we're doing−they've definitely helped improve my understanding of that … the series and all the other types of series that we've done in Complex Variables. I was a bit unsure about it when [the lecturer] went through it. I understood it, but it was just trying to remember when you use it, the formula and stuff. Coming in here, they've gone through it on the board, they've written down the formulas on the board and stuff and just said, "this is the ... one and this is this." And you look at it you think that it just straightens [sic] it up in your head. That's definitely helped. (PS06, PAL participants interviews)*

The comments made by PS04 and PS06 above illustrate that they were able to take responsibility for their own learning by engaging with the pedagogical intervention that was offered to enhance students' learning. These comments show that the students had awareness of how much they had learned in the lectures; and how much they understood of the mathematics they were being taught. By choosing to attend the voluntary PAL sessions they were exhibiting help seeking behaviour. Of course, there would be students who choose not to engage with PAL because they are doing well or prefer to study by themselves.

PS10 participated in PAL sessions in the second semester because he failed the Vector Spaces examination and realised that he had difficulty in understanding the course. For him, the motivating factor for participating was to improve his grades.

> *I made the mistake last term with Vector Spaces, I didn't go to them [PAL sessions] and I've got to re-take Vector Spaces this year, so that's why I'm going to [Complex Variables PAL session], mainly. I missed the first. But then, I went after that and since then it's helped me keep up-to-date with the subject so much more than before. (PS10, PAL participants' interviews)*

The comment made by PS10 above also suggests that he also had the metacognitive awareness which enabled him to take responsibility for his learning by engaging with the peer learning community to ensure that he does not fail *Complex Variables*. By engaging with PAL, PS10 also had the opportunity to ask for help with problems related to *Vector Spaces* even though the sessions he attended were focused on *Complex Variables*.

6.6.4 *Shared repertoire*

Table 6.3 shows that 45 references were made by the PAL participants to the theme *shared repertoire* while PAL leaders made 26 references. These references related to artefacts used on their courses and a comparison between PAL sessions and traditional undergraduate mathematics tutorials. The PAL leaders and the PAL participants have a shared history of learning first-year mathematics. They all studied first-year Calculus and Linear Algebra. In their narratives of how PAL helped them learn and understand the mathematics content better, they make comparison of their current learning experiences with their prior learning experiences. For example, S01 commented on a shared experience of learning Linear Algebra (a pre-requisite course for Vector Spaces): "*I liked how they had the 'gappy notes' and everything. I liked how everything was laid out, because it was really easy to revise from it, as well*" These gappy notes were *artefacts* that the PAL participants would have become familiar with on other course units. The Complex Variables lecture notes which were used in PAL sessions had spaces for students' self-completion during lectures or private study. The Vector Spaces lecture notes were not compiled as "gappy notes". This apparent differences between the two sets of lecture notes was often a source of "gossip" in PAL sessions regarding which sets of notes aided the students' understanding.

In their accounts of how the PAL leaders worked with them, the PAL participants talked about their use of the whiteboard as an *artefact* for engaging with mathematics and not as a tool for presentation of information in a monolithic way. The whitebeard was used as a tool for individual students to present their solutions to mathematics problems for peer review and feedback.

> *Yes. They go through it on the board, but also… first they [will] see if another person or group can answer it, because they might know it and we might not. Then they come up to the board and explain it (PS02, PAL participants' interviews)*

The PAL participants who often presented their solutions enjoyed that aspect of their mathematical practice. They were comfortable presenting their work to their peers in the absence of a more powerful authority – *the course lecturer*.

The group of PAL participants and PAL leaders who were interviewed talked about areas of Vector Spaces and Complex Variables that they found challenging which they also believed were often examined. For example, PS02 comments:

> *I think we've just started doing the Gram-Schmidt Procedure or something like that, so that's quite hard right now. (PS02, PAL participants' interviews)*

The shared repertoire of the PAL participants and PAL leaders also included artefacts such as past test papers and past examination papers. By analyzing past test and examination papers, and identifying mathematics problems that had been regularly examined, PAL participants and PAL leaders were able to focus their energy on working and reworking problems until they have achieved success in solving and understanding those problems. This is evidenced by this quote from PS07:

> *We did the Gram-Schmidt Process in Vector Spaces. The lectures were a bit tricky. Obviously, they have their little tips and stuff to help you work through ... We did a lot of work on that and it was on the exam, so it definitely paid off, as well. (PS07, PAL participants' interviews)*

The shared repertoire of the peer learning community also included narratives in their interview transcripts that compared the traditional undergraduate mathematics tutorials with PAL sessions. The PAL participants and the PAL leaders interviewed believed that PAL sessions run differently from traditional tutorials. For example, they suggested that the tutorials are too formal and akin to lectures although one student suggested that the Complex Variables tutorials are perhaps run in a similar way to the PAL sessions. When asked to describe, if any, the similarities and differences between traditional tutorials and the PAL sessions, PS04 and PS03 recounted:

> *It[PAL] just gives a bit more insight into the topics and stuff that we're studying, just because sometimes I feel that in lectures I don't obtain as much information as I would if I discussed it with people. (PS04 PAL participants' interviews,)*

> *".. even in tutorials, you're allowed to obviously discuss the problems, but you've still got that sort of authority figure in a way, so you still sort of feel like you want to dull your conversation down and keep it to whispers and things like that... It's still more to yourself, whereas PAL really encouraged open discussion and I found through discussing the maths, you got a better understanding, because not only were you trying to help yourself, you were helping others. (PS03, PAL participants' interviews)*.

The comments made by PS04 and PS03 suggest that they believed that discussions featured more in the PAL sessions than in tutorials. The PAL sessions provided the participants of this study the opportunity to engage with mathematical practices in a social context where they saw themselves as helping each other to become successful. While some students may see mathematical practice as an individual pursuit, for others, the social context which PAL provides engenders a learning community in which members have responsibility towards each other as PS03 explains above.

PAL sessions encourage group work and discussions both of which are considered active learning strategies in mathematics education. Although students can discuss mathematics problems in traditional tutorials, the presence of the course leader or a graduate teaching assistant – "tutor"– might inhibit the extent to which discussions can be had by some students. Thus, in tutorials, both the lecturer and graduate teaching assistant may be perceived as authority figures. In this study, the PAL participants believed that they were able to work in groups, discuss and reach a common understanding of material being studied due to the small class sizes of the PAL groups. A comment from PS01 supports this argument.

> *Yeah. I think because the groups are smaller, ... you can ask lots more questions. I mean, I ask questions in tutorials, but I think... I guess the peer support just gives you that extra time to be able to go over the things. (PS01, PAL participants' interviews,)*

But how do the PAL participants and PAL leaders see themselves as a consequence of their participation in the PAL sessions? Next, I discuss the identities of PAL participants and PAL leaders and how that might have changed over the two semesters based on their own interpretations of their learning trajectories in the PAL sessions.

6.6.5 *Identity transformation*

In the subsections below, I discuss the qualitative impact of participation in PAL sessions on PAL participants and PAL leaders in terms of identity change – thus the way they view themselves in terms of the learning of mathematics and their personal development. Tables 6.2 and 6.3 show that 127 references were made by the PAL participants to the theme *identity transformation* while PAL leaders made 46 references. These references related to *deep understanding of mathematics, mathematical and personal confidence, personal development* and *enjoyment of learning or role*. The number of references to these sub-themes by PAL participants and PAL leaders are shown Tables 6.2 and 6.3 respectively. The tables also show the unique number of PAL participants and PAL leaders who made the references to the themes.

6.6.5.1 PAL participants' identity transformation

Some of the PAL participants interviewed commented that by attending the PAL sessions attached to their course, they gained increased *mathematical understanding*. PAL participants made 60 references to *mathematical understanding*. The increase in the mathematical understanding of the PAL participants is plausible because by engaging in discussions and explaining concepts to each other, the students would have been able to clarify their mathematical thoughts to their peers, and get erroneous and illogical reasoning in problem solving corrected immediately. It is the immediacy of corrections and progression which enabled the students to solve more problems and gain experience and competence in their mathematical practice. PS03 and PS07 describe the effect of their participation in PAL on them as follows:

> *I found through discussing the maths, you got a better understanding, because not only were you trying to help yourself, you were helping others. (PS03, PAL participants' interviews)*

> *During that session, I developed a greater understanding of how to successfully complete questions of the in-class tests in the past, for example, questions about proving that a certain map was well-defined and linear in the rationales, and questions relating to that map. There were additional questions about how to generate the basis of an infinitely large eigenspace for a given map, for example, which we also went through in the same student leader session. And I became more comfortable with how to approach those problems. And in fact, when a similar, yet slightly different question came up in my exact Vector Spaces in-class test, I felt a lot more equipped to answer it and did in fact get most of the marks on that question. (PS07, PAL participants' interviews).*

When asked about their confidence levels prior to their first PAL session and just before their summer examinations, the majority of the PAL participant interviewees commented that they had gained *increased mathematical and personal confidence* not only with the courses for which they attended PAL sessions but also with mathematics in general. PAL participants made 26 references to confidence. Three comments from PAL participants that related to confidence are:

> *I never used to put my hand up, because I always thought, "maybe I'll be wrong." I used to be scared about that. Yeah. And then even presenting ideas on the board, as well. I'm not so shy as to doing that anymore. (PS04, PAL participants' interviews)*

> *I feel more confident talking to people and ... explaining my thought process. (PS05, PAL participants' interviews)*

> *I think it's [PAL sessions] made me more confident in terms of my maths, because obviously they give the incentive to go up and write on the board. A lot of the time, people have the answers written down in the tutorial and the lecturer will ask someone for the answer and everyone else stays back. But when the third years[PAL leaders] are asking and they've got sweets as well, everyone's keen to give their answers and they're not scared. They're not scared to be wrong, either, because no one is judging anyone and that sort of stuff. We all know each other. We're all friends, so it's good and it just sort of makes you more sure of your answers. (PS07, PAL participants' interviews)*

Although the majority of the PAL participants reported on their increased *mathematical and personal confidence*, for PS12, her negative perceptions of the competition in the PAL sessions impacted negatively on her confidence such that she had to cease attending further PAL sessions.

When the PAL scheme was set up the goal was clearly to enhance the student learning experience in relation to mathematics and to increase student achievement in the two courses. However, the data suggest that the outcomes of participation in PAL sessions is much broader than achievement. Reflecting on their non-mathematical related learning, most PAL participants interviewed described developing skills including improved communication and problem solving. For example, PS04 commented:

> *[I have gained] analytical skills, probably. I'd be able to analyse problems and solve problems from different angles, apart from just looking at the obvious. It might be a difficult way, so probably just looking at it from all possible aspects and finding an easier solution, really. (PS04, PAL participants' interviews)*

The non-mathematics skills developed by the interviewees contributed to their *personal development* (interns made 30 references to personal development) and their developing *graduate attributes* and therefore the transformation of their identity as future graduates. Of course, these generic skills may be developed through collaborative learning situations in other academic disciplines, and are not unique to mathematics. However, there is an increasing call for mathematics students to develop attributes which are additional to the mathematical competency which degree programmes aim to develop. PAL sessions provide opportunities for the development of these attributes as learning outcomes in addition to acquisition of mathematics knowledge.

Some of the interviewees reported on *social gain* in terms of meeting other students that they would have otherwise not met. For example, PS03 commented that:

> *I've met another couple of people that were not initially in the sort of friendship group that you get from the halls and just bumping into people. So, I met a few more people from that. So, that was another benefit from actually attending. (PS03, PAL participants' interviews)*

For some groups of students, such social gain may be the catalyst for their engagement with mathematics and hence their learning, achievement and progression. The social gain by PAL participants is possible because PAL sessions foster regular peer-to-peer interactions during the semester in which the sessions are run. The social gain arising from networking within the learning community may be viewed in terms of the development of interpersonal skills and communication which solitary learning of mathematics may not necessarily yield.

Some PAL participants continued to participate in PAL sessions because they *enjoyed* their interactions and relationships with the PAL leaders. Eleven references were made by PAL participants to *enjoyment*. For example, PS05's commented:

> *I enjoy having a chat with them [PAL leaders], mostly related to work whenever we're there. (PS05, PAL participants' interviews)*

This aspect of social interaction in the learning process may be overlooked in formal settings such as tutorials or lectures. The comments made by PS05 suggest how much he valued both the focus of PAL on mathematics learning content and social relations that may develop in the sessions.

The increased mathematical understanding, mathematical and personal confidence, enjoyment of learning, and personal development reported by the PAL participants are all indicative of their changing identities of the PAL participants within the learning communities of which they were part. However, identity change was not limited to the PAL learners. The outcomes of participation in PAL sessions are not limited to the PAL participants. The PAL leaders also derived some benefits from their roles. I now discuss the qualitative impact of participation in PAL sessions for the PAL leaders as reported by them during their interviews.

6.6.5.2 PAL leaders' identity transformation

The findings from the analysis of the PAL leaders' interview transcripts also showed that their narratives included accounts of change in the way they viewed themselves in relation to their study of mathematics. For example, the PAL leaders had to review course content, plan and prepare for the sessions they facilitated. Most of the PAL leaders interviewed reported that the review of the course content and the process involved in facilitating PAL sessions enabled them to gain a *deep understanding* of the course content. Eight references were made by PAL leaders to *understanding mathematics*. Some PAL leaders reported direct impact of their role on their third-year study. For those PAL leaders who studied a third-year Complex Analysis course – a follow up course to Complex Variables – the increase in their understanding was apparent to them when they attended lectures or engaged with Complex Analysis problems. For example, three PAL leaders commented:

> *There has been quite a few times, when I haven't understood what's been going on in Applied Complex Analysis. It's [PAL] sort of reinforced the foundation, really, of the module [Applied Complex Analysis]. I do think, anyway, that it did sort of bolster my understanding of the various concepts. (PL01, PAL leaders' interviews)*

> *… there are things that I didn't understand, and Applied Complex Analysis is just a carry-on of the Complex Variables, I got to learn a lot more which I didn't understand earlier. Even with the Vector Spaces. I'm not doing any module related to it, but still I learned a lot more, which I didn't in my second year, so it did help me a lot, yes. (PL11, PAL leaders' interviews)*

> *I am doing Applied Complex Analysis. Because I am [facilitating Complex Variables PAL sessions] … there are a lot of things which I didn't understand in the second year that I understand now. So, I'm learning in the process, as well. It's not just them [PAL participants]. I have gained a lot as well. (PL12, PAL leaders' interviews)*

These comments are important because they indicate that PAL leaders may develop increased understanding of their current course of study if the current course is related to a course that the PAL leader facilitates. In the current research, Complex Variables and Complex Analysis are related as the former is a pre-requisite for the latter. Some PAL leaders of the current study also studied Complex Analysis. Hence, as PAL leaders reviewed their notes for Complex Variables PAL sessions, their increased knowledge and understanding would be expected to prove useful for their comprehension of Complex Analysis.

The PAL leaders interviewed also reported on their increased *mathematical and personal confidence* which they attributed to their role in facilitating PAL sessions. Four references were made by the PAL leaders to mathematical and personal confidence. For example, PL11 reported that:

> *I think I'm a lot more confident now. It's just because - obviously - I get to interact with the students, which I wouldn't have done. And I want to be a teacher in the future, so it's just baby [sic] steps towards it. (PL11, PAL leaders' interviews)*

The above comment reveals that the mutual engagement of the PAL leaders and PAL participants through regular interactions was an antecedent of the increased confidence of the PAL leaders of this study.

Table 6.3 also shows that PAL leaders made 24 references to their personal development which they attributed to their role in facilitating PAL sessions. Comments on personal development related to improved study habits, time management, communication and interpersonal skills. For example, PL03 and PL08 commented that:

> *I think it's made me a lot more organised. So, when it comes to the time to do the dissertation and I've got deadlines and things like that to do, I'll be a lot more on top of it than I might have been beforehand. But also, actually studying and just being able to go through problems, it's been a big help. (PL03, PAL leaders' interviews)*

> *I think it has made me kind of a better student, actually, because I'm more likely now than I was last year to do extra work outside. I guess because I've seen the benefit for the second years, I'm trying to work things out and not just waiting until the exam and freaking out when you don't know everything. This year, I've put in a lot more work. I'm not spending every hour of the day doing maths. But if something is covered in a lecture and I don't know what they're talking about, I'm much more likely now to go, "Ok, let's sort that out now," rather than just sort of going, "Well, you can't always understand everything." And I hope that will carry on into next year, because that would be good. (PL08, PAL leaders' interviews)*

Again, these non-disciplinary specific outcomes had been attributed by the PAL leaders to their participation in the PAL sessions. In comparison to other disciplines where teaching and assessment often lend themselves easily to more flexible and non-traditional pedagogies, mathematics courses such as Vector Spaces and Complex Variables may not always create the space for the development of soft skills required of graduates for the real world of work.

During the interviews, when the PAL leaders were asked to describe how their role has impacted on them, the majority of PAL leaders cited *enjoyment* of their role as an outcome for them. Eleven PAL leaders made references to enjoyment. Table 6.3 shows that 11 references were made by PAL leaders to their enjoyment of their role as PAL session facilitators. Three comments relating to the PAL leaders' enjoyment are:

> *I've really enjoyed it [being a leader]. I think it's really allowed me to develop, within both maths and as a person. I think it's been really useful, and I think the atmosphere has been quite laidback, so that it hasn't been too much pressure and we can put in as much work as we want to. And the students have been great, so I think it's been really useful. Yeah, I've really enjoyed. (PL02, PAL leaders' interviews)*

> *I would say it was pretty enjoyable. And it's also got the benefits of giving and teaching you skills that will be useful later on. But also, it's just quite enjoyable just to help the second years, help them understand maths, to make their lives a little bit easier. (PL03, PAL leaders' interviews)*

> *It is nice to do something with other year groups because we don't get the chance to interact with them really. I think it would have been nice to have a relationship with third years when I was in second. Yeah it has been really enjoyable. (PL06, PAL leaders' interviews)*

For many of the PAL leaders, there was an opportunity to facilitate sessions for Vector Spaces and Complex Variables in semesters one and two respectively. The majority chose to continue their roles in the second semester because they had enjoyed their role in the first semester.

The evidence presented thus far indicates that PAL sessions offer an opportunity for undergraduate mathematics students to participate in a learning community as PAL leaders or PAL participants and to develop important graduate attributes while at the same time they grapple with the epistemological and ontological demands of undergraduate mathematics.

6.7 Summary

In Section 6.3 of this chapter, I presented evidence of undergraduate mathematics students' expectations of a PLS scheme. I also described the implementation process of the PAL scheme for undergraduate mathematics. The PAL scheme which was implemented for Vector Spaces and Complex Variables met most of the expectations of the cohort for whom the scheme was set up. In Section 6.4, I presented evidence that shows the extent of student participation in the PAL scheme in terms of attendance. The findings indicate that more than half of students enrolled on each of the two courses attended one or more PAL sessions. In Section 6.5, the Vignettes presented also show the nature and characteristics of the PAL sessions and of the mathematics with which the PAL participants engaged.

In Section 6.6, further evidence was presented to show the nature and characteristics of the PAL sessions and their qualitative impact on the PAL participants and PAL leaders. The evidence presented also showed that the PAL sessions were characterised by a learning community in which all participants mutually engaged, shared in a joint enterprise which was academic success. The evolved learning community had a shared history. Over time this shared history had led to the development of a shared repertoire consisting of ways of working and doing mathematics. This shared history has also led to the development of community knowledge of the type of teaching practices that enhanced or hindered participants' engagement *in* and learning *of* mathematics. The evidence shows that the PAL sessions at MCU were characterised by: a) focus on problem solving examples, b) discussions of printed lecture "gappy", notes, c) hints and signposting to specific sessions in lecture notes, d) peer review and feedback on participants' solutions to problems, d) paired and group work, e) regular use of the board by PAL participants not just PAL leaders, and f) co-creation of additional examples to those provided by the staff, and g) past tests and exam paper practice.

A key aspect of the PAL leaders' practice was the deployment of strategies that provided scaffolding to learners when they attempted to solve problems. This enabled the PAL participants to make progress with confidence. The PAL leaders shared their learning experiences with the PAL participants. In sharing their experiences, they mentored and acted as role models for the PAL participants.

The PAL leaders' practice in sessions could be described as PAL leader centred although PAL participants often engaged in active learning practices. Occasionally, when discussing topics such as theorems in Vector Spaces or Complex Variables, the PAL leaders' practice was in *alignment* with what is often described as traditional university mathematics pedagogy: transmission model.

In Section 6.6, I presented evidence to show that participation in PAL sessions also transforms the identity of PAL participants and PAL leaders in terms of their mathematical understanding, their mathematical and personal confidence, personal development and enjoyment of the additional mathematics learning opportunity. While the focus of this chapter has been on the qualitative impact of participation in PAL sessions on PAL participants and PAL leaders, in Chapter 7, I will present the results of the quantitative impact of PAL attendance on PAL participants (i.e. learners) in terms of their achievement *in* the two redesigned courses. I will also present the results of PAL participants satisfaction with PAL sessions, and the students' satisfaction with the redesigned courses generally.

CHAPTER 7 IMPACT OF PAL AND THE REDESIGNED COURSES ON STUDENT ACHIEVEMENT

> *Students participating in SI within the targeted high risk courses earn higher final course grades than students who do not participate in SI. This is still true when differences are analysed, despite ethnicity and prior academic achievement. (Martin & Arendale, 1994, p. 3)*

7.1 Introduction

The chapter focuses on the phase three study which investigated the *quantitative impact* (see definition in Section 1.6, p.15) of PAL attendance on PAL participants. The findings are reported within the context of the staff-student partnership in course design and delivery where students played active roles as partners and change agents in learning and teaching. The main findings are presented in four sections.

First, in section 7.2, I present analysis of demographic data that provides further evidence of *student participation* in the PAL programme. Second, in Section 7.3, I present results on the impact of PAL attendance on student achievement in Vector Spaces. Third, in Section 7.4, I present the results on the impact of PAL attendance on student achievement in Complex Variables. Fourth, in Section 7.5, I also present the results of an end of course feedback and survey of students' perceptions of the redesigned Vector Spaces course and its related PAL sessions. In the same section, I also present the results of an end of course feedback and survey of students' perceptions of the redesigned Complex Variables course and its related PAL sessions. Finally, I summarise the Chapter in Section 7.6.

7.2 Comments of PAL participation in relation to demographic data

Eighty-three students enrolled to study Vector Spaces during the first semester of the 2011/2012 academic year. These 83 students were the first cohort of second-year undergraduate mathematicians to be provided with the opportunity to take part in PAL sessions at Middle County University (MCU). Fifty-seven students participated in PAL sessions at least once. However, two students did not sit the Vector Spaces end of course examination. Hence, they were removed from the quantitative analysis which is reported in this chapter. Table 7.1 shows the demographic data of the remaining 81 students who studied Vector Spaces. The majority of the students who studied Vector Spaces were males (70%); were UK based (85%); and were studying for a single honours degree in Mathematics (79%).

Table 7.1 Demographic Data on Vector Spaces Students

Variables and Levels	Frequency	Percent
Gender		
Females	24	30
Males	57	70
Total	81	100
Student status		
International Students	12	15
UK Based Students	69	85
Total	81	100
Degree Programme of Study		
Single Honours Mathematics Degree	64	79
Joint Honours Mathematics Degree	17	21
Total	81	100
PAL Participation		
PAL Participants	55	68
Non-PAL Participants	26	32
Total	81	100

Of the 81 students, 26 chose not to participate in any of the PAL sessions. This was nearly a third of the known registered Vector Spaces students included in this study.
I explored whether there was any association between PAL participation and: (a) gender; (b) student status as international or UK based. A student is considered to have participated in PAL sessions if the student attended one or more sessions.

Table 7.2 PAL Participation and Gender: Vector Spaces

		Gender	
Variables	*N*	Females	Male
PAL participants	55	19 (16.3)	36 (38.7)
Non-PAL participants	26	5 (7.7)	21(18.3)
Totals	81	24	57

Numbers in brackets are the expected counts as opposed to observed counts.

Table 7.3 PAL Participation and Student Status: Vector Spaces

		Students' Status	
PAL Participation	*N*	International	UK based
PAL participants	55	2 (8.1)	53 (46.9)
Non-PAL Participants	26	10 (3.9)	16 (22.1)
Totals	81	12	69

Numbers in brackets are the expected counts as opposed to observed counts.

Table 7.2 shows the cross tabulation of the observed frequencies of PAL participation and gender. Numbers in brackets are expected frequencies. A chi square test showed that there was no statistically significant association between PAL participation and gender (χ^2 =1.986, N=81, p =.159). This suggests that there was no evidence that both males and females differed in their proportions in terms of their participation levels in PAL sessions.

Similarly, Table 7.3 shows the cross tabulation of the observed frequencies of *PAL participation* and *student status* as an international student or a UK based student. Numbers in bracket are the expected frequencies. One of the four cells in the cross tabulation had an expected count of less than 5.

Hence the Fisher Exact test rather than the Pearson chi-square test was used to test for the association between PAL participation and student status. The Fisher Exact test showed evidence of association between PAL participation and nationality status (p<.001, Fisher Exact test). Thus, UK students and international students have different levels of participation in PAL sessions with a higher proportion of UK based students attending PAL sessions.

Table 7.4 Demographic Data on Complex Variables Students

Variables and Levels	Frequency	Percent
Gender		
Females	41	34
Males	81	66
Total	122	100
Student status		
International Students	14	11
UK Based Students	108	89
Total	122	100
Degree Programme of Study		
Single Honours Mathematics Degree	91	75
Joint Honours Mathematics Degree	31	25
Total	122	100
PAL Participation		
PAL Participants	61	50
Non-PAL Participants	61	50
Total	122	100

One hundred and twenty-seven students enrolled to study Complex Variables. Of the 127 students, 62 participated in PAL sessions at least once and 65 did not participate in any PAL sessions. One student withdrew from the course and hence did not sit the end of course examination. Two other students did not sit the Complex Variables examination and there were no recorded reasons for their absence from the examination and were assumed to have withdrawn. Two Erasmus exchange programme students for whom there were no comparable prior attainment data available were also excluded. These five students were also removed from the quantitative analysis leaving a sample size of 122 students. Of the five students, only one participated in PAL sessions.

The demographic characteristics of the sample of Complex Variables students are shown in Table 7.4. Again, the majority of these 122 students (66%) were males; were UK based (89%); and studied for a single honours degree in mathematics (75%). Of the 122 students who studied the Complex Variables course, 50% chose not to participate in PAL sessions.

Table 7.5 PAL Participation and Gender: Complex Variables

		Gender	
Variables	*N*	Females	Males
PAL participants	61	26 (20.5)	35 (40.5)
Non-PAL participant	61	15 (20.5)	46 (40.5)
Totals	122	41	81

Numbers in brackets are the expected counts as opposed to observed counts.

Again, in relation to the Complex Variables course, I explored whether there was any association between PAL participation and: (a) gender; (b) nationality. Table 7.5 shows the crosstabulation of the observed frequencies of PAL participation and gender. Numbers in brackets are expected frequencies. Pearson chi square test showed that there was a statistically significant association between PAL participation and gender, χ^2 (1, 122) =4.445, p=.035. The test shows that male and female students who studied Complex Variables had different levels of participation in PAL sessions. The proportion of female students who attended PAL sessions was higher than male students.

Similarly, Table 7.6 shows the crosstabulation of the observed frequencies of PAL participation and students' status as international student or UK based. Numbers in brackets are expected frequencies. Pearson chi square test was used to test for the association between PAL participation and students' status. The test showed a statistically significant association between PAL participation and student status, χ^2 (1, 122) =14.55, p<.001.

Table 7.6 PAL Participation and Nationality: Complex Variables

		Students' Status	
Variables	*N*	International	UK Based
PAL participants	61	0 (7)	61(54)
Non-PAL participant	61	14 (7)	47(54)
Totals	122	14	108

Numbers in brackets are the expected counts as opposed to observed count.

Thus, in the case of Complex Variables PAL sessions, international students are less likely to participate in PAL sessions compared to UK based students. Of the 122 enrolled students, none of the 14 international students participated in Complex Variables PAL sessions while 56% of the UK based students (108) attended PAL sessions. This is not surprising given the small numbers of international students who took Complex Variables.

7.3 PAL impact on achievement in the Vector Spaces course

7.3.1 *Analysis of Vector Spaces achievement data*

I explored the relationship between PAL attendance and achievement in Vector Spaces by accounting for student lecture attendance and prior achievement (in Linear Algebra, a pre-requisite course). Table 7.7 shows the descriptive statistics of PAL attendance, lecture attendance, prior attainment (in Linear Algebra achievement), and overall Vector Spaces course marks. An independent *t*-test of the overall Vector Spaces course marks showed a statistically significant higher mean mark for PAL participants (*M*=62.71, *SD*=16.9) than for non-PAL participants (*M*=44.88, *SD*=15.7), *t* (81) =4.527, *p* <.001, d=1.08. This effect size is large according to Cohen's (1977) criterion.

Table 7.7 Descriptive Statistics of Vector Spaces Data (*N*=81)

	Minimum	Maximum	Mean	SD
PAL Attendance	0	9	3.77	3.4
VS Lecture Attendance	0	6	4.11	1.9
Linear Algebra Marks	40.0	96.0	65.20	14.1
Vector Spaces Course Marks	12	97	56.99	18.5

The pre-requisite course for Vector Spaces is Linear Algebra. An independent *t*-test of the first-year examination marks obtained in Linear Algebra by the 81 students who studied the collaboratively designed Vector Spaces course showed significant difference in the prior achievement of PAL participants and non-PAL participants. The *t*-test showed that the Linear Algebra marks were higher for PAL participants (*M*=68.3, *SD*=13.84) than for non-PAL participants (*M*=58.6, *SD*=12.54), *t*(81)=3.024, *p*=.003, d=0.71. This difference in prior attainment means that it may well be that the PAL participants are already more able. Hence any difference found in the Vector Spaces achievement needs to account for this prior attainment. Similarly, a *t*-test showed that Vector Spaces lecture attendance was higher for PAL participants (*M*=4.6, *SD*=1.67) than for non-PAL participants (*M*=2.77, *SD*=1.84), *t*(81)=5.080, *p*<.001, d=0.71. Again, this evidence also provides a justification for the need to account for lecture attendance in the investigation into the correlation between PAL participation and Vector Spaces achievement.

The overall Vector Spaces course marks are classified into grades by the mathematics department at Middle County University as shown in Table 7.8. Successful students are defined as those who obtained grades A, B, C, or D for the purposes of this research. Table 7.9 shows the crosstabulation of the observed frequencies of PAL participation and success in the Vector Spaces examination. Numbers in brackets are expected frequencies.

Table 7.8 Grade Structure at MCU

Grade	Course Marks
A	70% – 100%
B	60% – 69%
C	50% – 59%
D	40% – 49%
E	30% – 39%
F	Below 29%

Table 7.9 PAL Participation and Success in Vector Spaces Exam

		Success in Vector Spaces Exam	
Variables	*N*	Successful students	Unsuccessful students
PAL participants	55	53 (48.2)	2 (6.8)
Non-PAL participants	26	18 (22.8)	8 (3.2)
Totals	81	71	10

Numbers in brackets are the expected counts as opposed to observed count.

As one cell had an expected count of less than 5, the Fisher Exact test with p=0.001 was used and this indicates a statistically significant association between PAL participation and success in Vector Spaces examination. Thus, PAL participants are more likely to obtain grades A, B, C, and D than non-PAL participants. This analysis does not take into account students' prior attainment as measured by their achievement in Linear Algebra nor does it take into account the measure of motivation. Hence, a correlational analysis of PAL attendance, lecture attendance, prior attainment (Linear Algebra marks), and Vector Spaces course marks was conducted to explore the relationship between these variables further.

7.3.2 *Correlational analysis of attendance and achievement data*

The zero order Pearson correlations between the four Vector Spaces variables are shown in Table 7.10. There was a statistically significant correlation between PAL attendance and Vector Spaces course marks, $r = .496$, $p < .001$. However, as expected, there was also a statistically significant correlation between Linear Algebra marks and Vector Spaces course marks, $r = .622$, $p < .001$; between Vector Spaces lecture attendance and Vector Spaces course marks, $r = .435$, $p < .001$. This suggested a need for partial correlational analysis between PAL attendance and Vector Spaces course marks, controlling for Linear Algebra marks and Vector Spaces lecture attendance.

Table 7.10 Correlations of Vector Spaces Attendance and Achievement Variables

	1	2	3	4
(1) PAL Attendance	-	.561**	.496**	.321**
(2) VS Lecture Attendance		-	.435**	.228*
(3) Vector Spaces Marks			-	.622**
(4) Linear Algebra Marks				-

VS=Vector Spaces, *$p < .01$, **$p <.001$.

The results of the analysis showed a statistically significant positive partial correlation relationship, $pr = .250$, $p = .027$, between Vector Spaces course marks and PAL attendance. In other words, if two students had attended the same number of lectures, and had started the course with identical prior achievement in Linear Algebra, then the student with the higher PAL attendance would typically achieve a higher end of year course mark in Vector Spaces.

7.3.3 *A regression model of Vector Spaces achievement*

A multiple linear regression was conducted to investigate a model for predicting Vector Spaces achievement in terms of course marks from *PAL attendance, Vector Spaces lecture attendance*, and *Linear Algebra course marks* as dependent variables. The results of the coefficients of the independent variables, *B*, and the constant term are shown in Table 7.11 and the model was found to be statistically significant, $F(3, 77)= 26.726$, $p<0.001$.

Table 7.11 A Model Predicting Vector Spaces Marks (N=81)

Variable	*B*	*SE*	β	*t*	*p*
PAL Attendance	1.187	.525	.225	2.262	.027
Lecture Attendance	1.911	.952	.194	2.007	.048
Linear Algebra Marks	.661	.110	.506	5.992	.000
Constant	1.553	7.396		.210	.834

Note: R^2 = .51; F(3, 77)=26.726, p < .001

The coefficients of all three independent variables, *B*, were significant, suggesting that the three variables predict Vector Spaces achievement. The adjusted R^2 value was .491. This indicates that 49% of the variance in Vector Spaces achievement was explained by the model. The coefficient associated with PAL attendance was B =1.187. This means that an increase in PAL attendance by one session was associated with approximately 1.2% extra in the final Vector Spaces course marks. The PAL scheme was voluntary; hence there was no random assignment of students to groups of PAL participants and non-PAL participants. Hence, it is not possible to claim causation between PAL participation and Vector Spaces achievement. However, if there were such causation, then the regression coefficient of PAL attendance would suggest that a student who attends all nine Vector Spaces PAL sessions will gain over 10% in their final course marks.

7.4 **PAL impact on achievement in Complex Variables course**

7.4.1 *Analysis of Complex Variables achievement data*

Attainment data for Complex Variables were analysed in the same way as for Vector Spaces. Student prior achievement was measured by their first-year achievement in the pre-requisite courses for Complex Variables. The pre-requisite courses for Complex Variables were: *Calculus* and *Geometry, Vectors, & Complex Numbers (GVCN)*. PAL attendance, Complex Variables lecture attendance, and Complex Variables course marks were also collected.

Table 7.12 shows the descriptive statistics of the Complex Variables PAL attendance, lecture attendance, Complex Variables course marks, GVCN course marks, and Calculus course marks.

Table 7.12 Descriptive Statistics of Studying Complex Variables Data (*N*=122)

	Minimum	Maximum	Mean	SD
PAL attendance	0	11	2.67	3.5
Lecture attendance	0	6	3.95	1.7
Complex Variables marks	2	99	72.20	20.2
GVCN marks*	25	97	66.19	13.4
Calculus marks	30	96	62.93	13.6

*GVCN=Geometry, Vectors, and Complex Numbers

An independent *t*-test showed a higher Complex Variables mean course mark for PAL participants (M=80.07, SD=15.17) than for non-PAL participants (M=64.34, SD=21.60), t (107,61) = 4.652, p <.001, d=0.84. Similarly, an independent *t*-test showed a higher Calculus mean marks for PAL participants (M=66.31, SD=13.90) than for non-PAL participants (M=59.56, SD=12.58), $t(120)$=2.814, p=.006, d=0.51. A similar test also showed that the mean GVCN marks were higher for PAL participants (M=68.70, SD=13.97) than for non-PAL participants (M=63.67, SD=12.34), $t(120)$=-2.109, p=.037, d=0.38. An independent *t*-test also showed that Complex Variables lecture attendance was higher for PAL participants (M=4.72, SD=1.42) than for non-PAL participants (M=3.18, SD=1.72), $t(120)$= 5.407, p <.001, d=0.98.

In light of the above differences, a partial correlational analysis between PAL attendance and Complex Variables course marks that controlled for Calculus marks and Complex Variables lecture attendance was conducted. As we shall see in section 7.4.2, Calculus Marks and GVCN marks are highly correlated while Calculus is more highly correlated with Complex Variables course marks. Hence Calculus marks variable was controlled for in the partial correlation analysis instead of GVCN marks or both Calculus and GVCN marks. As with Vector Spaces, Complex Variables course marks are also classified into grades A, B, C, D, E, and F using similar grade boundaries as for Vector Spaces. Table 7.13 is a crosstabulation showing the observed frequencies of PAL participation and success in the Complex Variables examination. Numbers in brackets are expected frequencies.

Table 7.13 PAL Participation and Complex Variables Exam Success.

PAL participation	*N*	Exam Success	
		Successful students	Unsuccessful students
PAL participants	61	61(57.5)	0 (3.5)
Non-PAL participants	61	54 (57.5)	7 (3.5)
Totals	122	115	7

Numbers in brackets are the expected counts as opposed to observed frequencies

As two cells had an expected count of less than 5, the Fisher Exact test was used to test for association between PAL participation and Complex Variables exam success instead of the Pearson chi-square test. The Fisher Exact test showed a statistically significant association between PAL participation and success in Complex Variables p=0.013. Thus, PAL participants are more likely to obtain grades A, B, C, and D than non-PAL participants. A correlational analysis of PAL attendance, lecture attendance, prior attainment (Calculus and GVCN marks), and Complex Variables overall course marks was conducted to explore the relationship between these variables.

7.4.2 *Correlational analysis of attendance and achievement data*

The zero order Pearson correlations between the five variables are shown in Table 7.14. There was a statistically significant positive correlation between PAL attendance and Complex Variables course marks, $r = .381$, $p < .001$. There was also a statistically significant positive correlation between Complex Variables course marks and: (a) Calculus course marks, $r = .541$, $p < .001$, (b) GVCN course marks, $r = .516$, $p < .001$; (c) Complex Variables lecture attendance $r = .403$, $p < .001$. Since Calculus is more highly correlated with Complex Variables marks than GVCN, it was used as measure of prior attainment.

Table 7.14 Correlations of Complex Variables Attendance and Achievement Variables

Variables	1	2	3	4	5
1). PAL Attendance	-	.408**	.381**	.272**	.220*
2). Lecture Attendance		-	.403**	.287**	.234**
3). Complex Variables			-	.541**	.516**
4). Calculus marks				-	.660**
5). GVCN+ marks					-

+Geometry, Vectors, and Complex Numbers, **p* < .01, ***p* <.001

A partial correlational analysis between PAL attendance and Complex Variables course marks, accounting for Calculus achievement and Complex Variables lecture attendance was also conducted. As I noted in section 7.4.1, Calculus was controlled for (instead of GVCN) because it was more highly correlated with Complex Variables course marks than GVCN. The results of the analysis showed a statistically significant positive relationship, pr = .200, p = .028. Thus, given two students with the same number of Complex Variables lecture attendance and Calculus marks, the student with the higher PAL attendance will typically achieve higher overall course marks in Complex Variables than the student with a lower PAL attendance. A linear regression model based on the Complex Variables data was generated and the results are discussed in section 7.4.3.

7.4.3 *A regression model of Complex Variables achievement*

A multiple linear regression model for predicting Complex Variables course marks from PAL attendance, Complex Variables lecture attendance, and Calculus marks was statistically significant $F(3, 118)=24.665$, $p<.001$. Table 7.15 shows the results of the coefficients of the independent variables, *B*, and the constant term.

Table 7.15 A Model Predicting Complex Variables Marks (*N*=122)

Variable	*B*	*SE*	β	*t*	*p*
PAL Attendance	1.031	.464	.179	2.223	.028
Lecture Attendance	2.379	.932	.206	2.552	.012
Calculus Marks	.642	.113	.433	5.662	.000
Constant	19.647	7.157		2.745	.007

Note: R^2 = .51; F(3, 118)=26.665, p < .001

The adjusted R^2 was .37. This indicates that 37% of the variance in Complex Variables achievement was explained by the model. The coefficient associated with PAL attendance, B=1.031, suggests that an increase in PAL attendance by one session was associated with 1% increase in Complex Variables marks. Again, although it is not possible to claim causation between PAL attendance and Complex Variables course marks, if such causation were to exist this would suggest that a student who would have obtained a mark of 39% may well pass with a pass mark of 40% if he/she participated in PAL sessions.

7.5 Student perceptions of the redesigned courses and PAL sessions

About two weeks before the end of each course (i.e. Vector Spaces and Complex Variables), I collected an independent end of course feedback using a cross-sectional survey (Cohen, Manion, & Morrison, 2007). The survey had two aims. The first was to explore the perception of students registered on the two courses about the redesigned courses and their overall satisfaction with their learning experience. The second aim was to determine the extent to which the PAL participants were satisfied with the PAL sessions they attended. A copy of the survey instrument is shown in Appendix M.

The redesigned courses were offered to a new cohort of students in the academic year 2011/2012. The Vector Spaces course was taught in semester one, October 2011 – February 2012. At the end of November 2011, all registered Vector Spaces students were surveyed. Forty-five (out of a total of 83 registered Vector Spaces) students completed the questionnaire. Thus, the response rate was 54%. Students were asked to indicate their agreement or disagreement with 15 statements drawn from the bank of National Student Survey (NSS) questions. The percentage of students who responded to each of the 15 statements (see the Appendix S) are shown in Figure 7.1. Over 50% of registered students agreed or strongly agreed with the statements that the redesigned Vector Space course "was good enough for them", and that they were 'able to access the co-created resources' which were the output of the staff-student partnership in course design (see Chapter 5).

Similarly, over 50% of the respondents agreed or strongly agreed with the statements that the collaboratively redesigned learning resources for Vector Spaces: "enhanced their learning"; made them feel "being part of a learning community", and enabled them to be "able to explore academic interest with other students". Most students did not feel that the delivery of the course has been stimulating or motivating, although the majority agreed or strongly agreed that the redesigned course was well organised. Vector Spaces was delivered via lectures and tutorials and supplemented by the PAL sessions.

There was no opportunity for me to observe lectures or tutorials. Hence, it was not possible to verify the students' claim that the delivery Vector Spaces via lectures and tutorials has been unstimulating or demotivating. Nonetheless, the implication of the students' concern with the delivery of Vector Spaces is that any attempt to enhance the student learning experience should not only consider the design of learning and teaching resources but also solicit the *student voice* regarding the *nature of pedagogy* that could motivate and stimulate student engagement with the course in lectures and tutorials.

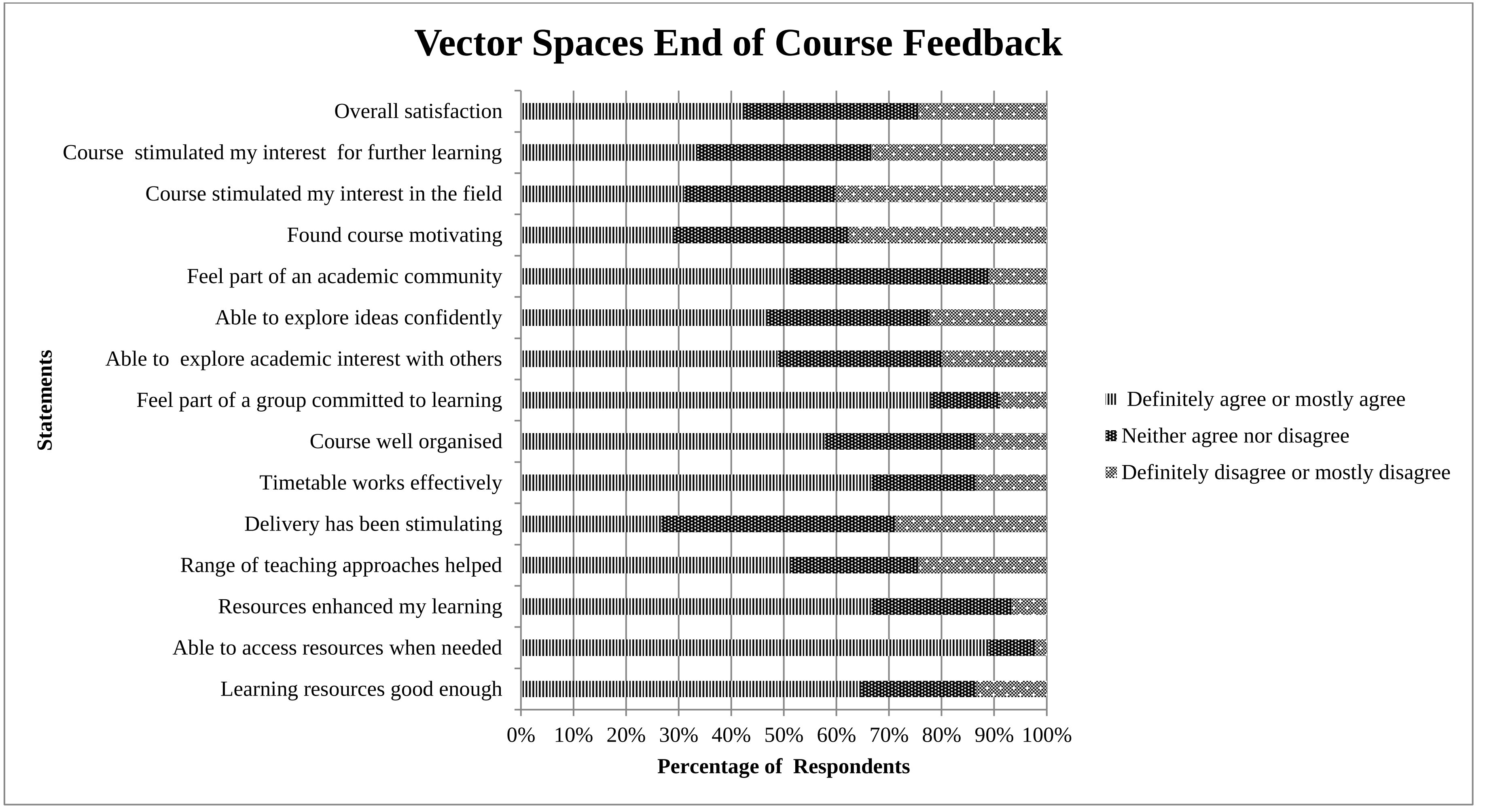


Figure 7.1. Vector Spaces end of course feedback

A week before the Complex Variable course ended in May 2012, registered students on the course were again surveyed about their perceptions of the redesigned course. Eighty-five students responded to the survey (out of a total of 127), a response rate of 70%. The percentage of students who responded in each category for each of the 15 statements in the feedback survey (See Appendix S) are shown in Figure 7.2. Over 85% of the respondents agreed or strongly agreed with five of the 15 statements: “overall satisfaction”, “course being well organised”; “that the resources enhanced their learning”; “able to access the learning resources”. The high percentage of “agreed or strongly agreed” to these statements is in contrast to that of the Vector Spaces course which was also collaboratively redesigned by staff and the student interns. In particular, over 90% of the respondents felt that they were satisfied overall with the course. This evidence from the survey again shows that course design alone may not be the only factor that impacts on student’s perceptions about courses.

The survey also showed that of the 55 Vector Spaces and 61 Complex Variables PAL participants (see Tables 7.1 and 7.2), 40 and 52 respectively responded to the question: “How satisfied are you with the Mathematics Peer Support/PAL sessions you attended? Ninety percent of the 40 Vector Spaces PAL participants claimed to be satisfied with the PAL sessions they attended. Eighty-seven percent of the 52 *Complex Variables* PAL participants also claimed to have been satisfied with the PAL sessions they attended. These results show that at least for those students who chose to participate in PAL sessions voluntarily, they derived some utility from the sessions.

Clearly the evidence presented here shows that an effort to enhance the undergraduate mathematics learning experience through collaborative course design cannot be isolated from what goes on in lectures, seminars or tutorials. Hence an investigation into the efficacy of collaborative course design and delivery such as the current study should also explore the student experiences in lectures in order to understand the full impact of the collaboration on students.

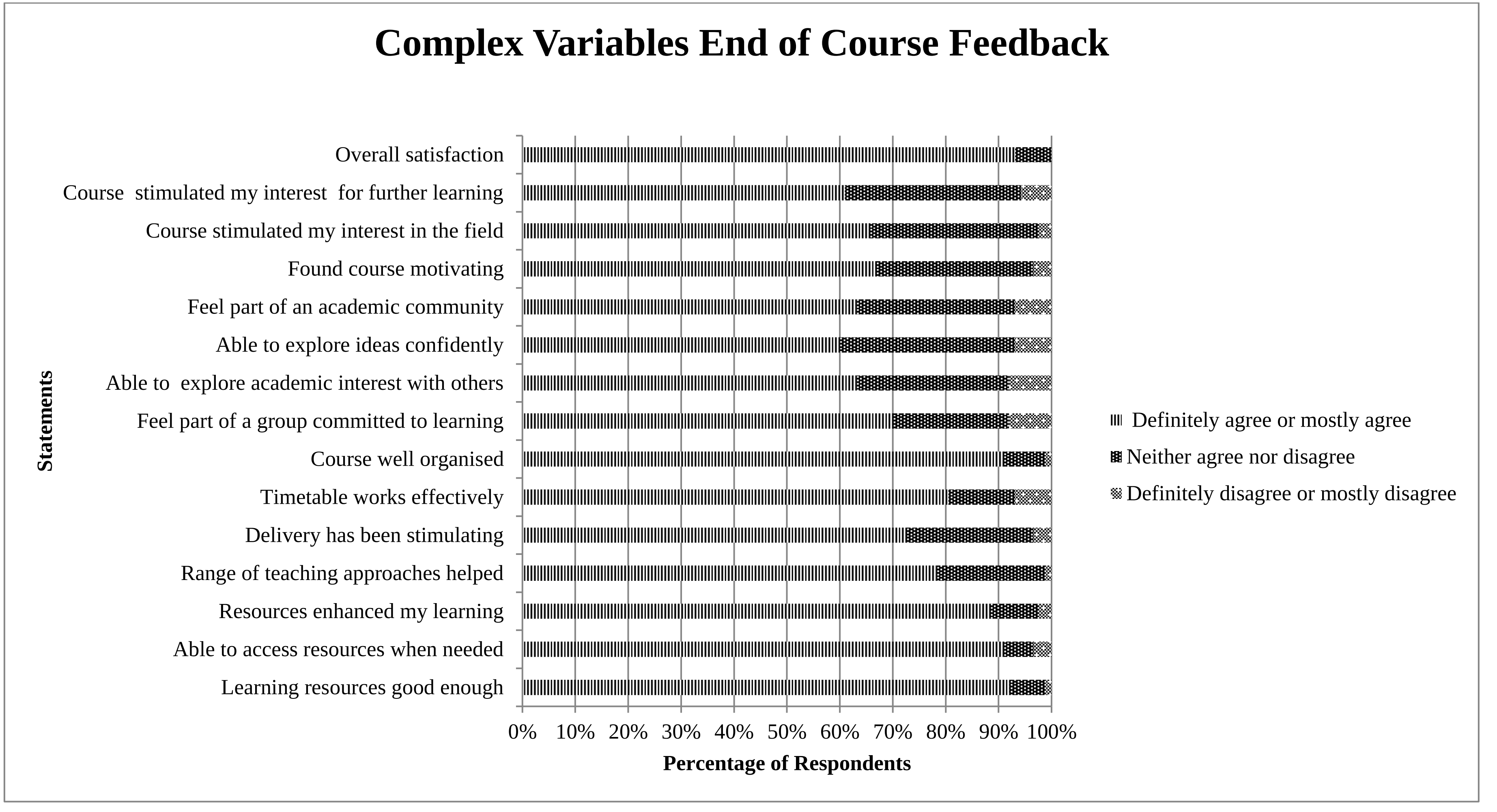


Figure 7.2. Complex Variables end of course feedback

7.6 Summary

In this chapter, I have presented evidence that shows the quantitative impact of PAL attendance on PAL participants. In Section 7.2, the demographic data on students who participated in PAL sessions were presented. The evidence presented indicates that a at least about half of the students who studied Vector Spaces and Complex Variables opted to participate in PAL sessions and to further engage with mathematical content of the courses.

The data show that in relation to Vector Spaces, about two third of registered students participated in PAL sessions; there was no statistically significant association between participation in PAL sessions and gender. However, there were differences in the participation levels of international students and UK based students. In relation to Complex Variables, half of registered students participated in PAL sessions; there was statistically significant association between participation in PAL sessions and gender. Similarly, there was statistical significant association between participation levels of international students and UK based students.

In Sections 7.3 and 7.4, I have presented evidence that indicate that participation in PAL has some effect on students' achievement in Vector Spaces and Complex Variables. Students attending PAL sessions were likely to achieve approximately 1.2% extra in the final Vector Spaces course marks for one unit of PAL attendance, after controlling for lecture attendance and prior achievement in pre-requisite courses. This equates to a gain of over 10% in their final course marks if students took advantage of the opportunity to attend all PAL sessions. Similarly, students attending PAL sessions were likely to achieve 1% increase in Complex Variables marks for every unit of PAL attendance.

In Section 7.5, I have also provided evidence that indicates that the majority of students were also satisfied with the redesigned Vector Spaces and Complex Variables courses as well as with their PAL experience.

CHAPTER 8 DISCUSSION AND CONCLUSION

8.1 Introduction

> *"Although student-faculty partnerships are not entirely new or novel, they are outside the norm at many colleges and universities". (Cook-Sather, Bovill & Felten, 2014, p.11)*

This thesis sought to explore the nature and the impact of staff-student partnership in course design and delivery in the context of university mathematics. As the above quote acknowledges, staff-student partnerships at universities are not new phenomena, although the recent focus of higher education researchers on staff-student partnerships is indicative of the growing importance of staff-student partnerships in learning and teaching. However, through the application of the theoretical framework based on the CoP theory (see Chapter 3, Section 3.1, p.65) and the relationships between PAL attendance and student achievements (see Chapter 3, Section 3.1, p.65), I have come to a better understanding of students as partners and students as change agents in learning and teaching of university mathematics. Therefore, I am now able to provide answers to the research questions posed in Chapter 1 (see Section 1.2.2, p.10).

In Section 8.2, I summarise the findings of the phase one (see Chapter 5) and phase two (see Chapter 6) studies and the results of the phase three (see Chapter 7) study. In Section 8.3, I outline the *contribution* made by this thesis to the research on staff-student partnerships in the context of university mathematics. In addition, the extent to which the CoP theory sheds light on the nature of the partnership is discussed. I also discuss the extent to which PAL can be a participatory pedagogy as advocated by Solomon (2007). In Section 8.4, I present the implications of the findings for the development of learning and teaching of university mathematics; limitations of the research; and suggest possible lines of inquiry for future research. Finally, I conclude the thesis in Section 8.5.

8.2 Discussion of findings and results from the data analysis

8.2.1 *Informing the staff-student partnership in course design*

The current research project began with the assumption that the staff-student partnership in undergraduate mathematics course design and delivery at Middle County University (MCU) brought different university mathematics CoP together. Undergraduate mathematics students and university mathematics teachers have been described as separate CoP (e.g. Biza, Jaworski, & Hemmi, 2014; Solomon, 2007, 2009). The CoP of the university mathematics teachers in this study was constituted by eight staff including two who, separately, taught Vector Spaces and Complex Variables. The other six staff taught different undergraduate mathematics course units which were not of interest in the current study.

I doubt that anyone will disagree that changes to mathematics course design, as in other disciplines, needs to be informed by evidence of what works. As Berry and Sharp (1999) argue, students need to be consulted on matters related to learning and teaching because they are the key players in learning activities. Staff knowledge of students' views of what needs changing will help them to avoid guessing how best students learn (Cook-Sather et al., 2014). Listening to the student voice in undergraduate mathematics is important because the two CoP of staff and students often may not intersect outside lectures or tutorial rooms. Listening to the students voice on learning and teaching and acting on the student voice is consistent with the values of democratic education by which students play active roles as citizens of the university community. In the staff-student partnership at MCU, the co-creation of the course design and course content began with focus group discussions that informed the course design process. This aspect of the partnership required the course design team to listen to and to give due consideration to the student voice on learning and teaching. This aspect of the course design process was similar to that of the case studies reported by Richardson (1973) and Moore and Gilmartin (2010).

The CoP of the undergraduate mathematics students was constituted by the twenty students including the four student interns as described in Chapter 4 (see Section 4.3.1, p. 96). As I described in Section 4.3.1, p. 96, the twenty students participated in focus group discussions in which they shared their perspectives on learning and teaching of Vector Spaces and Complex Variables and mathematics generally. The discussions were aimed at generating ideas to inform the course design process. The issues that emerged from the focus group discussions can be thematically summarised as: *teaching approach*, *learning resources and environment*, and *assessment* (see Section 5.3, p. 117).

Issues related to teaching approach centred on the pace of some lectures and the nature of the pedagogy that is deployed by some staff. The nature of the pedagogy deployed by staff was often framed in terms of the way staff communicated to students when they responded to students' requests for clarification about things they do not understand; and staff-student relationships in lecture halls and seminar rooms. The nature of learning resources and environment was also framed in the narratives of the the focus group participants in terms of the consistency between lecture notes provided in advance of teaching and those which are given in live lectures. Participants described how the two sets of lecture notes sometimes differed and how this difference made it difficult for them to understand the mathematical content. When the students referred to learning technologies as a learning resource that they valued, they often cited screencast as a technology that enabled them to engage with mathematical content at their own pace and wherever and whenever they wanted.

In the narratives of the focus group participants, the formality of lectures and tutorials sometimes discouraged them from opening up and asking questions. While the participants of the focus groups perceived assessments of all kinds as important, the value they placed on formative assessments and summative assessments differed from staff. Staff viewed both formative and summative assessments as important to the students' learning. However, for the participants, assessments that count towards their degree classification were valued more than those which did not contribute to their degree classifiction or bore little weight. Although the focus group participants thought that formative assessment was important, they felt that the time that they need to devote to credit bearing formative assessment needs to be proportionate to the contribution it makes towards their degree classification. The issues that emerged from the focus group discussions were considered by the course design team during the six week internship in which staff and the student interns co-created resources for Vector Spaces and Complex Variables.

The issues identified by the students who took part in the focus group discussions are consistent with findings of other studies on student experiences of learning mathematics. For example, Seymour and Hewitt's (1997) publication, *Talking about leaving: Why undergraduates leave the sciences*, highlights a number of issues cited by students who switch from science, mathematics and engineering (SME) degree programmes. The central issues that are of concern to switchers are pedagogy, curriculum design, and assessment practices. In addition, Seymour and Hewitt note that non-switchers who progress through their SME degree programmes also cite pedagogy, curriculum design and assessment practices as issues of concern to them.

More specifically, the extant mathematics education research literature also demonstrates that transition within undergraduate mathematics degree programmes poses challenges to some students and for some of those progressing through their degree programmes their enjoyment of mathematics decreases. As I wrote in Chapter 2, *Students' Experiences of Undergraduate Mathematics (SEUM)* (Brown et al., 2005) is a major English study on the learning experiences of a cohort of undergraduate mathematics students over the course of their degree programmes. Reporting on the findings from the analysis of the data collected as part of the SEUM study, Brown et al. (2005) concluded that some students, including those progressing through their degree programmes, experience challenges that can be addressed if the students can be identified early and provided with support. However, this model of support is the "medical model" (Arendale, 1994, p.17) which requires diagnosis of students' difficulties and prescription of a remedial programme to address those difficulties. Some students may feel targeted and stigmatised with this model of learning support. Alternative approaches to supporting students' transition within undergraduate mathematics are therefore needed. Staff-student partnership as advocated in the educational development literature (e.g. Bovill and Felten, 2015) seems to offer one such alternative model as we shall see in Sections 8.2.2 and 8.2.3

In a related publication to the SEUM project, Macrae, Brown and Bartholomew (2003) asked what else can be done to help students who experience difficulties with their learning of mathematics; but fail to seek help; and then withdraw and disengage from the subject? Indeed, Croft and Grove (2015) argue that there is room for improvement in the support that can be offered to students, and in the development of learning and teaching. Croft and Grove draw on a range of studies and evidence that support the view that students value peer learning support when faced with challenges in their learning of undergraduate mathematics (e.g. Goulding et al., 2003).

Fink (2003) argues that course design might be the most important barrier to quality learning and teaching in higher education. Therefore, attempts to provide support to students transitioning within undergraduate mathematics can examine and modify the pedagogy, curriculum and/or course design (see Berry and Sharp, 1999; Williams, 2015). Traditionally, staff create the learning experiences for students through their pedagogical practice, curriculum and course design, and assessment design. Thus, staff control the course design and delivery processes. This study shows that students can be *actively* and *productively* involved as partners and change agents in the development of university mathematics learning and teaching. Rapke (2016) also demonstrates how all students on a course could be involved in developing some aspects of assessment tasks which are then used as summative assessments. Staff-student partnership in course design and delivery via Peer Assisted Learning (PAL) therefore holds promise to address some of the challenges that some students face; challenges which may be inherent in course design rather than the pedagoy deployed by staff.

As I noted in Chapter 1 (see p.8), the staff-student partnership in learning and teaching at MCU was aimed at addressing the difficulties that a significant number of students face with two historically problematic courses, Vector Spaces and Complex Variables.

The partnership was an attempt by staff to draw on students' experiences and their expertise of being students to inform the redesign of the two courses. In addition to course design, the partnership involved staff and students in the co-design and implementation of a PAL scheme which offered additional study sessions to students who studied the redesigned courses. The PAL scheme involved third-year students as partners and as PAL leaders in the delivery of some aspects of the two courses. The aspects of the two courses which the PAL leaders helped to deliver were content identified by the PAL participants which then became the focus of discussions in PAL sessions. The current study explored the nature of the staff-student partnership in course design and its outcomes for staff and for the student interns. The study also investigated the staff-student partnership in course delivery via PAL, and the qualitative outcomes of participation in PAL sessions for PAL participants and PAL leaders. In addition, the relationship between PAL attendance and the achievement of PAL participants was also explored.

8.2.2 *Students as partners and change agents in course design*

The first research question of this current study is: "when undergraduate students are provided with an opportunity to collaborate as interns with staff in advanced undergraduate mathematics course design what is the nature of that collaboration?" I argue that during the six-week summer internship in which the four student interns co-created resources with staff, a learning community emerged. This community can be characterised as a CoP defined by the three dimensions of mutual engagement, joint enterprise and shared repertoire (Wenger, 1998). This CoP was an intersection of two pre-existing CoP (see Section 5.4, p. 126) – undergraduate mathematics students and mathematicians. The members of this third CoP were constituted by the staff and the four student interns. Although this CoP was short lived, it focused its attention intensively on developing new learning resources and reworking of existing lecture notes to make them more engaging to students than had been the case in the preceding year. This study shows that the new CoP does not automatically emerge but requires staff to deliberately cultivate the community (See Section 5.4, p.126). This requires sustained staff and student interns' mutual engagement in pursuit of a joint enterprise – informing, revising and creating learning and teaching material that enhances students' learning experiences and increases their engagement with the content of the related courses.

It is not surprising that the student interns, and to some extent other students from the same cohort as the interns, shared in the joint enterprise of the collaboration. The student interns had elected to participate in the partnership. Although they were paid for their role, their narratives of the reasons for taking part in the course design process included a desire to contribute to the course design in a way that helps future cohorts of students enjoy and engage more with the courses. However, not all students may be willing to commit to the joint enterprise as evidenced in Section 5.4.2 (see p. 134). Indeed, this research found that there are some students who believe that "it is [the student's] job to learn and [staff's] job to teach" (see Section 5.4.2, p.134), a comment agreed upon by a focus group. Hence the call for greater student involvement in the course design process cannot take for granted student willingness to be involved as partners in the course design process. Nonetheless as this study has shown, those students who share in the joint enterprise of the staff-student partnership bring their knowledge and experience as student experts to bear on the course design process.

As with the students, not all staff would want to work in partnership with students in the development of learning and teaching. Indeed, in the staff-student partnership that had been the focus of the current study, the staff whose courses were chosen for the redesign volunteered to work with students. Some staff, who did not volunteer their course for redesign, also provided content knowledge and socialisation support to the student interns in the community space that emerged. These staff may also be described as sharing in the joint enterprise of the staff-student partnership. Of course, many staff also neither volunteered their course for redesign nor did they participate in the emergent CoP. Through their active mutual engagement, the staff and the student interns who participated in the emergent CoP developed shared repertoires that were drawn upon as a resource to accomplish the joint enterprise of the partnership.

Although the CoP that emerged aimed to create teaching and learning resources that could help students engage with Vector Spaces and Complex Variables, the space created through the mutual engagement of staff and the student interns enabled sustained dialogue between staff and the student partners on learning and teaching of Vector Spaces and Complex Variables, and undergraduate mathematics generally. The staff-student partnership in course design did not only create space for staff and the student partners to mutually engage through their daily interactions but also time for reflection on their practices as teachers and students. Through these reflections, the student interns developed metacognitive awareness (Cook-Sather et al., 2014) of their learning and this awareness led to revisions of study habits (See Section 5.4.5.2, p.154).

Student partners gained the opportunity to be enculturated into the community of university mathematics staff. While the interns may not necessarily choose to become university mathematics teachers themselves, the enculturation provides them with a keyhole through which they may see academia as a profession. However, this study found that through their daily engagement and negotiations in co-creation of course design and course content, the student interns had the opportunity to develop identities of belonging to the emerged CoP. These identities were characterised by their alignment *to* and imagination *of* the practices of the CoP to which staff belong. This study found that the student partners aligned with staff practice (see Section 5.4.4, p.145) such that in some instances they conceded to staff wishes and arguments about what and how new course material was to be produced and set aside the views and the preferences of the undergraduate mathematics students who had previously taken the course.

This study has shown that the CoP that emerges out of a staff-student partnership in course design creates opportunities for the student partners to learn through social participation *in* and *enculturation* into the practices of university mathematics teachers. In many ways, the university mathematics teachers were the experienced and full participants of the emerged CoP. Staff were also the experts in the content knowledge within this community and while they shared in the responsibility of course design, they did not relinquish their responsibility to the students.

The second research question, was “how does the collaboration in course design impact on the student interns and staff?”. With respect to this question, the study shows that the staff and the student interns had shared a goal which they achieved. The realisation of what is possible as a result of student engagement in the course design process propelled a change in the student interns’ sense of who they are and their learning of mathematics (see Sections 5.4.5.1, p.151), and staff views of the capabilities of students as an additional resource for teaching and learning development (see Section 5.4.5.3, p.159). As Gärdebo and Wiggberg (2012) note, students are an unspent resource in pedagogical development.

The student interns reported (see Section 5.4.5, p.151) changes in their views of who they were, and how they felt about learning. These changes in the student interns’ views of themselves related to their beliefs about their level of knowledge of the content of the course they helped to co-create, their mathematical understanding, personal development and their affective dispositions.

I argue that the change in the student interns’ views about themselves and their practice of learning mathematics, in my view, represents *identity transformation* (Section 5.4.5, p. 151) which encompasses engagement in, imagination of, and alignment to, the mathematical practice of the staff. Similarly, staff also reported identity change with respect to awareness of the student perspectives on learning; and their enjoyment of the partnership relationship. This finding is consistent with the work of Cook-Sather et al. (2011).

Staff-student partnership in undergraduate mathematics course design can develop the student partners’ deep mathematical understanding of the course they helped to redesign (see Section 5.4.5.1, p.151). The student partners who co-create learning and teaching resources get the opportunity to engage further with the content of the mathematics they had previously studied. This extended engagement with mathematics, which involved example generation, enabled the student interns to reflect on and then clarify any conceptual misunderstanding with staff who often provided feedback to them. The student partners gain increased confidence because of their increased understanding and the value that staff place on their contribution and outputs.

The opportunities that the staff-student partnership in mathematics course design afford the student partners also helps them to develop skills for employability (see Section 5.4.5.2 p.154). These generic transferable skills, which are not taught explicitly in lectures, include improved communication skills, development of technological skills, and maturity. Of course, these skills may be developed by student partners of other disciplines who are engaged to work with staff. However, for undergraduate mathematics students, the disciplinary pedagogy may not explicitly afford them the opportunities for development of soft skills required for real world employment.

8.2.3 *Students as partners in teaching*

The third research question that this study set out to answer was: "what are the characteristics of PAL sessions for advanced undergraduate mathematics? PAL sessions can be attached to individual undergraduate mathematics course units to enhance the learning experiences of undergraduate mathematics students. As discussed in Chapter 2 (see Section 2.3.3, p.39), PAL involves a partnership between PAL leaders (senior students who facilitate sessions), PAL participants who study the courses to which PAL is attached, and university mathematics teachers who teach those courses. Such partnership offers additional scheduled sessions in which students can learn actively and collaboratively under the direction of trained PAL leaders.

The phase two study found that the PAL sessions I observed were attended by groups of students with different levels of mathematical and personal confidence (see Section 6.6.5, p. 208). Students who participated in PAL sessions often worked in pairs or in groups, they helped each other to learn in groups, discussed material to reach a common understanding and supported one another. When they engaged in individual work rather than group work and discussions, support was always available from other PAL participants for anyone who needed it. In the sessions, often the PAL participants shared their approaches to solving problems publicly for peer review. However, I argue that the facilitation strategies of the PAL leaders were similar to those used by the SI leaders in Burmeister et al.'s (1994) study in which SI leaders used questions and answers and appeared to lead from the front.

Thus, the PAL leaders in the current study often led from the front, posed questions to which they expected answers from the PAL participants. The question and answer strategy was used often and was aimed at creating a dialogue between the PAL leaders and the PAL participants. In the PAL sessions, the PAL leaders and the PAL participants had mechanisms for sharing what each has learned (see Section 6.6.2.2, p.198). These were often through presentations on the board by a group representative or an individual who has worked on their own. These presentations were often accompanied by oral commentary on the steps involved in the solution of a problem. In the PAL sessions, there was emphasis on learning how to solve the particular types of mathematics problems that most students had found difficult.

The above findings are important in that they call for regular observations of PAL sessions and feedback to PAL leaders to ensure that they are facilitating sessions rather than "teaching". Of course, there is a thin line between the concepts of teaching, tutoring, and facilitation and this line can easily be crossed by both university teachers and PAL leaders. The nature of the discipline, which is content driven and abstract, is such that it is all too easy for PAL leaders to "facilitate" learning through the "transmissionist mode". However, as Zerger (2008) advocates, the canonical strategies required to be used by PAL leaders can be adapted to address disciplinary differences.

When provided with the opportunity to deliver aspects of undergraduate mathematics courses, undergraduate mathematics students can be successful in motivating their peers to engage with mathematics in a *learning community*. The learning community is characterised by a *mutual engagement* (interactions), *joint enterprise* (a shared purpose), and *shared repertoire of resources* (stories, artefacts, ways of solving problems). Each group (PAL leaders, PAL participants, or university mathematics teachers) brings to bear on this emergent CoP their own practice from the other communities of which they are part. PAL leaders may also act as *brokers* (see Section

6.6.2.4, p.202) brokering between the learning community and the CoP of university mathematics teachers. The PAL leaders share and discuss practices with staff which enable the latter to respond to student feedback on learning and teaching before the course ends.

The learning community that emerges in PAL sessions offers PAL participants the opportunity to engage in mathematics practice akin to that of academic mathematicians: *using the board*, *discussing mathematics problems with peers*, *critiquing each other's solutions* and *suggesting alternative approaches to problem solving*. Thus, learning in PAL sessions engenders "collective student work" (Iannone & Nardi, 2005, p.198). This approach is seen by some lecturers as the best learning tool there is. In the learning community, PAL leaders draw on their learning experiences (i.e. having previously taken and passed the courses) to guide and support PAL participants and act as *role models* for the PAL participants (see Section 6.6.2.2, p.198).

In the learning community, PAL participants and PAL leaders drew comfort from the "safety in [small] numbers" (Solomon, Croft & Lawson, 2010) of students in sessions. Thus, they "feel safe" and comfortable to ask questions and be asked questions and to state that they do not understand a problem. This is made possible because of the *supportive* and *trusting learning environment* that PAL sessions attempt to foster.

The fourth research question was: "what is the qualitative impact of the staff-student collaboration in course delivery via PAL on PAL participants and PAL leaders?" The PAL participants and PAL leaders reported views about themselves that showed a change in the way in which they positioned themselves in relation to their mathematics learning. I refer to this change of view in their abilities, study habits and confidence as *identity transformation*. This transformation may include a change in the ways in which they engage with mathematics; their relationships with their peers. PAL sessions encourage students to *discuss mathematics* collaboratively and to offer help to each other. This identity transformation may include a change in PAL participants' sense of belonging and change in their mathematics practices. For example, students who would otherwise not put up their hand to say that they do not understand a concept or problem, may become more willing to do so in the company of their peers without staff. Students who attend PAL sessions may gain confidence and this is important as Parsons, Croft and Harrison (2009) note that confidence does matter in undergraduate mathematics learning. These outcomes are similar to those reported by other researchers (e.g. Dobbie & Joyce, 2009a; Miles, Polovina-Vukovic, Littlejohn, & Marini, 2010).

This study also shows that PAL sessions could result in affective gains and personal development of both the PAL participants and PAL leaders. These findings are consistent with findings in earlier studies reported in the international literature on PAL. Topping (2005) notes that the affective and personal development gains include social and communication skills, increase in self-esteem and self-confidence. To this list, I will also add *identity transformation* in relation to the mathematics learning.

The fifth research question was: what is the quantitative impact of the staff-student partnership in course delivery via PAL on PAL participants? In Chapter 7 (see Sections 7.3, pp. 222-229), I presented the detailed results of the quantitative impact of PAL attendance on PAL participants' achievement and the perception of their learning experience in PAL sessions. I highlight the main results that answer the fifth research question.

The study demonstrated that there is a statistically significant positive partial correlation between Vector Spaces course marks and PAL attendance, $pr = .250$, $p = .027$. In other words, if two students had attended the same number of lectures, and had started the course with identical prior achievement in Linear Algebra, then the student with the higher PAL attendance would typically achieve a higher Vector Spaces course mark.

A linear model that predicts the Vector Spaces course marks also indicates statistically significant B coefficients of all three independent variables, PAL attendance, lecture attendance, and first-year Linear Algebra achievement. The adjusted R^2 value was .491. This indicates that 49% of the variance in Vector Spaces achievement was explained by the model. The coefficient associated with PAL attendance was B =1.187. This means that an increase in PAL attendance by one session was associated with approximately 1.2% extra in the final Vector Spaces course marks. The PAL scheme was voluntary; hence there was no random assignment of students to groups of PAL participants and non-PAL participants. Hence, it is not possible to claim causation between PAL participation and Vector Spaces achievement.

However, if there were a causation, then the regression coefficient of PAL attendance would suggest that a student who attends all nine Vector Spaces PAL sessions will gain over 10% in their final course marks. In other words, if two students had attended the same number of lectures, and had started the course with identical prior achievement in Linear Algebra, then the student with the higher PAL attendance would typically achieve a higher Vector Spaces course mark. Although it is not possible to rule out the possibility of some unknown confounding factors accounting for this linear relationship, this finding is sufficiently encouraging and leads me to call for greater use of PAL beyond first year introductory mathematics courses.

The study also demonstrates that there is a statistically significant positive partial correlation between Complex Variables course marks and PAL attendance, after controlling for Complex Variables lecture attendance and first year Calculus marks, pr = .200, p = .028. Thus, given two students with the same number of Complex Variables lecture attendance and Calculus marks, the student with the higher PAL attendance will typically achieve a higher overall course mark in Complex Variables than the student with a lower PAL attendance.

As in the case of Vector Spaces, a linear model that predicts the Complex Variables course marks indicates statistically significant B coefficients of all three independent variables: PAL attendance, Complex Variables Lecture attendance, and first year Calculus achievement. The coefficient associated with PAL attendance, B=1.031, suggests that an increase in PAL attendance by one session was associated with 1% increase in Complex Variables marks.

Again, although it is not possible to claim causation between PAL attendance and Complex Variables course marks, if such causation were to exist, this would suggest that a student who attends all ten Complex Variables PAL sessions will gain about 10% in their final course marks. Thus, given two students with the same number of Complex Variables lecture attendance and Calculus marks, the student with the higher PAL attendance will typically achieve a higher overall course mark in Complex Variables than the student with a lower PAL attendance. This evidence supports earlier studies reported in the international literature on PAL (e.g. Dawson et al., 2014; Fawyoski & McMillan, 2008; Parkinson, 2004) which also report improved student grades for those students who choose to attend PAL sessions.

Despite the encouraging findings and results reported in Sections 8.2.1 (see p. 237). through to Section 8.2.3 (see p.245), I wish to stress that staff-student partnerships in course design and course delivery via PAL are not a panacea that will address all the difficulties that students face within their transition in undergraduate mathematics. Indeed, there are challenges and hurdles that confront staff who endeavour to engage students as partners and change agents in the development of learning and teaching of university mathematics (Cook-Sather et al., 2016). I discuss some of these challenges in the next Section.

8.2.4 *Challenges in staff-student partnerships*

First, the nature of the staff-student partnership in course design described and discussed in this thesis does not completely address the issue of inclusivity. This is because, in the current study, not all students were involved as co-creators, in contrast to those in Rapke’s (2016) study. Cook-Sather et al. (2014) caution that those who run staff-student partnerships should consider the possibility that underrepresented students and staff may feel left out of the process if they are overlooked in the selection of staff and students. In the current study, the four student interns were the main beneficiaries of the enculturation into the practices of the academic mathematicians during the six-week internship in which they co-created resources for learning and teaching.

As Healey et al. (2014) note, where some students are to be selected to partner with staff, the selection criteria need to be clearly communicated and justified to students. Indeed, the internship positions created in the staff-student partnership at MCU were advertised to all students and as I described in Chapter 4, the students who applied for the positions were interviewed and the final selection of the four interns was made from these.

Similarly, following the six-week internship in Summer 2011, other staff were invited to bid for funding from the teaching and learning committee to undertake similar partnership activity. However, on that occasion, only two staff volunteered to partner with students to redesign their courses and these two staff therefore were awarded funding. It is important to note, where students work as paid partners, adequate funding needs to be sought and in the face of reduced funding in the sector, such partnerships may prove difficult to sustain.

Second, sustaining such partnership in course design process is also difficult as course redesign is not undertaken every year and may not always even be necessary. Third, the collaboration in course design takes time and staff who are concerned about lack of time may not be willing to engage with the kind of partnership that is reported in this study despite the benefits reported earlier in the preceding Sections.

The answers to the research questions and the discussions above provide evidence to support the view that this thesis makes an important contribution to the knowledge base of staff-student partnerships in general, and of the development of university mathematics learning and teaching particularly. In the next Section, I clearly outline and substantiate the specific contribution that this thesis makes to knowledge.

8.3 Contribution to research and reflection on theory

8.3.1 *Contribution to research*

Staff and students collaborate in many areas of the university enterprise and throughout their higher education careers. Staff and students collaborate in many areas to achieve the university mission the focus of which is on research, teaching, and knowledge creation. Staff-student partnership in the development of learning and teaching of university mathematics is one aspect of academic practice which is increasingly being subjected to empirical research (e.g. Biza & Vande Hey, 2014; Rapke, 2016). When the staff-student partnership in the development of Vector Spaces and Complex Variables at MCU was conceived, such an approach to the development of learning and teaching of university mathematics was a novel enterprise in UK HEIs. As I have demonstrated in Chapter 2, the academic development and mathematics education research literature is now beginning to report examples of, and research into, staff-student partnerships in course (or module) design and delivery. Although Bovill et al. (2011) explored examples of collaborations in which students acted as "co-creators of teaching approaches, course design, and curricula", their examples were in non-mathematical sciences disciplines. As I wrote in Chapter 1, Vector Spaces and Complex Variables are viewed as advanced undergraduate mathematics courses (see Section1.6, p.15 for definition). And while the phase one study was motivated by the work of Bovill et al., it was not certain that the current study would yield the same outcomes as reported in their work. Therefore, this thesis contributes to the academic development research generally and mathematics education research particularly.

While research on staff-student partnerships in university mathematics course design had been limited, staff-student partnerships in the delivery of university mathematics courses via PAL have been a focus for considerable research for more than four decades (Arendale, 2004).). PAL has been found to be effective in supporting non-specialist students who study mathematics courses at undergraduate level (e.g. Burmeister, Kenney, McLaren, & Nice, 1996; Cheng, & Walters, 2009; Fayowski & McMillan, 2008; Harding et al., 2011; Kenney, 1994; Malm et al., 2012; 2012; Parkinson, 2009).

Through this study, we also know that despite the advanced nature of courses such as Vector Spaces and Complex Variables, third-year students who had previously taken these courses will be able to draw upon their tacit knowledge and implicit pedagogy to facilitate the learning of other students, and that their (the third-year students) efforts will be appreciated and be valued by their more junior peers. However, Duah, Croft, and Inglis (2014) note that when a didactic contract is established between students and staff after the school-university transition, it is questionable whether PAL could be effective in advanced undergraduate mathematics in raising the achievement and enhancing the student learning experience. This study contributes to the knowledge base of PAL research because it has also demonstrated that PAL can be effective in improving the student achievement in university mathematics courses taught to specialist undergraduate mathematics students. Considering this discussion, I argue that this thesis fills a gap in the literature and informs the university mathematics teaching community including students, university mathematics teachers, university administrators and higher education policy makers.

8.3.2 *Contribution to theory*

The key constructs of CoP theory – *joint enterprise*, *mutual engagement*, *shared repertoire*, *identity*, *engagement*, *alignment*, *imagination*, and *brokering* provided insights into the nature of the staff-student partnership in the course design and delivery and its impact on the student interns, on staff practice, PAL participants, and PAL leaders. The current study has shown that staff-student partnership can foster a partnership learning community of like-minded individuals interested in the learning and teaching of university mathematics who look for ways in which they could enhance the student learning experience and increase student engagement with the subject. This study also demonstrates that the emergent partnership CoP can act as a "stimulating force" and as a driver for "collective learning" (Mittendorff, Geijsel, Hoeve, de Laat, & Nieuwenhuis, 2006) by staff and the student partners. In this CoP in which students co-create learning and teaching resources, staff are still accountable for the quality of resources produced by the student partners. This mutual engagement of staff and students allows for the necessary quality assurance process in which material produced for learning and teaching can be checked and feedback provided to the student partners.

In the context of the current study, the student co-creators were the four student interns who worked with staff during the six-week summer internship. The importance of feedback from one student intern to another, and from staff to students on the material produced cannot be understated. This is because the university mathematics teachers are ultimately responsible for the *mathematical integrity* of the content of the material produced by the student interns. It is through this feedback mechanism that student interns gain a much deeper insight into the mathematics courses on which they worked. It is also through this feedback mechanism that staff and student interns engage in *negotiation of meaning* of mathematical language and symbols and student interns are enculturated into the work of academic staff.

I suggest, based on the findings reported thus far in this research, that:

a) it cannot be assumed that students' will always be willing to participate in a partnership aimed at developing learning and teaching resources in undergraduate mathematics because not every student may share in the joint enterprise of a staff-student partnership learning community,
b) those students who choose to participate in a staff-student partnership in course design as interns enter an intersecting community which, as I have argued, may emerge as a short lived CoP. On the one hand, the concept of *legitimate peripheral participation* may not provide an explanation of the learning trajectory of the student interns since they may not aspire to become academic mathematicians or university mathematics teachers. On the other hand, staff are full and legitimate participants of the emergent CoP as they are the experts of the disciplinary content knowledge,
c) student interns who engage in a collaborative course design process have an opportunity to engage in *mathematical practices* of university mathematics teachers. These practices provide the interns with the opportunity to engage further with the mathematical content which they had previously studied,

d) involving students in the course design process will by itself not lead to the production of quality resources that enhance the learning experience of students who use the material. Deliberate *mutual engagement* of staff and student interns is necessary; the student interns' actions as brokers can lead to transformation in staff and student collaborators' practices in learning and teaching respectively,

e) staff and the student interns occupied different levels of the university hierarchy. This adds complexity to the staff and student interns' relationship in that there is an element of a power differential between staff and student interns. This may impact on the extent to which student interns may change the way mathematics content is presented or taught.

The contribution made by this thesis to research and the insights provided by the CoP theory into the staff-student partnership, have implications for future developments of staff-student partnerships in the learning and teaching of university mathematics. I discuss these implications, the limitations of the current study, and areas for future research in Section 8.4.

8.4 Implications of the findings, limitations and further research.

This study focused upon a staff-student partnership in advanced undergraduate mathematics course design and delivery at one HEI. The extant research into staff-student partnerships in course design focuses on the nature of the collaborative process and qualitative outcomes of the partnership for staff and student partners. Accordingly, the research often employs qualitative approaches to research design and qualitative data collection methods (e.g. Bovill, Cook-Sather, & Felten, 2011; Cook Sather, Bovill & Felten, 2014). The findings of the studies are often judged to be transferable to other settings but generalizability is usually not the goal of the studies. Similarly, as I discussed in Chapters 4 and 5, the phase one study reported in this thesis adopted an ethnographic approach to study the staff-student partnership in course design. The findings reported in Chapter 5 are transferable to other institutions but the methods and processes of the staff-student partnership in the design of Vector Spaces and Complex Variables may need to be adapted to suit a local and national context.

It is important to point out that the findings of the phase one study (see Chapter 5) have limitation because the study focused on only one institution and two courses. The context specific nature of the study suggests that the findings may not be generalizable in the context of university mathematics. However, the goal of the study was not to obtain generalizable findings but to explore and document the nature and the process of the partnership to facilitate transferability of the intervention to address the transition challenges that students face within undergraduate mathematics.

As I reported in Section 5.4.6 (see p.162), under the National HE STEM Practice Transfer Adoption Scheme (http://www.hestem.ac.uk/PracticeTransferAdopters), the partnership model at MCU was shared with other institutions where students had also been involved as co-creators of course content for course units including *Analysis, Abstract Algebra*, *Differential Equations*, and *Rings Groups and Fields*. Reports of the outcomes of the partnerships at these institutions for staff and the student partners are similar to those reported in this thesis. This suggests that the staff-student partnership is a transferable pedagogic intervention. Thus, other university mathematics teaching staff may adopt or adapt the methods and processes to suit their own specific context, and to inform their own practice.

Regarding the staff-student partnership in course delivery via PAL, one important limitation to the analysis of the quantitative data in Chapter 7 is that the reduction in "cooling off" or "sophomore slump" phenomenon was considered in terms of an increase in the proportion of student examination success. This was one of the reasons my analysis focused on attainment data (see pp.224, 228). Although earlier researchers have proposed that either phenomenon is characterized by a lack of students' success (e.g. Clark, 1960), it is also characterized by a lack of enthusiasm and general reduction in engagement with academic mathematics. It would be extremely valuable if, in future, investigations which study interventions designed to address the 'cooling off' or "sophomore slump" could find strategies to measure affective aspects such as enthusiasm and engagement. Of course, it is particularly difficult to effectively collect such data from students who have actively disengaged from their studies but such data is critical if the “cooling off” or “sophomore slump” phenomenon is to be understood from all angles.

Around one-third of the cohort studying Vector Spaces and one-half of those studying Complex Variables chose not to attend any PAL sessions. These figures are sufficiently large to suggest that on its own, staff-student partnership via PAL is not a complete solution to the challenges that students face in their transition within undergraduate mathematics. The qualitative evidence from the phase two study which is reported in Chapter 6 (see Section 6.6.2, p. 197) suggests that one student attended two PAL sessions and then decided not to attend anymore sessions. The student, PS12, preferred staff teaching to the PAL sessions which were facilitated by the PAL leaders. The nature of the PAL sessions, which was participatory and discursive with the PAL leaders using rewards to increase student engagement with the mathematics was seen as a competition. These results are therefore inconsistent with Solomon’s (2007, p.92) suggestion that mathematics “can only be made accessible to all in a participatory pedagogy”, and perhaps might be better stated as mathematics can only be made accessible to all in an environment that offers access to a participatory pedagogy for those who would expect to benefit.

Furthermore, students who took part in PAL sessions as learners or leaders were not randomly selected and assigned to the PAL sessions. In relation to the study that looked at the impact of PAL attendance on achievement, although differences in the prior attainment of the PAL participants and non-PAL participants were controlled for as far as it was possible, I acknowledge that random assignment of students to the two groups would have been perhaps more robust than a quasi-experimental design which was adopted in this study. However, it is difficult to conduct such random assignment given the ethics of denying some students the opportunity to engage with a pedagogic intervention in which they could potentially accrue positive outcomes.

The findings presented demonstrate that staff-student collaboration in course design and delivery, as a pedagogic intervention, could enhance the student learning experience. However, bringing about pedagogic change in university mathematics teaching is a difficult endeavour. Curriculum development projects such as the staff-student collaboration described in this thesis are often funded for a short period (e.g. one year). Future research may look at the sustainability of these collaborations within departments and across the HE sector beyond the funded period. To explore a general pedagogical change in university mathematics teaching and how staff and students' practices are transformed by such collaboration, a longitudinal research study into such collaborations is needed.

The staff-student collaboration in course design involved a selected few students. It will therefore be illuminating if such collaborative work could be embedded in the curriculum as mini-projects for students to undertake during the academic year. Such an approach, in my view, will provide opportunities for diverse groups of students to create mini activities or learning material that could be made available to other students to use. These activities and learning materials may be assessment tasks, practice problems, or examples that other students may use. This model of the collaboration also has the potential of getting students to shape their own learning during the academic year. The outcomes of the collaborations may therefore extend to a wider group of students than the select few described in this thesis. For staff who may want to adopt a collaborative course design model in their practice but do not have adequate funding, such an approach may need little money and has the potential to achieve the same outcomes for staff and students.

8.5 Conclusion

This thesis has presented evidence to show that *staff-student partnership* in undergraduate mathematics course design can: 1) lead to change in university mathematics teachers' practice, 2) engender *identity transformation* on the part of the partners and 3) provide opportunities for university mathematics students and staff partners to engage in *reflection* on learning and teaching through informal *discourses* which are often difficult to achieve during routine teaching sessions.

As *experts* in being *undergraduate mathematics students*, student partners bring to bear on the partnership the student perspectives on course design to help staff bring about effective change in their teaching practice. When such perspectives are acted upon in the course design process, many positive outcomes accrue to staff and student partners.

Advanced undergraduate mathematics students can also play critical roles in the delivery of teaching by facilitating the learning of students in lower years. In these roles, although advanced students may not be trained teachers, and may not have the same level of advanced mathematical knowledge as academic mathematicians, they can draw on their *tacit and implicit pedagogy* to facilitate the learning of their peers. In these roles, advanced undergraduate mathematics students do not only act as role models who encourage their peers to persist with their learning of undergraduate mathematics, but also develop in them important academic and graduate attributes.

Through their mutual engagement, staff also provide feedback to students on the material that they produce. It is through this feedback mechanism that student interns gain a much deeper insight into the mathematics courses on which they work. It is also through this feedback mechanism that staff and students engage in negotiation of meaning of mathematical language and symbols and students are enculturated into the work of academic staff. The importance of the feedback, from one student intern to another and from staff to student interns on the material they produce, cannot be overemphasised. This is because the university mathematics teachers are ultimately responsible for the *mathematical integrity* of the content of the material produced by the student interns.

University mathematics teachers engage in local, national and international collaborations in research, learning and teaching. The notion of *staff-student partnership* in *course design and delivery* extends what university mathematics teachers already do with potential *outcomes* of: academic development and achievement for students. Staff-student partnerships are efficacious when “rooted in the principles of respect, reciprocity, and responsibility” (Cook-Sather, Bovill, & Felten, 2014, p. 2) and to which staff and students may need to subscribe. Amongst the goals of staff-student partnerships in learning and teaching are *enhanced and* *successful student learning experience* and *high levels of student achievement*. This thesis demonstrates that such goal can be achieved through careful planning and implementation. Therefore, this thesis recommends that university mathematics departments consider holistically the evidence presented in the thesis and respond to the call to join the movement advocating *active* student involvement in the planning and delivery of their courses.

APPENDIX A PARTICIPANT INFORMATION

Participant Information
5 February 2011

Dear ……….

It is an expectation of the HE-STEM Grant Awarding Body that the Mathematics Education Centre will research good practice and outcomes that may result from the second-year mathematics curriculum development project and disseminate such findings to the wider mathematical sciences community. Coincidentally, as part of my PhD Thesis on Undergraduate Student Engagement with Mathematics, I intend to research the role that undergraduate students can play and their experiences as partners in mathematics curriculum development projects. Therefore, as you have already been informed, I would like to conduct an interview with you before you commence your work with staff on the module design. Preferably the interview should be conducted before you have any further meeting with staff involved in the design of the modules.

The interview will be 40mins to 60mins long. The purpose of the interview is for me to learn about:

- students as change agents;
- students as partners in their learning,
- ways of improving student engagement with mathematics modules.

I would like to assure you that I am involved in the HE-STEM project as an independent researcher and the views that I collect from you will be summarised anonymously in research reports and every effort will be made to ensure that views expressed cannot be traced back to individual interviewees. I will also ensure that what I discuss with you is kept strictly confidential. The interview will be digitally recorded and later transcribed. However, the recording will be kept secured under lock and I will be the only person with access to the recording. As soon as the data have been analysed and anonymously summarised, I will delete the files so that no one can have access to it in the future. I acknowledge that your participation in the interview is voluntary and you can call the interview off without question at any time.

I look forward to meeting you in the next few days.
Thank you very much.

Francis Duah Postgraduate Research Student
Mathematics Education Centre.

APPENDIX B INFORMED CONSENT FORM

<u>INFORMED CONSENT FORM</u>

Insert Name of Research Proposal

INFORMED CONSENT FORM

(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Approvals (Human Participants) Sub-Committee.

I have read and understood the information sheet and this consent form.
I have had an opportunity to ask questions about my participation.
I understand that I am under no obligation to take part in the study.
I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

Your name:____

Your signature:____

Signature of investigator :____

Date:____

APPENDIX C FOCUS GROUP

Preamble

(1) Welcome, (2) Ground rules, (3) Overview of the topic and (4) First question.

The purpose of this focus group discussion is to gather information from you regarding your experiences of learning and teaching of Vector Spaces and Complex Variables and how each module could be redesigned and taught to enhance students' experiences, enjoyment and satisfaction with the modules. It is hoped that you will be frank in expressing your views and not be inhibited in any way during this focus group session. As you already know, this session is one of five focus group discussions to be held as part of the research into elements of the HE-STEM Project. By the end of the five sessions, we would have about 20-24 participants, therefore enabling the anonymity of each participant in relation to their expressed views to be guaranteed. Anything that is said here must be and will be kept confidential by everyone present at this focus group. Although the discussion will be recorded, the recording will be securely kept under lock and key and so no one other than the researcher will have access to it. Computer files of the discussion will be password protected to prevent unauthorised access. When the data have been analysed and summarised in a report, the recording will be deleted so that future access by anyone with access to the recorder will be prevented. When reporting the findings from all the focus group discussions, what is said will be anonymized and summarized so that it will not be possible to trace expressed views to individual participants?

Our role here is to guide the discussion. You will be talking to each other. You don't have to agree with others, but you must listen respectfully as others express their views.

<u>**Themes for discussions (Estimated Duration 1 hour)**</u>

1 As mathematics students, how much do you want to work with staff as partners in designing mathematics courses?

a) In what ways?
b) Student representation; student voice; active participation in curriculum design etc

2 What aspects of the teaching of Vector Spaces helped you learn the module well?

a) What aspects would you like improved or changed and

b) In what ways?

3 So far, what aspects of the teaching of Complex Variables have you found helpful in your learning?

a) What aspects would you like improved or changed and

b) In what ways?

4 What kinds of learning resources would you like to see developed for;

a) Vector Spaces?

b) Complex Variables?

c) What is your preferred medium or media of learning resources; paper, electronic pdf, video tutorials, on-line exercises or tests?

d) Which of these media are most useful and why?

5 For those mathematics students who disengage with mathematics, is it because they do not understand the content of what is taught in lectures and tutorials or could there be other reasons for their disengagement? If so what could these other reasons be? e.g. Too busy doing other things like socializing, sporting, working…?

6 How best can module lecturers and tutors reach students, particularly disengaged students, in order to provide support to help them in their learning?

-Online Forum, Facebook? Blogs?

7 How do you feel about the assessment regime of the two modules?

8. On a scale of 1 to 5, 1 being not satisfied and 5 being very satisfied, how satisfied

(a) were you with learning and teaching of Vector Spaces

(b) are you with learning and teaching of Complex Variables

APPENDIX D INTERNS' INTERVIEW SCHEDULE

Students as partners in mathematics curriculum development:

1) Have you any experience already of working with staff (other than as their student in lectures/tutorials/project supervision or personal tutor)?

   a) If so, how did that work?, b) How valuable was the experience for you?, c) How was the experience for the staff?

2) a) How did you find your selection interview to become an intern?

   b) What aspects of the interview surprised you?

3) Why did you want to become a Student Intern?

4) What role do you think students can play in shaping the design and delivery of the mathematics curriculum in general? (Please describe what you think that role is?)

   (Your own views – not necessarily the views of the 'HE-STEM project')

5) From your point of view, what do you see as your role in the design and delivery of the new Vector Spaces/Complex Variables module for which you have been employed?

   (Your own views – not necessarily the views of the 'project')

   a) What sort of things (AS OF TODAY) should you be doing to change the way the modules had previously been designed and delivered to engage most students?

   b) What sort of relationship do you expect to have with staff who are involved in the design of the new Vector Spaces/Complex Variables modules?

6) To what extent do you see yourself as a typical undergraduate mathematics student?

Measure of Success of the Innovation

7) What positive outcomes do you expect from your involvement in the design of the new Vector Spaces/Complex Variables modules for:

a) yourself

c) future students

b) staff

8) a) What barriers to successful outcomes of the module design do you envisage?

b) Are there any particular things you think need to be in place for the module design process and the subsequent delivery of the new module to work well?

10) How will you know that the activity you have been involved in with staff has been successful or not?

11) How do you intend to lead the rest of the undergraduate students to ensure that the views of those not directly involved in the design process are taken into account?

12) If you were not involved in the project at the moment, what do you think it would take to persuade you that it is worthwhile to get involved?

Professional Development

14) What could the staff possibly learn from working with you in designing the Vector Spaces/Complex Variables module?

13) As a student, what could you learn from your involvement in the design of the new Vector Spaces/Complex Variables module?

Miscellaneous Theme

16) To what extent do you see yourself either as an expert or a novice learning mathematics?

15) What does being a mathematician at a university mean to you?

APPENDIX E STAFF PRE-INTERNSHIP INTERVIEW SCHEDULE

INTERVIEW QUESTIONS

Students as partners in mathematics curriculum development:

1) Have you any experience already of working with undergraduate students (other than as their lecturer /project supervisor/personal tutor)? E.g. have you had an employed undergraduate student working for you in the past?
   a) If so, how did that work?
   b) How valuable was the experience for you?
   c) How was the experience for the student?

2) a) How did you find the selection interview for the interns?
   b) What aspects of the interview surprised you?

3) a) How motivated do you think the Student Interns are in becoming involved in the mathematics curriculum development project?

4) What role do you think students can play in shaping the design and delivery of the mathematics curriculum? Please describe what you think that role is?
   (Your own views – not necessarily the views of the 'project')

5) From your point of view, what do you see as the role of the interns in this particular project as regards your module, Vector Spaces/Complex Variables?
   (Your own views – not necessarily the views of the 'project')

   a) What sort of things (AS OF TODAY) do you envisage asking the interns to do?

   b) What sort of working relationship do you expect to have with them?

Measure of Success of the Innovation

6) What positive outcomes can the interns derive from working on the project?

7) a) What barriers to successful outcomes of the module design do you envisage?

b) Are there any particular things you think need to be in place for the module design process and the subsequent delivery of the new module to work well?

8) How will you know that the activity you have been involved in with the interns has been successful or not?

9) If you were not involved in the project at the moment, what do you think it would take to persuade you that it is worthwhile to get involved?

Professional Development

10) As an experienced university Professor/Lecturer what could you possibly learn from your working relationship with the interns?

11) What professional development opportunity do you think the working relationship with the interns could provide you?

Miscellaneous Theme

12) To what extent do you see the interns either as experts or novices learning mathematics?

13) What does being a mathematician at a university mean to you?

APPENDIX F STAFF PRE-INTERNSHIP EMAIL QUESTIONNAIRE

Survey Questions

Dear All

I would like to know your candid and considered responses to the following questions in relation to the Symbol Project. Instead of a timed interview, I have chosen to do a small survey and I would be very grateful to receive your responses before the Student Interns start working on 4th July. Your responses will be kept confidential and when reporting upon the project, your name will be replaced by a pseudonym so that your anonymity will be maintained. You may send your responses by clicking on "REPLY" not "REPLY ALL" for privacy of your responses. If in doubt, you may copy and paste the questions in Word and type your responses directly below each question and attach the file to the e-mail. Thank you in advance for your time and effort.

1. What personal benefits do you expect the student interns to gain from their engagement with staff in redesigning the two courses, Vector Spaces and Complex Variables?

2. What additional mathematical knowledge and expertise, over and above course requirements, could the student interns gain from working with staff as partners?

3. What barriers do you think could arise and possibly make an impact on the contribution the student interns make to the course redesign process?

4. Describe the nature of the working relationship you expect to develop between yourself and the student interns as they assume their role full time.

5. What professional development benefits do you personally expect to gain from the partnership between staff and the student interns in the course redesign process?

Best wishes.
Francis Duah

APPENDIX G STAFF POST-INTERNSHIP INTERVIEW SCHEDULE

INTERVIEW QUESTIONS

Lecturers: L01 and L02

1. How will you describe your experience of the six weeks student summer internship?

2. How have you benefited from the staff-student partnership in the course redesign process?

Probe: professionally, personally, socially, relationship

3. In what specific ways do you think the two interns who worked on your module benefited from the internship?

4. Could you describe any instances when the students learned or gained insights into some aspects of Vector Spaces/Complex Variables?

5. How do you the define teaching of Vector Spaces/Complex Variables?

Probe: In what ways is teaching of Vector Spaces/Complex Variables different from other disciplines?

6. How do you envisage relating lectures, tutorials, supplementary notes, and problems produced in the […] project and the peer support scheme to enable students to access these resources to facilitate their learning?

7. How important is it that students take full advantage of all the resources produced for your Vector Spaces/Complex Variables?

8. How do you intend to modify lectures to incorporate the peer support scheme and the additional resource into the learning and teaching experience of Vector Spaces/Complex Variables?

Probe:

Lecturers: L03 - L8

1. How will you describe your experience of the six weeks student summer internship?

2. How have you benefited from the staff-student partnership in the course redesign process?

Probes: professionally, personally, socially, relationship

3 In what specific ways do you think the interns benefited from their internship?

4 How would you respond if you were invited to redesign any of the modules you teach with students?

5. How do you the define teaching in relation to the modules you teach? You may name a specific module.

APPENDIX H PEER LEARNING SUPPORT SURVEY SCHEDULE

Q1. How much do you value peer support in your mathematics learning?

Very much □ Not very much □ Of value to me □

Q2. Would you access a formal peer support scheme to enhance your learning experience if one was set up within the department of Mathematical Sciences at Middle County University? Yes □ No □

Q3. From which of the following student year group would you prefer to receive support for your mathematics learning?

Same Year Group □

Year Above me □

Taught postgraduate Student Group □

PhD Student Group □

Q4. What role do you expect students who provide mathematics peer support to play?

Q5. What characteristics and attributes do you expect students who provide mathematics peer support to have?

Q6. Describe the features of a peer support scheme you would like to see set up to support your learning of mathematics.

Q7 Would you like an opportunity to work directly with staff to redesigned one of your mathematics courses to improve student learning?

Yes □ No □

APPENDIX I PAL LEARNERS INTERVIEW SCHEDULE

FACTS

1. Participant's Gender: ………………………………………………………..
2. Degree Programme of Study: …………………………………………..
3. How many of the mathematics peer support sessions so far have you attended?:………………………..
4. Do you go alone, or with a friend? If with friends, would you have gone alone in the first place, or not wanted to?

PEER SUPPORT SESSIONS IN PRACTICE

5. Why do you choose to go to mathematics peer support?
[**Probes:** What are the reasons? Academic? Social? Personal? Worry that you cannot cope? You just want to learn as much as you can?...etc.]
6. Tell me about some aspects of mathematics peer support that you enjoy.
[**Probes:** Do you enjoy doing mathematics with the other students and the Student Leaders who are the third-year students providing peer support?]
7. How do the Student Leaders, the third-year students who provide peer support, work with you?
[**Probes:** Talk about how a peer support session works in practice? Think about the last session you went, how did it unfold?]
8. Please describe the ways in which the mathematics peer support sessions differ from going to normal tutorials (if there is a difference).
9. Tell me something that you have learned by going to mathematics peer support.
10. Tell me how you prepare, if anything, in advance of going to a mathematics peer support session. [**Probes:** What are your friends' views about the peer support?]
11. What do you talk about the mathematics peer support sessions with your friends, outside of the session time?
12. Do the Student Leaders ever contact you, or do you contact them, outside the peer support session time. Why? How does this work?

CHANGING BEHAVIOUR

13. What, if anything, in terms of your study habits have changed by going to the mathematics peer support sessions?
[**Probes:** I am thinking of your study habits, your motivation to attend? Does it make you work harder, or less hard because you think you can catch up during peer support?]
14. In what ways has going to the mathematics peer support changed the way you think about the mathematics you are studying?
[**Probes:** What do you like more/less, the same?]
15. Have you become more or less confident with the mathematics by going to the peer support sessions.
[**Probes:** If more confident, can you give me an example of something specific you are more confident with?
16. Tell me about how your confidence has been impacted upon by going to the peer support sessions.
[**Probes:** Have you become more confident as a person, with your peers, with the Student Leaders?]

GENERAL

17. Next year would you like to be a Student Leader? If so, would you do things the same or differently to the current Student Leaders of your session?
18. In what ways do the student leaders act as role models for you?
19. This is the first year we have run mathematics peer support. You have seen it in practice. Do you think we should have done things differently?
20. Talk about any non-mathematical skills you think you have learned which will be useful in other aspects of your life, or your future career?
21. This year we are offering peer support for ***Vector Spaces*** and ***Complex Variables.*** Which modules would you have preferred to have peer support for and why?
22. Would you like to say anything else about mathematics peer support?

APPENDIX J NON-PAL LEARNERS INTERVIEW SCHEDULE

INTERVIEW QUESTIONS

FACTS

1. Participant Gender:……………..

2. Programme of Study:……………

3 a. Did you study Vector Spaces during the first semester 1?

b. How did you find your Vector Spaces learning experience?

4 a. Did you study Complex Variables during the first semester 2?

b. How did you find your Complex Variables learning experience?

5. How did your tutorial for either Vector Spaces or Complex Variables run?

PEER SUPPORT SESSIONS

6. Why did you choose not to go to mathematics peer support?

[**Probes:** What are the reasons? Academic? Social? Personal?..etc.]

7. What could have been done to encourage you to attend the Mathematics Peer Support?

STUDY HABITS

8. Do you enjoy studying on your own or working with other students?

9. How confident are you with mathematics?

GENERAL

10. Next year would you like to be a Student Leader? If so, would you do things the same or differently to the current Student Leaders of your session?

11. This year we are offering peer support for ***Vector Spaces*** and ***Complex Variables.*** Which modules would you have preferred to have peer support for and why?

12. Would you like to say anything else about mathematics peer support?

APPENDIX K PAL LEADERS' INTERVIEW SCHEDULE

Participant: ……………………………

Programme of Study:……………

[Questions for all participants]

Q 1. Have you enjoyed your role as a Student Leader?

Q 2. What are the similarities and differences between the PAL sessions you have run and the usual timetabled tutorials you experienced with *Vector Spaces* and *Complex Variables*?

Q 2 For students in which year (1,2,3) do you think PAL sessions can have the most benefit - why?

Q 3. How much thinking about the PAL sessions do you find yourself doing outside of the timetabled slot? (*Do you find yourself thinking about ideas to make your sessions more engaging? Do you think more about the maths and how to support students with it? How do you plan and prepare for your PAL sessions?*)

Q 4. Describe an example of a mathematics problem or theory that you and your colleagues helped the second year students to understand.

Q 5. What are your views about the Student Leader training that was provided by the SYMBoL team?

Q 6. How helpful did you find the training and was it adequate?

Q 7. How did you make use of the Student Leader handbook? Did you follow the policies and procedures set out in the Handbook?

Q 8. Did you communicate with the second year students outside PAL sessions and how?

Q 9. Following a PAL session, have you ever fed any information back to the module leader about his teaching, the learning resources, how students are finding the module? (Did you offer to do so?)

Q10. Have you ever shared your own experience of doing either or both of the modules (*Vector Spaces* and *Complex Variables*) with the second years? Give an example? What sort of advice are you giving them?

Q 11. Describe your relationship with the second year students in and outside timetabled PAL sessions?

[Questions for the Student Interns who were also PAL leaders:

[Q12a. How did your involvement in the summer internship help you in your role as a Student Leader?]

Q 12b. How has your role as a PAL Leader impacted on your study of mathematics in your third year? (For MMath students: Will your role as a PAL leader make a difference in your final year study of mathematics?)]

[Questions for all participants]

Q 13. What non-academic benefits have you gained from you role as a Student Leader? What can you say about your confidence with your study of mathematics and as a person?

Q 14. Do you think you could have run the sessions alone? Are there benefits of having two or three student leaders at a time?

Q 15. What is the most difficult aspect of being a student leader? Have there been sessions where things have gone wrong - if so, how have you handled this?

Q 16. Starting again from scratch now - would you do things differently? Should the project team have organised things differently? (How could the PAL scheme within the Department of Mathematical Sciences be improved for future cohort of second year students?)

APPENDIX L PAL OBSERVATION FORM

1. Date/Time: ___________________ 2. Place: ________________________

3. Number of Participants: ☐ Females: ☐ Males: ☐

4. Number of Student Leaders: ☐

5. Seating arrangement: ____

6. Topic for the Session: ____

7. Resources employed by the PAL leaders/leader were:

Designed by the Student Interns ☐ Designed by Module Leader ☐

Designed by Participant (s) ☐ Designed by Student Leaders ☐

Obtained from the Internet ☐ Obtained from textbooks ☐
Other ☐ ____

8. PAL leaders/leader get (s) students involved Yes ☐ No ☐

Strategies used:____

9. Techniques used in conveying information:

Handouts ☐ Whiteboard ☐ Flashcards ☐ Other ☐ ___________________________

10. Are students asked open-ended questions: Yes ☐ No ☐

11. Are students given enough time to answer questions: Yes ☐ No ☐

12. Study methods used:
Small group discussions and feedback ☐

Whole group discussions and feedback ☐
Whole group quiz ☐

Discussion of parts of lecture notes ☐

Strategies from PASS strategy cards ☐
Discussions and practice of examination and test items ☐

Other s ☐
____

13. PAL leaders/leader facilitate(s) sessions from
Front ☐ Sits with the students ☐ A mixture of both ☐

14. PAL leaders/leader encourage(s) students to summarize concepts to end sessions.

Yes ☐ No ☐

Strategies used:____
____

15. PAL leaders/leader encourage(s) students to attend subsequent sessions

Yes ☐ No ☐

16. General Sequence of events during the session:

(a) Opening:

(b) Development:

(c) Closing:

17. Strengths of the session

18. Areas for development

APPENDIX M END OF COURSE FEEDBACK SURVEY

Mathematics Satisfaction Survey

Please tick the boxes that apply to you.

Part A Satisfaction

	Yes	**No**
Have you already completed this particular survey online?		

1 Learning Resources **Consider all those learning resources (lecture notes, tutorial sheets, other supporting material) that have been made available for studying the module Vector Spaces.**	**Definitely disagree**	**Mostly disagree**	**Neither agree nor disagree**	**Mostly agree**	**Definitely agree**
1.1 The learning resources are good enough for my needs.					
1.2 I have been able to access the resources when I needed to.					
1.3 Learning materials made available on the module have enhanced my learning.					
1.4 The range and balance of approaches to teaching have helped me to learn.					
1.5 The delivery of my course has been stimulating.					

2 Organisation and Management	**Definitely disagree**	**Mostly disagree**	**Neither agree nor disagree**	**Mostly agree**	**Definitely agree**
2.1 The timetable works effectively as far as my activities are concerned					
2.2 The module is well organised and is running smoothly					

3 Learning Community	**Definitely disagree**	**Mostly disagree**	**Neither agree nor disagree**	**Mostly agree**	**Definitely agree**
3.1 I feel part of a group of students committed to learning					
3.2 I have been able to explore academic interest with other students					
3.3 I have learned to explore ideas confidently					
3.4 I feel part of an academic community on this module					

4 Intellectual Motivation	**Definitely disagree**	**Mostly disagree**	**Neither agree nor disagree**	**Mostly agree**	**Definitely agree**
4.1 I have found the module motivating.					
4.2 The module has stimulated my interest in the field of study.					
4.3 The module has stimulated my enthusiasm for further learning.					

5 Overall Satisfaction	**Definitely disagree**	**Mostly disagree**	**Neither agree nor disagree**	**Mostly agree**	**Definitely agree**
Overall, I am satisfied with the quality of the module at this point.					

Part B Mathematics Peer Support Sessions

Please tick the boxes that apply to you.

	Yes	**No**
6 Have you watched the Vector Spaces video on LEARN entitled "Solving Linear Equations over Finite Fields"?		

	N/A	**Not at all**	**A little**	**Very much**
7 Has the video increased your understanding of "Solving Linear Equations over Finite Fields"?				

	Yes	**No**
8 Have you watched the Vector Spaces video on LEARN entitled "Eigenvalues of Differentials of R [[x]]"?		

	N/A	**Not at all**	**A little**	**Very**
9 Has the video increased your understanding of "Eigenvalues of Differentials of R [[x]]"?				

*12 What could be done to improve the Mathematics Peer Support /Student Leader Sessions for the current and future modules?

13 Other comments about your second-year mathematics experience to date.

APPENDIX N PAL OBSERVATION 1 – FIELDNOTES

Date: 27/10/2011, **Time:** 11.00, **Place:** W143

Topic: Vector Spaces over Fields: Solving Linear Equations

PAL leaders: PL01, PL02 and PL03

PAL participants are referred to as S101, S102, S103, S104, S109…S115, S116

PL01: Hello please get started with the problem: Granny Buttler Problem. Today we are revising the example on page 6. Solving Linear Equations in a Field.

PL01 gets the students' attention by raising his voice a little and speaks to the whole group.

PL01: You are solving a system of linear equations. Consider the variables x_1, x_2, x_3 and form your linear equations. You can set up simultaneous equations with three symbols. You may use m, l and r instead of x_1, x_2, x_3. Another main clue is…..

PL01: Has anyone managed any of the equations?

PL02 goes up to the board because she realize that many students' heads were up and that perhaps they have formed some set of equations. PL02 begins to copy the system of equations on the board:

$m + r - 2l = 0$

$m + r + l = 3$

$m - r - l = 0$

PL01: You can use Gaussian Elimination to solve the system of equations

PL01: Does everyone get where these equations are coming from?

PL01: You can work in $\mathbf{F}_5$. Whoever gets the solution gets a prize.

PL02: Warns the students that she is about to put up the solutions on the board.

S101: We don't want the solution yet!

PL01: Is anyone still confused about how to find the solution to the variables

PL01: Where did you get to in your lecture notes?

PL01: Chapter 3?

S102: Symmetric Matrices with the same Trace.

PL01: Now please work on the Practice Test.

PL01: I always do well in semester 2 compared to semester 1

PL01 working from a definition to help a student find an answer to a problem and giving examples that students' can draw upon. SL0202 does the same with another student.

PL03, though a quiet person, is also engaged with her group chatting.

Closing

PL01: Next week we will have a look at the mini test. Do what you can on your own.

APPENDIX O PAL OBSERVATION 2 – FIELDNOTES

Date: 01/12/2011, **Time:** 10.00am, **Place**: G007

Topic: Spectral Theorem

PAL leaders: PL04 and PL05

PAL participants are referred to as S201, S202, 0203, S204 and S205

PL04: Do you know spectra theorem? Do you understand it at all?

PL04: We will go through the lecture notes. The topic is on page 6. We will do this one and step at a time. We will take it step by step.

PL04: What he did in the lecture on this topic is different from the lecture notes.

PL04: Can anyone come up with the definition of spectra theorem?

PL04 suggest that there are three parts to the theorem. We will break up the definition of the spectra theorem.

PL04: There is a secret version of the Spectral Theorem which is easier to understand.

PL04: Does everyone understand what orthonormal basis is?

S201: I don't know when we going to use this theorem.

PL05 Took charge to write on the board while PL5 asked the students questions to enable them to recall the theorem themselves. Feedback or responses from the students were then written on the board for all to see.

PL05 writes on the board:

Part 1

V is a finite dimensional real or complex Hibert space.

Let $f \in$ End (V) be a self-adjoint map.

Endomorphism. (See Chapter 4 of the lecture notes)

$$f: V \to V$$

Then there exists an orthonormal basis of V consisting of eigenvectors of f.

Every Self-adjoint map is a diagnosable. If $e_1, e_2 \ldots e_n$ is an orthonormal basis consisting of eigenvectors then we can express f by,

$$f = \sum_{i=1}^{n} \lambda_i \langle e_i, . \rangle e_i$$

Part 2

Let V be a finite dimensional real or complex Hilbert space and let $f \in$ End (V) be a self-adjoint map.

Let P_λ = orthogonal projection onto the λ eigenspace.

Then $f = \sum_{\lambda} \lambda P_{\lambda}$

Part 3

Let A ∈ Mat (n, ℝ) be a symmetric matrix. Then there is an orthonormal [sic] matrix C such that $C^{T}AC$ is a diagonal matrix. Then there is a unitary matrix C such that: $C^{*}AC$ is a diagonal matrix.

PL04: This could be a big thing in the exam. Emphasizing the importance of the theorem at least from the Lecturer's point of view.

Problem:

Use Spectral Theorem to conclude that for a self-adjoint map $f \in$ End (V) on a Hibert space V, we have V = ker (f) ⊥ rg (f).

$$f = \sum_{i=1}^{n} e_i \langle e_i, v \rangle \, \lambda_i$$

Ker = {v/f(v)=0}

$$f = \sum_{i=1}^{n} e_i \langle e_i, v \rangle \, \lambda_i = 0$$

$$\Rightarrow e_i / \lambda_i = 0$$

S201 suggest the following steps:

$$\langle e_i, e_i \rangle = 1, k = i$$

$$\langle e_i, e_i \rangle = 0, k \neq 1$$

$$e_1 \lambda_1 = 0$$

$$\lambda_i = 0$$

PL04: We have our kernel

PL04: Definition of range

R g f = {W=f(V) form some $v \in V$

$$f = \sum_{i=1}^{n} e_i \langle e_i, v \rangle \, \lambda_i$$

$$\Rightarrow W = f = \sum_{i=1}^{n} \lambda_i \langle e_i, v \rangle \, e_i$$

PL04: Does everyone follow everything we have done so far?

Writes

Let $v = e \Rightarrow \langle e_i, e_i \rangle = 1$

$$W = \sum_{i=1}^{n} \lambda_i \, e_i$$

r gf= $\{e_i \mid \lambda_i = 0\}$

V=rgf+ker f

PL04: You need to show that these are orthogonal for all ker *f* and $w \in$ r g $f \langle \lambda_{i,} e_i, \rangle$

$\langle V, W \rangle = \langle \lambda_{i,} e_i, \lambda_{k,} e_k \rangle$

PL04: Remember that $\lambda_i=0$

PL05: If the scalar product is zero what do you expect?

S204: Orthogonality

V= *r* g *f* ⊥ ker *f*

PL4: This is a very possible exam question. Any questions about anything?

APPENDIX P PAL OBSERVATION 3 – FIELDNOTES

Date: 24/11/2011, **Time:** 11.00, **Place :** A128

Topic: Inner Product Space and Orthogonality

PAL leaders are referred to as PL06, PL07, PL08

PAL participants in the session are referred to as S301, S302, S303, ….., S306, S307

The PAL leaders reminded the students that the topic can be found in Chapters 5 and 6 of the lecture notes.

PAL participants were asked to work in pairs to solve a problem a starter activity which included:

Let V be a complex inner product space with the inner product $\langle P, Q\rangle := \int_0^1 x^2\overline{P(x)}\ Q(x)\mathrm{d}x$

Determine the matrix of the scalar product on $\mathbb{C}_2\ [x]$ with respect to the basis $(\mathrm{i}, \mathrm{i}x, x^2)$

PL06: Does everyone know how to get the matrix?

PL06: Is it connected to Inner Product?

S301: He's given us an example. I don't understand what he has done to get an answer.

PL08: Do you think you can do a similar one?

PL06 gets a board marker and hands it over to PL08

PL08: If anyone thinks I am getting it wrong please let me know

PL06 Uses humour and makes a suggestion to PL08.

PL06: Take a crack at it.

PL08 attempts to provide scaffolding as shown in Figures O.1 in this appendix.

$b_1 = 1 = x^0 = x^{1-1}$

$b_2 = x = x^0 = x^1 = x^{2-1}$

$\{b_i\ , \mathrm{i}=1,2,3\} = \{\ b_1\ , b_2\ , b_3\ \}$

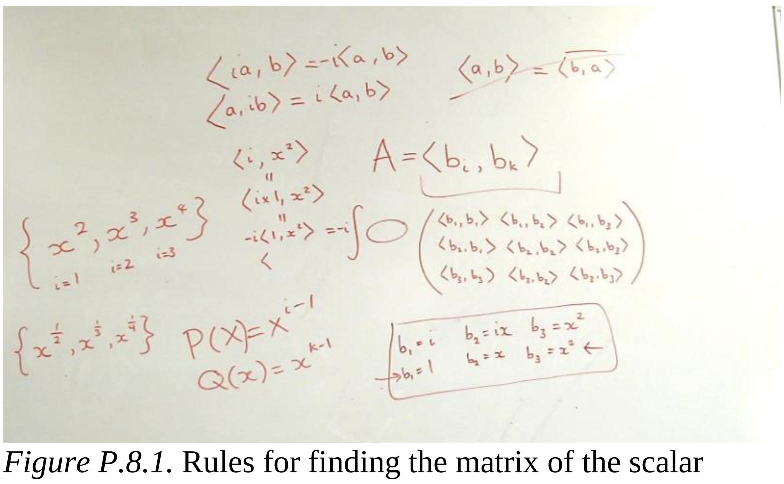


Figure P.8.1. Rules for finding the matrix of the scalar product presented by a PAL leader.

S0302: Yeah. That makes sense.

PL08: In the question, I think its literary conjugate of 2 + i is 2 – i.

PL08: We all turned up and {L02 wasn't there}.

PL08: Exam papers are lot easier.

PL08: I will say the next few lectures please turn up.

S301: Lets do Problem Sheets. They are horrible.

PL08: There will come a time where its all going to make sense.

S301 : I loved it eventually after struggling with the material.

S301 was asked to come up to the board to present his solution which is shown Figure O.1.

the rules	$<ia, b> = -i<a, b>$
and	$<a, ib> = i<a, b>$
and so	$<b_2, b_2> = <ix, ix>$

$$= \int_0^1 x^2 \times x \times x \, dx$$

$$= \int_0^1 x^4 \, dx$$

$$= \left[\frac{x^5}{5}\right]_0^1 = \frac{1}{5}$$

Figure P.1.2. S301 demonstrates finding an element of the matrix.

S303: We were not told the rules.

S301: Two definitions put into one.

PL08: It is very important to know why but in practice you need to remember the rules. I struggled at the start not knowing what to do.

APPENDIX Q PAL OBSERVATION 4 – FIELDNOTES

Date: 15/05/2012, **Time:** 13:00HRS **Place:** A128

Topic: Integration along contours

PAL leaders: PL01 and PL02

PAL participants are referred to as S401, S402, …S420

PL01: We will go through Problem Sheet 4, Q1b. We will put an extra example on the board.

PL01: You will need the theorem on page 44.

S401 goes up to the board to explain and writes:

$$\int_0^{2\pi} \frac{1}{5 - 4\cos\theta} d\theta, \text{ Let } z = e^{\mathrm{i}\theta}$$

$$\mathrm{d}z = \mathrm{i}\theta^{\mathrm{i}\theta}\mathrm{d}\theta$$

$$I = \int \frac{1}{5 - 2z - \frac{2}{z}} \text{[sic]}$$

$$I = \mathrm{i}\int \frac{1}{2z^2 - 5z + 2} dz$$

$$I = \mathrm{i}\int_{c_1(0)} f(z) dz$$

$$\text{when } f(z) = \frac{1}{(z-2)(2z-1)}$$

which has singularities at $z = 2$ and $\frac{1}{2}$ but only $z = \frac{1}{2}$ lies within $c_1(0)$

PL01: I am going to change "Singularities" to "Poles"

S401: So by the Residue Theorem

$$I = \mathrm{i}\int (2\pi\mathrm{i})\mathrm{Res}_{z=\frac{1}{2}} \frac{z - \frac{1}{2}}{(z-2)(2z-1)} \text{ [sic]}$$

$$I = \mathrm{i}(2\pi\mathrm{i})\mathrm{Res}_{z=\frac{1}{2}} \frac{z - \frac{1}{2}}{(z-2)(2z-1)}$$

$$= -2\pi\mathrm{Res}_{z=\frac{1}{2}} \frac{1}{2(z-2)}$$

$$= -2\pi\left(-\frac{1}{3}\right) = \frac{2\pi}{3}$$

PL01: I am going to let you process that.

PL01: Now try the extra question for about 3mins.

$$\text{Evaluate } I = \int_{c_1} \frac{z}{z^2 - 1} dz$$

PL01: What is the difference between pole and singularity? (Question posed quietly to PL02).

PL01: Has anyone finished that question?

S402: Goes up to the board.

$$\text{I}=\int_{c1}\frac{z}{z^2-1}\,\mathrm{d}z=\int_{c1}\frac{z}{(z+1)(z-1)}\,\mathrm{d}z$$

So I=2πi Res $f(z)$, simple poles at $z=1, z=-1$ but only $z=1$ is in $C(1)$

$$2\pi\mathrm{i}\lim_{z\to1}\frac{(z-1)z}{(z+1)(z-1)}=2\pi\mathrm{i}\frac{1}{2}=\pi\mathrm{i}$$

PL01: If you can do 2c and 3a, you can do the extra question for prize. Here is an extra question:

$$\text{Evaluate I}=\int_{-\infty}^{\infty}\frac{dx}{x^2+1}$$

S403: Consider

$$I_{C^+}=\int_{C^+}f(z)\,\mathrm{d}z \text{ where } f(z)=\frac{1}{z^2+1}$$

$$\text{On } C^+_{R(0)},\ z=Re^{\mathrm{i}\theta}$$

$$|z^2+1|\geq|z^2|-1=||z|^2-1|=|R^2-1|$$

$$\text{So } |\mathrm{f}(z)|=\frac{1}{z^2+1}\leq\frac{1}{|R^2-1|}\text{ , theorem 4.1}$$

$$\text{Hence, }\int_{C^+_{\beta(0)}}\frac{1}{z^2+1}\,\mathrm{d}z\leq\frac{\pi R}{|R^2-1|}$$

$$\text{So that }\lim_{R\to\infty}\int_{C^+_{R(0)}}\frac{1}{z^2+1}\,dz=0 \text{ as R}\to\infty$$

The integrand has simple poles at $z = \pm$i but z = i is inside C^+

$$\text{Res } f(z)=\lim_{z\to\mathrm{i}}(z-1)\frac{1}{(z-(z+\mathrm{i}))}=\frac{1}{2\mathrm{i}}$$

$$\text{By the residue theorem, } I=\int_{C^+}f(z)\,\mathrm{d}z=2\pi\mathrm{i}\left(\frac{2}{2\mathrm{i}}\right)=\pi$$

PL01: Okay problem sheet 3. Who is struggling with that?

APPENDIX R PAL OBSERVATION 5 – FIELDNOTES

Date: 02/10/2012, **Time:** 10:00am, **Place:** A128

Topic: Laurent Series

PAL leaders: PL04

PAL participants are referred to as S501 and S502

PL04: You have been doing Laurent Series. Where did you get to in the notes? What did we go through last week?

S501: I have highlighted examples of what … did

S502: Let's do some questions on Laurent series.

S501: I have to remind myself of what Laurent series is. I will get the real definition. We will go through the definitions first. Then we will go through question 5. Can someone give me a formal definition of Laurent series?

S502: Is more like Taylor series.

PL04: It is analytic at a point (0,0). If it is analytic around a point… It is equal…. It has been a year since I've done this.

S502: The open disc you have drawn… there will be a singularity and the Taylor series converges f(z) around z_0

PL4: Suppose f is analytic in an open annulus A={z: R_1 <|z-z_0|<R_2} where $0 \leq R_1 < R_2$. Let C be orientated simple closed contour within A. Then ∀ ∈ A ∃ series about z_0 s.t $f(z) = (z) = \sum_{n=1}^{\infty} \frac{u_n}{(z-z_0)} + \sum_{n=0}^{\infty} u_n\,(z-z_0)^n.\ a_n = \frac{1}{z_n}\int_c \frac{f(s)}{(s-z_0)(s-z_0)^{n+1}}ds$

PL4: The series converges to…

S501: Is it your understanding it…

PL04: $\sum_{-\infty}^{\infty} a_n\ (z-z_0)^n$, What will make it not a Taylor series?

PL04 Should we continue with this or do an example?

S501 and S502: Example

PL04: $f(z) = \frac{1}{z+5}$ Where will that point be analytic? Have a think about that definition. It has a radius L where L tends to ∞,

PL04: There is this result that we use. I think they are in the lecture notes on page 34.

$$\frac{1}{1-z} = \begin{cases} \displaystyle\sum_{n=1}^{\infty} z^n, & |z| < 1 \\ \displaystyle-\sum_{n=1}^{\infty} z^n, & |z| > 1 \end{cases}$$

$$f(z)=\frac{1}{5(1-\frac{-z}{5})}=\frac{1}{5}\left(\frac{1}{1-\left(\frac{-z}{5}\right)}\right)$$

,

PL04: What can you say about this using the same function?

S501: What is the point of doing this?

PL04: These results are used to get a geometric series.

$f(z)=\frac{1}{5}\sum_{n=0}^{\infty}\left(\frac{-z}{5}\right)^n=\sum_{n=0}^{\infty}\frac{(-1)^n}{5^{n+1}}$

PL04: Where is this valid?

S501: $|z|<5$, $f(1)=\sum_{n=0}^{\infty}\frac{(-1)^n}{5^{n+1}}$

PL04: The only function you could be given will look similar to $f(z)$.

PL04: This is a formula I have just made up and it will help you.

PL04: What is Laurent Series actually used for?

PL04: If you need a motivation why you should learn this, you could ask Peter, I will say it is on the exam.

APPENDIX S PAL OBSERVATION 6 – FIELDNOTES

Date: 4 May 2012, Time: 10am Place: Room A128

Topic: Series, Poles and Residue

PAL leaders: PL06, PL09 and PL10

PAL participants are referred to as S601…….S612

PL06: I am going to put a question on the board.

Obtain the series expansion for $f(z) = \dfrac{1}{z^2+4}$, valid in the region $|z - z_0| > 4$

PL06: On page 41, there is an example. Does anyone know how to get the first step?

PL06: Has anyone got the first step or finished it?

PL09: We are using the geometric series. Do you know which one to use?

PL06: I am hoping that someone will volunteer to come to the board to explain the solution.

PL06: Okay crack on for 5mins. I think this one is causing more confusion than the previous one.

PL06: Who wants to be brave and come to the board?

S602: Goes to the board and writing.

$$f(z) = \frac{1}{z^2+4} = \frac{1}{(z-2\mathrm{i})(z+2\mathrm{i})} = \frac{1}{w(w+4\mathrm{i})}$$

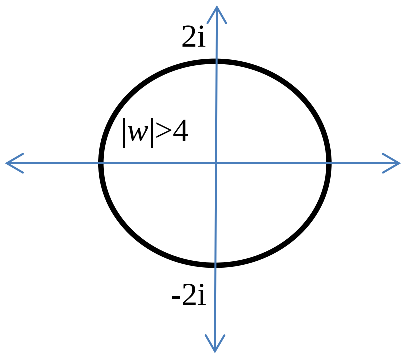


Figure S.1.3. Visual representation of z^2+4 presented by a PAL leader.

S602: When do you have to draw the circle?

PL06: Because it is easier to see what you are doing.

S602 wrote on the board:

$$\frac{1}{w}\,\frac{1}{4\left(1-\frac{w}{4\mathrm{i}}\right)} = \frac{1}{4w}\left(-\sum_{n=1}^{\infty}\left(-\frac{4\mathrm{i}}{w}\right)^{n}\right) \text{ [sic]}$$

PL06: Then what are we going to do?

S602:

$$= -\sum_{n=1}^{\infty} \frac{(4\mathrm{i})^{n-1}}{(-1)^n w^{n+1}} =$$

$$= -\sum_{n=1}^{\infty} \frac{(4)^{n-1}}{\mathrm{i}^{n+1} w^{n+1}} =$$

$$= -\sum_{n=1}^{\infty} \frac{(4)^{n-1}}{\mathrm{i}^{n+1}(z - z\mathrm{i})^{n+1}} = \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

PL06: What next?

S605: Why have you got I at the bottom?

S606: To make it easier

S602 continues writing.

$$\sum_{n=2}^{\infty} \frac{(4)^{n-2}}{(1)^n (z - z)^n}$$

PL06 attempts to explain how *n*-1 in the numerator of the fraction has become *n*-2 but it was not certain if the students understood her explanation.

PL06: OK. Now please practice Problem Sheet 3.

PL06: Who is struggling with Problem Sheet 3. We can go through that…

APPENDIX T INTERNS' REPORT TO STAFF

Student Voice as input into Module Design

Authors: S01, S02, S03, S04

Middle County University

Before Easter, we carried out 5 focus groups involving a total of 20 mathematics students to discuss student engagement within the department. In particular, we looked at the modules Vector Spaces and Complex Variables. Our sample was just under a quarter of the total participants for these modules and each focus group lasted around one hour. There were five group categories: interns, male, female, mixed and disengaged students.

Each of the interviews followed the same structure of questions, with further probing into specific points that were raised. Surprisingly, although the five groups were characteristically different, the opinions that were expressed were quite similar. We will now analyse the topics covered by the focus groups; these include lectures, tutorials, learning resources, communication, assessment and student/lecturer relationship.

The focus groups felt that there should be a better level of interaction in lectures, for example; open questions, discussions between students and ensuring students' continuous understanding of the content of the lecture. The focus groups also believed that different examples from the notes being worked through in lectures would encourage attendance. It was also brought up that in Complex Variables tutorials one further example in addition to the current example would be beneficial. Likewise, in the Vector Spaces tutorial, if there were a clearer structure of the problem sheets then students would have a greater understanding; a shown example followed by a worked example was suggested as a good format. Some students suggested that there should be revision lectures every six weeks. Additionally, it is worth noting that the highest level of student satisfaction and understanding was in the lectures for Differential Equations and Analysis.

Following on from lectures, we then analysed the learning resources available. The results from the focus groups suggested that students would like gaps in lecture notes for additional remarks and examples. One student said, “I just want to have some more things to write in lectures, if not anything, to be more involved in lectures”. They also believed that lecture notes should have a more hierarchical structure, such as chapters, which in turn can be linked to problem sheets.

In respect to additional resources, students suggested that harder content or more complex examples should be presented in video form, or as e-proofs, so that students can review them in their own time as most students had positive responses to video examples on Learn. However, students thought that full lecture videos would have a negative impact on attendance. One student suggested having a short glossary to reference notation and short definitions.

In terms of communication, students were against the use of social networking sites, such as Facebook, to supplement their learning. However, they believed that online forums, with the option of anonymity, would be a useful medium for communication. Postgraduates and/or lecturers should monitor these online forums to ensure accurate information, as well as identifying and correcting any general misconceptions. It was also brought up that although e-mail communication is still valued, the volume of unrelated e-mails received could cause many students to lose interest in checking e-mails on a regular basis.

Looking at assessment, the focus groups believed that the ratio between coursework weighting and content/workload required was completely disproportionate, especially in Vector Spaces. Students appreciated continuous assessment similar to Analysis or Scientific Programming, as they found it encouraged attendance and motivated them to work throughout the semester.

Finally, all of the focus groups said that they would value being treated with respect and as adults. They would like to think that lecturers genuinely care about their success and are approachable and available both in office hours and via e-mail. Although it may be difficult, students would appreciate lecturers making an effort to learn students’ names to provide a more personal approach, as students do not like to feel intimidated or patronised.

To conclude, the students in the focus groups had many opinions and suggestions that should be taken into account. The main areas were interaction in lectures, better links between chapters and problem sheets, supplementary video material, effective use of Learn forum and a more personal relationship between the staff and student body.

APPENDIX U A FOCUS GROUP TRANSCRIPT

Name: FGS1

Created On: 15/01/2016 00:17:14

Created By: F K Duah

Modified On: 18/01/2016 17:46:48

Modified By: F K Duah

Size: 12 KB

M: Moderator

AM: Assistant Moderator

S13 -. S16: Focus Group Participants

¶1: M:You may have to speak a bit louder. This is the focus group for S01 held on 29th of March. The first question that I have for you all is this. As mathematics students how much do you want to work with staff in designing mathematics courses?

¶2:

¶3: S13:[Laughter] Not much.

¶4:

¶5: AM: Really?

¶6:

¶7: M:And why is that?

¶8:

¶9: S13:I don't know. [Laughter] I think we have enough on our plate as it is.

¶10:

¶11: S14: think is our job to learn a and it is their job to teach kind of...

¶12:

¶13: S13:You don't pay your tuition to come and...

¶14:

¶15: S14:...teach yourself.

¶16:

¶17: S13: Yeah teach yourself and design your own courses?

¶18:

¶19: S14:...because you don't know what you've got to learn.

¶20:

¶21: M: Okay before we continue, I can recognise the two voices but I am going to ask you to mentions you names so that I can put names to the voices. You have given me a reason that you have paid your fees and don't have the time to be doing that. What is your name?

¶22:

¶23: S13

¶24:

¶25: M: Okay. Do you want to explain a bit further?

¶26:

¶27: S13: I think with the amount of lectures I've got each week, I have got fifteen hours plus doing everything else I've not got enough time to come and talk to the teachers to tell them how they should do things, they should have the experience to do it.

¶28:

¶29: AM: In which case if you could talk to a student in the lecture to say...well I don't think this is being done well and they take the time to talk to the lecture, do you think that that system will work?.

¶30:

¶31: S13: I think feedback form is probably the best solution even if you talk to someone you are not always going to... I know some people have those forms you don't put your names on and sometimes you can write on them. So I think it is going to be from year to year anyway because different students need different needs. So can classify one class on.

¶32:

¶33: AM: So in which case not repetitive feedback forms but say one every three weeks to say have you found any issues with if you have collect them the next week.[S13:Yeah: Affirmation]

¶34:

¶35: S13: It should be about the method, if there any issues, rather than e-mail you can quite easily make your point made and may be some it done better.

¶36:

¶37: S15: I suppose that the problem there is that it is quite sort of passive isn't it? Whereas doing things like this is about getting people's ideas about how to improve things and making him think.

¶38:

¶39: M: What is your name by the way?

¶40:

¶41: S15

¶42:

¶43: M: You have not spoken[Laughter]. What is your name?

¶44:

¶45: S16

¶46:

¶47: M: S16 Yeah? Okay S16 so what do you think?

¶48:

¶49: S16: These types of things are better but again it is hard to get people to come. Whereas with feedback form, you are already in the lecture and you can get them to fill them out, whereas this people might think it is out of the way.

¶50:

¶51: M: Yeah often with the feedback forms you wait till the end of the module or course to fill them in isn't it? Will be that not be too late?

¶52:

¶53: S14: Too late for you but there comes next years. I suppose.

¶54:

¶55: AM: In which case I will give them not the module feedback form but similar feedback forms, similar topics but just more structured for that module part way through the course and asking people to fill in so that the lecture knows how they doing?

¶56:

¶57: S13: Lecture notes needs changing

¶58:

¶59: AM: So that can get ready for next year but also if you are not talking loud enough

¶60:

¶61: S13: Slowdown that so I do not miss anything.

¶62:

¶63: AM: So I am jumping over.

¶64:

¶65: M: No that is good. That is the whole point of the exercise. Chip in when you feel like you can. What aspects of the teaching of Vector Spaces helped you learned the module well? And let's start with S14?

¶66:

¶67: S14: I have got food in my mouth [Laughter]

¶68:

¶69: M: Okay you take your time…, and we will come back to you. What is your name again?

¶70:

¶71: S13

¶72:

¶73: M: S13

¶74:

¶75: S13: Yeah

¶76:

¶77: Okay S13

¶78:

¶79: S13: I thought it was taught quite well. The only bit I didn't find easy is that amount of writing we had in the lecture but to an extent that quite helped. The amount of examples...The examples we had were quite abundant at times for what we need so we could learn it a lot it will be easier. The lecture notes were brief but he always went into quiet a depth anyway and I think that helped me learn the module well.

¶80:

¶81: M: What about the learning resources, apart from the lecture notes?

¶82:

¶83: S13: The one that we had limited exams for...there were not many past exams...

¶84:

¶85: S16: There was not solutions you had to go to him, didn't you? [S13:Yeah Affirmation]

¶86:

¶87: S13: The solutions as well.... Did he put any up?

¶88:

¶89: S16: I think he put [AM: Interrupts]

¶90:

¶91: S13: So I think if he had a few more past exams that you've got and later put the solutions there as well. Then you allowed practicing one and you have got. Not to learn any tricks or anything but how much time you might have for each type of questions, so that you can prepare yourself for the exams.

¶92:

¶93: M: Okay you have to mention your name again please.

¶94:

¶95: S15. Pretty much what you said there. I found the actual lecture themselves quite good. I have got some intuitive understanding of the module, I but when it comes to exams turning that intuition to getting results asking and answering questions even I find that harder. There is lack of problems with answers it is quite hard to go back to check. You have to go to the lecturer or it is just hard work.

¶96:

¶97: M: To what extent did the Vector Spaces module make use of Learn?

¶98:

¶99: S15: Err I don't think it made use of Learn. Obviously, there are the notes and problem sheets but it's just basic. It has minimum amount of work there whereas some lecturers are more active like [name of a lecturer] putting up a lot work problems proof and stuff. So I think supplementary materials. I think there is a little bit at the very end of the module. It was like other uses of Vector Spaces. More stuff like that but throughout the module will be quite good, I think. Details examples of where it is actually used.

¶100:

¶101: M: What about you? Your name first please?

¶102:

¶103: S14: S14, [M: S14?] I think the lectures were good like the others have said. The style of lectures notes, like the headings made it easier to follow. These lecture notes are quite good. The resources on Learn, problems and lectures, I haven't found a need for anything else. But other people may find applications and other used or like worked examples and stuff like that. Also past exam papers are probably the best kind of revision, because you learn how to sit the exam. Sometimes you've got the knowledge but you don't know what they are looking for whereas if you know the answers they are looking for you can obviously give. [Laughter]

¶104:

¶105: M: Back to you S16.

¶106:

¶107: S16: Err... just follow on what everyone has said. Lectures notes were good, useful. Past papers may be a couple more with solutions rather than going to the maths centre to have your work marked by a lecture which is a bit inconvenient, rather than being able to get on Learn to get your stuff. I don't know, maybe it is restricted by timetabling, because it was two back to back lectures if there was a lot of material in the lecture, I find sometimes it is too hard to take in. Just because it was back to back lectures. But it must be a bit restricted, the way the modules are in the timetable

¶108:

¶109: AM: If…for example, I think it was L03 last year with calculus, she had the forum on Learn, where people could ask questions and they get feedback on Learn and everyone could see that. Will that work a bit better?

¶110:

¶111: S16: It could do but if you have a whole past papers you have done and gone through, it is hard to use that get a full set of solutions to that. Like convey in a way you will might be able to understand it. Whereas, if you have like the actual set of solution you could read through which might be easier.

¶112:

¶113: M: Alright. You've mentioned some of the things that helped you learned well. But what aspects of teaching and learning of Vector Spaces do you think could be improved upon or could be changed altogether?

¶114:

¶115: S16: I think there was a lot of material to get through. A lot of theorems to remember. I don't know how you could change that, other than the current. I just found that there is a lot to remember come exam time.

¶116:

¶117: S13: I think my personal opinion...the lecture notes he gave us, I couldn't really follow those because what he did in the lecture was a bit different. I find it easier to write but if I wrote my notes out, I was writing like nine pages worth of lecture notes every single lecture we did. So by the end of it is brain killing because we've learnt so much, you couldn't remember what you learnt in the first hour because of the double lecture. You couldn't actually remember what you learnt at the start. And then by the time we get back next week and done it again, your hands are aching after was. I think it was a bit too much. I think like...L05 has got for differential equations the gappy notes, if he has something like that so that all the lecture notes match up rather than two sets of lectures we went through. If he did it like that and you bits to fill in rather than copying a very bit of definitions. Because it was constant like definitions...this dadada… and by the time you've got like fifty definitions you have not realised what you have written down.

¶118:

¶119: S16: So if he wrote down the key bits and then the other bits you supplement where it is already printed on the notes. So write the key bits so that you know that is what you've got to learn. You will definitely read them because you have written them.

¶120:

¶121: S13: That is what I think...because differentials. Because he writes the examples and you have to write it down, so you've got to get to the lecture anyway. It is quite good because it gets you to the lecture. And you've got all the key bits where you know there. You have I think that helps a lot. If the notes are a bit more organised…[Listen Again].

¶122:

¶123: S16: It makes stuff easier to take in. You don't want have to write down everything. You can listen to the supplementary material and take that in better. And when it comes down to the definition then you think now I can write this and focus on trying to understand it and not worry about missing things out.

¶124:

¶125: S14: In a lecture I was copying stuff down and I was thinking I am not paying attention. I am not actually understanding. I am just copying the words and I don't think you learn from that.

¶126:

¶127: S15: You don't really have time to think, do you. You are too busy like you don't want to miss anything in case he click it later.

¶128:

¶129: AM: Key thing in mathematics it is about intuition. If you are thinking about it it gets to a point you just blank out of it and It takes a lot long to get back into the sort of understanding it.

¶130:

¶131: S14: And trying to learn it later is much more difficult.

¶132:

¶133: S13: I think vector spaces...I think I learnt a lot more from examples than from actual definitions and theorems he wrote down. I got my understanding from what he was doing.

¶134:

¶135: S16: I think it did get heavy on theory rather than on examples.[Listen Again]

¶136:

¶137: M: Okay. Right we move on to Complex Variables? Which aspects of Complex Variables do you find helpful? I know you have not finished it? What aspects of it are helping you learn the subject or course well?

¶138:

¶139: S14: I think the notes are good because they are printed. So all you've got to do is write down the examples. Which means you get used to doing questions and writing out examples which is what is examined so you get used to the calculations. And the theory you can read through and he can talk about it and you can refer back and it can make you understand it better.

¶140:

¶141: S15: I think it will be good if there was like gap in the Lecture notes. Because I find sometimes you just tune out.

¶142:

¶143: S16: There are stuff you don't actually write down.

¶144:

¶145: S15: Yeah. You just like skip sections and you just sort of can back in and say oh crap I still have stuff there. Whereas having gappy lecture notes will help you focus a bit more.

¶146:

¶147: S16: Where you have to write examples down most them are already written in. You can go to two or three lectures in a role where you just sit there and your concentration drops and you just think I need to write something down just to...

¶148:

¶149: S13: You are likely to miss it aren't...you sit there you have nothing to do. I will go sometimes you don't want to go there if it is already and it is done for you.

¶150:

¶151: M: Anything else?

¶152:

¶153: S16: Err. I don't think I've got anything. He taught it well. We started off with things we've covered, we've moved on to kind of introducing new topics that we haven't done. I think he didn't jump in or go too quickly. I think it might have gone the other way. He could have gone too slowly at the start and it might have made some people think this is too easy module. That could have encouraged them to miss lectures thinking I've done this before, but may be somewhere in the middle like not too slow, not too fast.

¶154:

¶155: S15: The first couple of lectures was just a bit fast for me because of all the stuff we have previously done before. You can compress it down a bit.

¶156:

¶157: S16: [Check S16 and S14 Voice] Have everyone previously done it like...?

¶158:

¶159: AM: I think so yeah. I think the prerequisite...

¶160:

¶161: S16: Otherwise he could have been doing for the people who haven't. If everyone has done it then that probably could be…

¶162:

¶163: AM: If it is a pre-requite as well...but on top the complex number stuff that you have already done. The actual opinion of the statutory committee meeting is that having an expert talk through something is better even though you already know it to have them explain their view point on it. But with complex number stuff is so basics so there is not real view point you can have on it. [Group Affirmation: Yeah]. The only difference is the Principal Argument. That is about it. Everything else we've done before. He did really give an opinion on it.

¶164:

¶165: M: Okay. What would like improved or changed in the way complex variables are taught?

¶166:

¶167: S16: [Check S16 and S14 Voice] I just want to have some more things to write in the lectures. If not anything, to be more involved in it.

¶168:

¶169: S14: I like the idea of...the tutorials he goes through the examples and you get a little sweet at the end it. [Laughter].

¶170:

¶171: S16: It gives you the incentive to actually go to the tutorial.

¶172:

¶173: S14: It doesn't though because a lot of the time only one or two people wining it.[Laughter]

¶174:

¶175: AM: Speaking from experience

¶176:

¶177: S14: [Laughter] Sometimes you just don't want to go because you know you don't have a chance [Laughter from Group]

¶178:

¶179: M: What about you S13?

¶180:

¶181: S13: I don't do it?

¶182:

¶183: M: Oh. You don't do Complex Variables?

¶184:

¶185: S13: No.

¶186:

¶187: M: Okay. And S15?

¶188:

¶189: S15: Yeah. Like I said, slightly gappy notes will be good. Perhaps a few like small examples. A few more examples, smaller examples. Sometimes you have two massive examples and you plough through for half an hour and you don't learn much. Whereas with smaller ones you will be able to get to the point faster.

¶190:

¶191: M: To what extent does course or the module make use of Learn?

¶192:

¶193: S14: I can say I have never been on Learn.

¶194:

¶195: M: Is that for this course or module?

¶196:

¶197: S14: He gave us the problem sheets and he gave us the notes. So there is no need to go on Learn to download anything. So I wouldn’t know if there any resources there.

¶198:

¶199: S16: Doesn’t he give the solutions at the bottom of the sheets? Does he give details to that?

¶200:

¶201: AM: Yeah. He does. I remember an e-mail to that.

¶202:

¶203: S16: I haven’t been on and checked yet so...

¶204:

¶205: AM: Yeah, I think he sent an e-mail saying he’s put problems solutions other than that I don't think there are any other resources. In which case will adding resources helped, do you think? Anything you might need?

¶206:

¶207: M: In fact that is the next question. [AM: Laughter]. Basically what resources would you like developed for either Vector Spaces or Complex Variables that perhaps you don't have at the moment?

¶208:

¶209: S15: [Laughter...S14... I don't know really]. I think outside resources, like stuff that other people have done. Quite often I find it quite helpful to have slight different viewpoint on it. If you have like lecture notes from other universities for example, often it have slightly different angle on it, slightly different emphasis. I find that quite good. Broad knowledge, I quite like it.

¶210:

¶211:

¶212: M: And S13 what do you think?

¶213:

¶214: S13: For external sources. Err mm...maybe if they have like good external website that have different things...I know like GCSE's have things like BBC Bitesize. If they have something like that rather than drugging through your lecture notes you can just click on it to give you a quick brief. Something like that might be helpful.

¶215:

¶216:

¶217: S14: Recently I was trying to Google something because it was not in my lecture notes. But the things that come out are so complicated. You just want a result that is just going to give you your answer. If you can't find that on Learn, but I don't think there is anything where you can go really if you have that kind of problem.

¶218:

¶219:

¶220: M: In other words the Google throws up a lot more than you need whereas... MCU Apps for the phone has something on but that is just basic. If you have that every module you won't use. Something that is quite brief that will give you the key points might help.

¶221:

¶222: S15: I supposed the only problem with that is quite a lot of work. It is a very specific little thing. For a lecturer it is pretty hard work.

¶223:

¶224:

¶225: AM: It is quite a big undertaking to develop something like that. But if it was developed say over...I am jumping ahead of this project over several years if that was done in consultation with other lectures, I don't know which universities Loughborough is affiliated with. If they got lecturers who are specialist in that module to give their opinions on it, will that be more... will you expect something like that?

¶226:

¶227: S15: That will be good.

¶228:

¶229: AM: And then you could create a pool of lecture notes for each of the universities. It's a huge undertaking. It probably won't happen. [Laughter]. It will be good if did I think.

¶230:

¶231: S14: Think back to Vector Spaces, did he have communication with the class during lecture? I know L01 in Complex Variables he never really ask questions and we never have to interact with him.

¶232:

¶233: AM: I think he did give some in class exercises or whatever we call it? I don't think he asked direct questions in class exercises.

¶234:

¶235: S16: Is like here you go. Have a go at this. [Group Affirmation]

¶236:

¶237: S14: Sometimes when they ask questions people who aren't listening say "what, what?" and they kind of start paying attention, because they are being asked questions.

¶238:

¶239: AM: And it is not a personal question. It is not you, what is the answer? It is an open one but they here a question, that is, they jump. [S14: They say what? I don't know the answer don't ask me]. When the lecturer looks round they get panicking because they think he is going to ask them. It sparks them to learning. [AM: Laughter].

¶240:

¶241: M: This discussion that we have just had throws up questions about your preferred medium of learning resources, yeah? So I am going to go around the table starting with S13. You've got PDF, Video Tutorials, on-line exercises or tests? What is your preferred medium of learning? You can put them in any preference order you want.

¶242:

¶243: S13: I prefer the paper stuff to be honest. If it's got be paper stuff, I don't want to be just reading it. I need to be able to interact with it. I need to be able to write some bits so the gap lecture notes. I think that is probably the best. But errm, I do like what L05 did at the start where he's got in differentials he puts the examples, rather than give you the solution if you didn't get he did a you tube video of how to do it. I quite like that. I know [name of a lecturer]'s done a video lecture as well. If we missed a lecture, he did it online. I think some lectures if they missed a lecture they are not bothered to catch up with it. Because he puts the extract in I think that is good. I like this.

¶244:

¶245:

¶246: M: And S13?

¶247:

¶248: S15: I get gappy lecture notes. I think it is broken up in the style that [name of a lecturer] did as well. If you just have a huge document of lecture notes you might loose it. I prefer it when it is split up into three or four lectures or sets so that you can read through it. Its just a good length I thin. It splits the module up a bit as well.

¶249:

¶250: M: S14? Oh sorry, you can hold on to that and I will come back to. S16, we've got video tutorials, online exercises and tests or PDF files. Which of these do you prefer and why?

¶251:

¶252: S16: I prefer gap notes like the PDF. PDFs you can go through and highlight this. Whereas you could not do that on the internet. Whereas if you have a big block of text and you are reading through it you think this is daunting. It doesn't appear as bad to me personally.

¶253:

¶254: S14: I like the PDFs and the lectures and the problem sheets which are useful. But if you are like don't understand it completely and you want to try problem sheet it can be overwhelming. So I think, like [name of a lecturer] did the videos or something where she broke up proof into like sections to help. If there was like a check list of stuff to do or sometimes people don't know where to start. If there was like a video or may be a sheet that said how to attempt each problem. I think that will help a lot.

¶255:

¶256: M: Next question. Errm. Some students are disengaged. In other words they don't go to lectures or they don't...they are not into the subject or course. What could be the reason why they are disengaged? Is it because they are too busy doing other things, socialising...?

¶257:

¶258: S14: I think their priorities are wrong. I know some people. They just...they see lectures as like a second part of uni as opposed to the social side. I think they need to find the balance. And you think [S13: It doesn't] Sometimes times they are just happy with not doing well and I don't know who do to spur them on.

¶259:

¶260: S13: It kicks them gear for about a week.[Listen Again]

¶261:

¶262: S15: I think a lot of it is like, if you fall behind is like mentally you've got a big fight; you've got your work cut out for you. It will be easy to skip this one.

¶263:

¶264: AM: My suggestion from one of the previous Focus Group was to have some catch-up lecture, which highlights the key topics.

¶265:

¶266: S14: But if you've been to every lecture would you go to that one?

¶267:

¶268: AM: It is optional not a compulsory one.

¶269:

¶270: S13: What happens if he taught something that was important but was not said before?

¶271:

¶272: AM: That is why the lecture on recap everything that have been done, but it was just a shared idea. It is not definite that we are going to do that. But we are thinking some form of catch-up. [Listen Again]

¶273:

¶274: S16: So, to give me an incentive to come to the catch-up I will miss every lecture.

End of Transcript

APPENDIX V AN INTERN'S INTERVIEW TRANSCRIPT

Name: S3.1

Created On: 15/01/2016 00:18:24

Created By: F K Duah

Modified On: 15/01/2016 00:18:24

Modified By: F K Duah

Size: 8 KB

PGR: Postgraduate Researcher Interviewer,

S03: Interviewee

1:

¶2: PGR: Interview with S03. I have got a few questions. Like I said it should take us about 30 mins probably. First Question. Have you had any experience of working with staff other than as student in lectures or tutorials?

¶3:

¶4: S03: Working with staff at University?

¶5:

¶6: PGR: Yeah

¶7:

¶8: S03: No, Not at all.

¶9:

¶10: PGR: And how did you find the selection interview for the interns?

¶11:

¶12: S03: The selection interview it was quiet good actually. A lot of ideas were placed

¶13:

¶14: PGR: And what surprises came up.

¶15:

¶16: S03: Surprises?

¶17:

¶18: PGR: Yeah, Any surprises at all during the interview?

¶19:

¶20: S03: Erhm none that I can think of.

¶21:

¶22: PGR: Alright. Not even in relation to the questions that came up?

¶23:

¶24: S03: The questions were pretty standard, what I expected.

¶25:

¶26: PGR: And why did you want to become a student intern?

¶27:

¶28: S03: .... experience of working in university and maths education department which I am looking into as a career and just so to get some real experience in that to see how it works.

¶29:

¶30: PGR: And what role do you think students can play in shaping the design and delivery of the mathematics curriculum in general?

¶31:

¶32: S03: Erhmm very big role obviously students are what the whole thing is aim at so and if we have...certain students have some idea of what the rest of students want what, they need how they see ...how everything is taught that can massively change things.

¶33:

¶34: PGR: Can you give specific examples of as to how that can be done?

¶35:

¶36: S03: Erhmm, just like if people or students as a whole think certain lecture notes are hard to understand in some parts going, back to the lecturer, they can change things to make it easier. That is a very simple example.

¶37:

¶38: PGR: Right, from your point of view, what role do you think you are going play in the design of the module that you have been assigned to?

¶39:

¶40: S03: Erm...[Silent S03 not sure]

¶41:

¶42: PGR: Do you know the module you have been assigned to?

¶43: S03: Yeah. Complex Variables

¶44:

¶45: PGR: Right. So what role do you think you are going to play in the design of the new complex variable module?

¶46:

¶47: S03: Erhm. (Silence) It is hard actually (Silence)

¶48:

¶49: PGR: Mmmm.

¶50:

¶51: S03: Erhmm (Silence).

¶52:

¶53: PGR: Think about some of the things you may have told them at the interview. If you can remember any of them think in broad terms. When you start working, what is it that you are going to do to make a difference?

¶54:

¶55: S03: Alright, of the students how they think of the module I rely that back to the lecturer. [Review]

¶56:

¶57: PGR: How will you get to know that information?

¶58:

¶59: S03: Just by chatting with someone I will not assume what I say. It won't be too hard to find that information? And just how I think it might be improved, what I will do extra, how problem classes can be changed if not changed it is improved[Review]

¶60:

¶61: PGR: Urhm you have talked about some of the things you might do. I would also like to know the kind of relationship you will have with staff when you are working with them. What kind of relationship would you expect to have with staff?

¶62:

¶63: S03: And informal one where they see me as an asset and not just one of their students that they can overrule easily. I hope they listen to my ideas as a what useful ideas and not to be dismissed.

¶64:

¶65: PGR: That is fine. So to what extent do you see yourself as a typical undergraduate mathematics student?

¶66:

¶67: S03: To what extent?

¶68:

¶69: PGR: Mmm. To what extent do you see yourself as a typical undergraduate student like the rest of the cohort?

¶70:

¶71: S03: Pretty typical. I get pretty average results from what I've seen in other peers I know I am stereotyping my student sample. I know quite a lot of the maths students and we get along so.

¶72:

¶73: PGR: You selected yourself obviously. You opted to apply and to go through the selection process. Others did not. So what makes you either different similar to those people not involved now?

¶74:

¶75: S03: May be my interest for what I do after university has to do with maths education. while other people looking to go into pure maths or business will not see this internship not any use to them in the end [This is an important point].

¶76: PGR: Thanks for that. What positive outcomes to expect to expect from your involvement in design of the Complex Variable module for yourself?

¶77:

¶78: S03: What am I hoping to get out of it?

¶79:

¶80: PGR: Yeah

¶81:

¶82: S03: Erhm the experience of it all. Learning how the modules are thought will help me learn future modules because all the modules will use the same sort teaching structure just different content? Learning how little things like that can be improved. [Expectation of successful outcomes to be applied to future modules]

¶83:

¶84: PGR: And what positive outcomes do you think will emerge for the rest of the student body?

¶85:

¶86: S03: At the end of it next year second year students they have a much easier to learn module and they will be able to take in much content I don't know how it is possible, but probably find it enjoyable.

¶87:

¶88: PGR: Erm what about staff? What outcomes could emerge out of your involvement in the project with staff?

¶89:

¶90: S03: Staff after working closely with students will have a understand better how students learn and what the students think of their teaching methods and how their different teaching methods different effect on different students.

¶91:

¶92: PGR: Okay and erm what barriers to successful outcome of the module design do you think could crop up?

¶93:

¶94: S03: The barriers of it? Yeah

¶95:

¶96: PGR: Yeah

¶97:

¶98: S03: Erm mmmm. If the lecturers feel too strongly about the way they are teaching the module like if they think this way is definitely right well that could stop improvement from that point of view otherwise errm I can think of any other negative effects.

¶99:

¶100: PGR: Okay. Thanks for that. You talked about lecturers' strong views. What relationships as well?

¶101:

¶102: S03: Yeah if the...the relationship between the interns.

¶103:

¶104: PGR: Yeah between the interns and the lecturers. [S03 also repeating the same sentence.]

¶105:

¶106: S03: If that doesn't work out as well as it could that could also have negative effect.

¶107:

¶108: PGR: Right. And why...what could be some of the potential problems in the relationships?

¶109:

¶110: S03: Errmm obviously professional difference between...because these are professors of mathematics...and for them to listen to undergraduate in mathematics it might take them a bit of...there is a huge difference in I don't know what you will call it in authority or...

¶111: PGR: Power difference

¶112:

¶113: S03: Yeah

¶114:

¶115: PGR: Right what about your relationship with the other interns? Do you know them all?

¶116:

¶117: S03: Errm I know all of them all I speak to a few of them.

¶118:

¶119: PGR: What about the person you are going to work with?

¶120:

¶121: S03: Naomi is the only of the interns I don't know. I recognise her from lectures?

¶122:

¶123: PGR: Right. Are there any particular things you think need to be in place for the module design

¶124: process and subsequent delivery of the module to work well?

¶125:

¶126: S03: ...needs to be in place? [not sure pondering] Errm

¶127:

¶128: PGR: In order for things to work well, what measures need to be in place before you start working to ensure that things work out quite well?

¶129:

¶130: S03: Err. we need a proper structure of what we are doing as a work we can just be told go and improve this module we need to be told what parts need to be improved what statistics of how students did in their exams, how they did learn in their problem classes, lecture attendance will be pretty good for that. Knowing what we are knowing what we are with and what we are working to of course.

¶131:

¶132: PGR: How will you know that the activity you have been involved in has been successful or not.

¶133:

¶134: S03: You normally just tell like after a meeting whether progress has been made or not or whether good ideas have come up. But with something like this you don't actually know how the final outcome will be until it is taught next semester.

¶135:

¶136: PGR: Okay that is fair. Obviously when it is taught next year, you will still be here in your third year. How will you personally know that its worked out well?

¶137:

¶138: S03: Well we are doing the student leader programme as well, we will be mentoring them. Just mentoring the young students to see their understanding, whether or not the ideas we put in place they mention them that oh year that bit helped me. That will be the best way to find out if we are doing anything right there. [Review this]

¶139:

¶140: PGR: Right. And how would you if it has not been successful? If it has not been successful how will you know?

¶141:

¶142: S03: Well the same if they say that oh we tried these thing and it didn't work at all and I didn't understand it then that is when we know our ides have not been successful.

¶143:

¶144: PGR: Errm how do you intend to lead the rest of the undergraduate students studying mathematics to ensure that the views of those not directly involved in the design process are taken on board? How would you lead them?

¶145:

¶146: S03: How will I take into account what they think and pass it on?

¶147:

¶148: PGR: Because at the moment you are being employed to do this job. How will you go about leading the rest?

¶149:

¶150: S03: Quite a few ways of doing and I just chat to students anyway. But if you want a formal way of what you actual think you draw up a survey and ask people can you fill this in for 3mins. It is pretty easy from that point of view. [Review]

¶151:

¶152: PGR: Apart from surveys, you moved from chatting to surveys. Apart from surveys what esle could you do to ensure that others views are taken into board?

¶153:

¶154: S03: Errhm,online way if you have any problems, queries, questions about how it is taught and then I can pass them on to the lecturer. So asking for detail views like that if they are struggling errhm...[not sure]

¶155:

¶156: PGR: Okay obviously you guys are going to be involved in the design of resources, isn't it?

¶157:

¶158: S03: Yeah

¶159:

¶160: PGR: What sort of resources do you anticipate producing?

¶161:

¶162: S03: Errm. Help with the lectures, LaTex documents, everyone doing it knows how to use LaTex so we should be alright with that how to get notes and write equations and other resources as well. For some of the other ideas we talked about online discussion, a sort of forum for people to ask questions, I am hoping that could be done on LEARN or Facebook, something that all student are able to use, and create a page or link to something that everyone can discuss their module on.

¶163:

¶164: PGR: That is fine. These are all resources.

¶165:

¶166: S03: Yeah

¶167:

¶168: PGR: Err if you were not in evolved in the project at the moment, what do you think it will take to persuade you that is worthwhile to get involved?

¶169:

¶170: S03: If I felt that the module was being taught badly then I would want to do something about to change it

¶171:

¶172: PGR: Is there anything else that will probably get you on board other than being in the lecture and knowing that things are really going well?

¶173:

¶174: S03: Seeing people who are involved talk about it or working on it and want be interested from that point of view seeing what they are doing.

¶175:

¶176: PGR: Alright. And what could staff possibly learn from you working with you? in designing the Complex Variable module? What could they learn from you?

¶177:

¶178: S03: Learn the way that most students learn the modules and how they go through notes and how they talk to each other about the notes and what they do in their own time. Because of obviously most lecturers put up real English and most students won't go through them unless another student says yeah this is really good, learning how we actually work.

¶179:

¶180: PGR: Right and apart from learning how you guys work is there anything else they could from you

¶181:

¶182: S03: Err...learning how we don't work. [Sighed did not seem to be sure] [Laughter]

¶183:

¶184: PGR: Right, as a student, what could you learn from the design of the Complex Variables modules? What could you learn?

¶185:

¶186: S03: I wish it give me appreciation of the subject, help me with my grades, going through the notes like that. But it will help me appreciate the work and how efforts that goes to creation of modules design how to teach all modules and therefore I realise who these notes are set out like that and other notes are set out in different ways, advances in "different achievement" how to learn differently from each one.

¶187:

¶188: PGR: Err. Last couple of questions? To what extent do you see yourself as either as an expect or a novice learning mathematics?

¶189:

¶190: S03: Novice. Second Year like, I have done no. much in math e. A level I thought I knew everything come here you don't at I knew nothing. Compared to PhD students or Professors a novice completely.

¶191:

¶192: PGR: You have just compared yourself to PhD students or Professors. But when you compare yourself to the general public for example.

¶193:

¶194: S03: Expert. Normally when you say you are doing maths, every go ...[Surprise]Compared to most people I am know a lot more maths.

¶195:

¶196: PGR: So maybe you are not really a novice isn't it?

¶197:

¶198: S03: It depends on where you are [Laughter PGR and S03]

¶199:

¶200: PGR: And that last question. What does being a mathematician at university mean to you personally.

¶201:

¶202: S03: It personally mean seeing the world in different ways and seeing how people implement arguments in a structured way and to solve them in a systematic way and seeing the world in a logical way.

¶203:

¶204: PGR: And Errm, the lecturers and tutors here they consider themselves as mathematicians and professors. If you take Complex Variables Professor McIver will consider himself as a mathematician. Now and so the question that I have just asked is you as well to say what it is that I mean to be a mathematician. At this stage of your school career do you see yourself as a mathematician?

¶205:

¶206: S03: No

¶207:

¶208: PGR: And why not? Because I am still a student. [Laugh] You've got to respect that mathematicians have a lot more education than you and work professionally researching ne fields of mathematics while we are studding fields that have already been explored or solved. So Mathematicians will be people who do research in mathematics. That is about it. Thank you very much.

APPENDIX W AN INTERN'S DIARY

Name of Intern: S03

Created On: 15/01/2016 00:18:24

Created By: F K Duah

Modified On: 15/01/2016 00:18:24

Modified By: F K Duah

Size: 6 KB

L01, L02, L03, L07 are pseudonyms for staff.

S3.3, Diary of S03, A Student Intern and Student Partner

PGR: Postgraduate Researcher

¶1: [Name of the intern]

¶2: Date Entry in the diary

¶3: 4 July 2011 1st day we were introduced to all the computers and software we have and the health and safety stuff. [Name of L02] wanted a meeting straight away and gave us a list of 13 problem topics where people slipped up in the exams. We started looking into it and started writing a report on suggestions for each topic on why there may be difficulties there.

¶4:

¶5:

¶6: 5 July 2011 Finished the report in the morning and gave it to L02, he seemed impressed with how much we have done. He said he will take it into account as he re-writes the lecture notes and then we agreed we'll start on the supplementary handouts. Also I came across a problem with one of the problem sheets and asked L02 and L07 for help, they spent 10 minutes looking at it before noticing I didn't use substitution properly, definitely identified a major tripping point here.

¶7:

¶8: 6 July 2011

¶9: Spent most of the day writing a supplementary handout on parameterization. The focus groups showed students want to see every single step in the difficult problems with explanations, so this is exactly what I did. Took longer than it should as I'm still not that fast with Latex. After meeting with L03We spent the rest of the day fiddling about with Camtasia to get to grips with it for our video tutorials

¶10:

¶11:

¶12: 7 July 2011 Today I finished the handout on parameterization I started yesterday, and then did another one on Cauchy's integral formula, and then one on bilinear transformations. Getting fast with Latex and using templates I'm getting through them quite fast, the hardest thing is coming up with original example problems that work. So I got a lot done but pretty boring day to be honest.

¶13:

¶14:

¶15:

¶16:

¶17:

¶18:

¶19: 8 July 2011 Spent a long time today going through the handouts, changing some of the examples and making corrections. Also got some feedback from L05 saying it was really good and pointed out a few things that might make a mathematician cringe. PGR showed me something called Beamer for Latex that can make a slide show so spent some time on that testing out a few things because they would be good for the videos.

¶20:

¶21:

¶22: Date Entry

¶23: 11 July 2011 This morning we got feedback from L02 about our handouts. The sheet was handed back to me covered in red ink. Though all his suggestions were either grammatical errors or mathematical grammatical errors, which to be fair should be corrected, the last thing we want is to give out something with different notation to the lecture notes.

¶24:

¶25:

¶26:

¶27: 12 July 2011 S02 and I actually made a plan this morning, so our work is a bit more coordinated. So I'm taking the handouts we're making, making a Beamer file for them and then sending them to Naomi to record the video tutorials. Teamwork at its finest.

¶28:

¶29: 13 July 2011 Spent most of today on Limits, the handout is going fine but putting it in Beamer video form is not as easy as first thought, I know how to do everything in Beamer but its more of a content problem. We could spend time going through the graphical representation of limits or be it any other topic in the module, which should give help build a real understanding and be fresh start from the algebra in the text books. But whether this would be seen as extra material that can be avoided, or more material to learn is unclear. I managed to get help from Martin with a problem just by knocking on his office, nice to see the lecturers are willing to help.

¶30:

¶31: 14 July 2011 Progress meeting today, got a few compliments and suggestions form all the lecturers but I got the feeling we were pretending we knew the direction we were going better than we actually did. Although we now have experience in LaTeX and Camtasia, and we have a set format for all videos and handouts,

¶32:

¶33:

¶34:

¶35: 15 July 2011 Short day. S02 wasn't in so I tried my hand at recording tutorials, definitely not as easy as it seems. In an earlier meeting with L02 the idea of a lecturer doing the voice over for the tutorials was discussed. Though this may seem unpractical as they take a long time to record and L02 may even want to change a lot of the content so its discussed his way. Haven't really had much contact with him this week but will bring it up in our meeting on Monday.

¶36: Diary/Journal Entries Week 3

¶37: Date Entry

¶38: 18 July 2011 Today was a very good day in terms of learning and interaction with lecturers. I feel like I am part of the community of practicing mathematicians. We had a long and very productive meeting with L02 where we discussed progress, expressed the idea of visual representations of the topics, and he shared his knowledge on difficulties with this idea. Knowing this could be beneficial to me during my third year. This idea was taken seriously and not overruled.

¶39:

¶40: 19 July 2011 Managed to make another Beamer file, along with script all ready to be made into a video today. Looking at starting on other topics I'm realizing that to make these resources I need to read the topic a bit further than the module requires to fully understand it and its applications. I suppose this could be a good revision technique. At the same time I think if I was the sort of student who got 100% in the module I would not be as good at explaining concepts in these videos and handouts. Knowing where people struggle from personal experience is definitely useful.

¶41:

¶42: 20 July 2011 On Monday I asked L02 if he knew a good visual example for limits, got an email at 8am with the example that worked perfectly. So he definitely put some time and effort into finding something we suggested which was good.

¶43:

¶44: 21 July 2011 The Tea breaks this week have all been really productive and useful, and its good to be able to comfortably talk to lectures about interesting points in mathematics, it's also interesting to hear what they do as mathematicians and how they work together or alone.

¶45:

¶46: 22 July 2011 L02 came in today to personally answer a question I emailed him about how to approach bilinear transformations, saying what I suggested was a nice idea and he could use it to explain the lecture notes. This week I've had really good feedback from L02, however on the issues with video tutorials this is not the case, we're half way through the module and have only 2 videos "completed". I have constructed beamer files, along with scripts and even diagrams of what to draw on skim for S02 to follow for 3 video tutorials, and they have been on her desk all week. Suggestions that she should spend more time on video tutorials and leave the handouts to me seem to go ignored, this will need resolving if we are to get the videos ready before the 6 weeks are up. This could probably be avoided with some formal prioritization.

¶47: Date Entry

¶48: 25 July 2011 Another good meeting with L02, nothing much interesting happened today.

¶49:

¶50: 26 July 2011 L02 came in today with more examples with interesting results today, and I gave out my handouts in the tea meeting which have been constantly improved over the weeks, apart from the fact that I "assume" that a circle has an inside and an outside, they were well received.

¶51:

¶52: 27 July 2011 Today a thought something I wish as discussed in the focus groups; how do students picture complex functions? I suppose as the focus groups were taken early in the semester the students wouldn't have really thought about it. But knowing how many students are visual learners like myself could have had a strong effect on the direction the project went in. During the preparations for the limits video I found that S02 was completely baffled by the idea of a z plane and a w plane for the domain and image, whilst I had always pictured the functions in this way. Creating handouts/videos/student leader sessions that use these visual aids will definitely benefit visual learners but will only confuse other students further. Maybe the student leader groups could be split into different learning abilities, though sorting this out would be extremely difficult.

¶53: 28 July 2011 Interesting meeting this morning, a lot was discussed but the main thing I got from it was we are doing alright, we may not get everything done but we will get enough done for the project to be a success. And no one can agree on what the student leader project is about. The visualization problem from yesterday was kind of resolved, L02 has sent us a brilliant video that displays what I was trying to explain much better than we could have done with a pen, and he liked the suggestion of the visual aspects of the course being taught in the student leader meetings, though it will be up to us to recognize whether or not our group is responding well to this.

¶54: 29 July 2011 DAY OFF!!!

APPENDIX X AN INTERN'S REFLECTION ACCOUNT

Name of Intern: S03

Created On: 15/01/2016 00:18:24

Created By: F K Duah

Modified On: 15/01/2016 00:18:24

Modified By: F K Duah

Size: 6 KB

¶1: [Name of the intern]:………………..

¶2: [Name of the institution]……………..

¶3: [Self Reflection Account]………………

¶4: [Name of the curriculum development project]

¶5:

¶6: **Item 1.**

¶7: Reflecting on the focus group discussions you had, what student suggestions for improvement in the module have you not incorporated into the redesigned module for 2011-2012 academic year and why?

¶8:

¶9: Certain things that were suggested in the focus groups were not taken into account. Though at the time of the focus groups the interns would have agreed with most of what the students said, after careful consideration and discussion with lecturers some suggestions were deemed unfeasible.

¶10: The first suggested topic on our report was about interactivity in lectures. Though at the time it seemed like a good idea to have an energetic enthusiastic lecturer making each student feel part of the discussion we know this is impossible. The lecturers' want to use the lectures to lecture. L01 convinced me of this when he spoke about the fundamental differences between school and university. Though interactivity can be incorporated into tutorials, all we can do is suggest this to lecturers, how they conduct the tutorials should be down to them. If students want more interactivity they should go to student leader sessions.

¶11: The other suggestion that was not incorporated was making a clearer ratio between workload and module weight in coursework and exams. Students felt that in VS in particular the 10% coursework actually covered more content than the 90% exam. Though this may be an exaggeration, we have discussed this with lecturers and been convinced that the reason the ratios aren't the same is because of revision, if the coursework only covered 10% of the module then that's all that the students would learn in the upcoming weeks. Coursework is there to make sure that content is being followed throughout the semester, and failing a 10% test because you are not up to speed with the module is better than turning up to the exam thinking you are up to speed when you're not.

¶12:

¶13**: Item 2.**

¶14: Select one example of an aspect of mathematics you have learnt during your internship. Describe what you learnt and how you know you have learnt it well. For instance, you can demonstrate your learning by choosing a previously unseen example and explain it on pieces of A4 paper as if to someone unfamiliar with the mathematics (e.g. Second Year Student or the Researcher). You may also attach a copy of a handout you have produced that relate to the example of the mathematics you have selected.

¶15: Of the many aspects I have learnt, the most fresh in my head is the residue theorem, and its applications for real integrals. This was a part of the course I purposely missed out during the module with the intention of not doing that question on the exam. But on Monday in week four I spent nearly a whole day surrounded by 4 textbooks all with slightly different ways of describing the method. How I learnt it was by splitting the worked example given in the lecture notes into 3 separate parts, writing out each line in general form on scrap paper with wide spaces in between. I then dissected each line to make sure I knew how it was true, and how it logically implied the next line of calculation. This took a while as almost every line used a different theorem or topic from earlier in the module, each text book had it's own way of explaining each step so I had to choose the best from each. When I convinced myself that the 3 steps were true by themselves I looked at the process as a whole. The amount of other material from the module that was needed for this process surprised me, especially the fact that none of these are mentioned in the notes but rather just assumed. I know for a fact I fully understand this topic as I have been able to come up with my own example questions and visualise how the solution will unfold. When the solution did not follow the format I wanted to show, I knew how to change the question so that it did. In my handout, I have incorporated this 3 step method, which is my own, none of the text books used this. Though I mention in the key points at the end that this is more of a guide than a rulebook, and encourage the students to think of their own method to dissect the process. The handout also includes various explanations of the steps, which are my interpretations of the best explanation.

¶16:

¶17: **Item 3.**

¶18: Describe any study and research skills you used during your internship that enabled you to learn and understand the mathematics you needed for all or parts of your work as a module/course designer.

¶19: Throughout the 6 weeks I've been using up to 8 different textbooks on the subject and related areas. Previously in my course I've only used 1 textbook. The ability to shift through different texts to find different approaches to theorems and examples is definitely a skill I hope to carry into third year. Seeing through small changes in notation between sources has become nearly automatic now, and I can instantly recognise variables by the properties they hold rather than what they look like. This research skill would help when reading other notes but I found I always need a standard notation to refer back to, the lecture notes. Though nearly every source I've read refers to a complex function that is differentiable within a domain as holomorphic I still call it analytic just to be consistent with the notes.

¶20: These techniques along with a bit of creativity have helped me come up with new ways of presenting concepts. The Residue technique came from going through the examples backwards. This obviously does not always work logically so it helped me understand which steps follow in both directions and which needed certain conditions to make sense, therefore made it possible to split into steps, which logically make sense alone. The ability to make perfect examples with logical steps and commentary is definitely a study skill. It's the sort of skill I will need to get high marks on an exam.

¶21:

¶22: **Item 4.**

¶23: What specific transferable/employable skills have you developed in your role as a student intern working in partnership with academic mathematicians?

¶24: Identifying skills I've developed here that an employer would like is identifying fractions between 0 and 1, you can find as many as you like depending on how specific you want to be. A lot of the skills I've learnt here could have equally have been learnt in any temporary office job, so you can list them as you please.

¶25: The skills developed that would be unique to this particular job are more academic, most of which are mentioned in item 3. The furthest ahead I'm thinking is next year and I have definitely developed skills that would be useful in my course. In particular study and research skills and communicating mathematics skills.

¶26: **Item 5.**

¶27: Using specific examples, describe any problems/challenges you faced during your internship and how they were resolved or could be resolved for future interns.

¶28: Time management, though we had more than enough time to complete the required work, there could have been more of a structure to work allocation. Rather than going through the weeks concentrating on resource at a time we could have had a better overall view of the project. This would have stopped us spending time making resources that we later decide not to use at all.

¶29: Resource editing was pretty inefficient; many times someone's given me suggestions for edits on a handout that I re-did a week before. With so many lecturers willing to give suggestions on edits there should be a single place where they can put them up, either a word document alongside the pdf file on Dropbox or if we put up the latex file they can write notes on with %.

¶30: These are really the only problems I could think of.

¶31:

¶32: **Item 6.**

¶33: What advice will you give a student who may be considering entering into partnership with staff to design mathematics modules/course?

¶34: 1. You can ask the lecturers anything about mathematics. If you show that you genuinely want to understand a concept, no matter how basic, they would love to explain it to you. Sometimes even if you do understand something you can ask a lecturer and they may give you a perspective you didn't think of before.

¶35: 2. You work will be criticised. Mathematicians are among the most pedantic people you will ever come across. Even if you convince yourself that your work is perfect in every way a lecturer will find a way to say it's slightly misleading/incomplete/completely wrong. But remember that if just one of the pieces of work you have made has mathematical errors in it then your whole product looses credibility. Leave enough time to make changes to your work and ask more than one lecturer to get out his red pen on your work.

¶36: 3. Plan what you aim to do every day. It may seem like 6 weeks is along time, but with so many different directions you can go to improve a module you can easily get disorganised with what you are actually doing. It is possible you will spend 2 days making a resource and then decide that it's better to not have it. Make sure you have an overall vision of where the whole project is going rather than just concentrating on one resource at a time.

¶37: 4. Take time to really know the subject. Even if you got 100% in the module you are working in, you can always learn more. Use textbooks and any other sources to read into the topic from a different perspective. And once you have got through the part of the textbook that covers the module, read on another chapter, so you can know where the module leads.

¶38: 5. The resources you create will need to be different from the lecture notes, that is the whole point of the project. When you explain something differently, some people will prefer it and some will become more confused. There is no way you can make a resource that everyone finds enlightening and better than the lecture notes, but you can avoid confusion by at least sticking to the same notation as the notes. Use the same wording and copy and paste any theorems you use. There is no point changing anything that is a mathematical result or definition, even if your way is still correct.

APPENDIX Y A PRE-INTERNSHIP STAFF INTERVIEW TRANSCRIPT

Name: L02

Created On: 15/01/2016 01:09:07

Created By: F K Duah

Modified On: 15/01/2016 01:09:07

Modified By: F K Duah

Size: 10 KB

I: Interviewer

L02: Interviewee

¶1: I: Right, the first question that I have it's about your working experience with students. Have you any experience already working with undergraduate students other than as their lecturer or project supervisor or personal tutor?

¶2:

¶3: L02: Err, I think the answer is no. [Laughter]

¶4:

¶5: I: Right.

¶6:

¶7: L02: I certainly don't remember anything.

¶8:

¶9: I: Okay

¶10:

¶11: L02: I have been lecturing for quite a long time but I don't remember anything.

¶12:

¶13: I: Mm. Aright. The reason why I asked that question is so that perhaps we could contrast your previous experience with the current one but obviously if you have not had any experience then that is okay. Were you at the selection interview?

¶14:

¶15: L02: For the interns?

¶16:

¶17: I: For the interns, yeah, how did you find it?

¶18:

¶19: L02: How did I find it. Err it was useful to hear what they said. I mean it was very striking some of the differences between... I mean some seem to come in essentially unprepared. Whereas others have come in, they have obviously thought about what could be done possibly to improve the modules. So it was useful to have them and to notice the ones who had these ideas and were prepared to share them. That is what decided which ones to appoint.

¶20:

¶21: I: Okay so what was very surprising to you in terms of what they've got to offer?

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¶23: L02: I am not sure… if anything was particularly surprising in terms of what they have to offer. Some hadn't really prepared for the interview in the sense of not having thought about what they could do whereas others did come along with suggestions, like using Facebook for instances. We have thought about that already. But some have clearly thought about what they might say at the interview and others have not.

¶24:

¶25: I: Right and how motivated were the students in terms of wanting to be involved in the mathematics curriculum development?

¶26:

¶27: L02: How motivated? It's difficult to say. They all said they were motivated to be involved. I think the only way we will find out really is when they actually come along and do it.

¶28:

¶29: I: So from the response they gave you couldn't really tell?

¶30:

¶31: L02: I suppose what I just said that may be some were not all that motivated or they would have thought about what could be done before hand. That is an indication that they were not motivated as they could have been, if they wanted to come.

¶32:

¶33: I: And what role do you think the students can play in shaping the design and the delivery of the mathematics curriculum?

¶34:

¶35: L02: Well...

¶36:

¶37: I: And I am looking for your own views.

¶38:

¶39: L02: The actual design of the curriculum?

¶40:

¶41: I: Of the module? Yeah.

¶42:

¶43: L02: I am not sure we are looking for that at all. The actual design of the curriculum is ... I don't think they will be able to make that sort of judgment. They have not got the mathematical maturity to say anything about the curriculum. I mean what we are looking for is more to do with the way it is delivered rather than what material is delivered. So it is the method of delivery rather than the content.

¶44:

¶45: I: Okay, in relation to the specific module that you teach, which is complex variables, what role are they going to play or would you expect them to play in designing the new module?

¶46:

¶47: L02: The hope is that we would be able to come up with some new methods for delivery and additional resources. So one of the big things we found, not just for these modules but also for most modules, is getting the students to actually turn up. So hopefully we can have more attractive experience that will encourage the students to go to lectures and tutorials or whatever we decide to have. One of the things to talk about with the students is to find out: are conventional lectures and tutorials the best things to have?

¶48:

¶49: I: You did mention earlier on that some of them mentioned Facebook. Are there any other things they may have mentioned at the interview that perhaps you have not mentioned?

¶50:

¶51: L02: I actually wrote them down somewhere, what they were saying, more or less. One student thought that students were not good at communicating with staff, they thought students were not good at communicating with staff, so that is one thing that says what the problems are and ...err another student said we need to have a range of resources... students are not all the same basically so some students are better off with different things compared to others, so we need to have a range of resources available. Oh yes, notation is another thing that came up. Two or three students mentioned notation. The most difficult thing with a new module is coping with the notation that is used. In fact, it was suggested by one of them that we have a book, this yellow formula book, we have a book of notation as well as a book of formulae. There is another one here mentioning they feel that there is a barrier between students and staff. This going about what I said about students communicating with lecturers. Again looking at ways of improving interactions in lectures. They think it is useful for students asking questions and get answered in lectures. There is a barrier to overcome to get the confidence to do so. Again students read books, never been useful [… Not clear][Laughter]. One of them talked about having small groups but I am not sure if that is a practical thing. Small groups and better lecture rooms. We have no control over lecture rooms and we have not got enough staff for smaller groups. I can't remember what your question was now...

¶52:

¶53: I: Yeah you have answered it. I asked that other than Facebook what other things, the may have mentioned. You have actually answered it quite well. Unless you have something else that you want to mention.

¶54:

¶55: L02: No they were saying fairy similar things

¶56:

¶57: I: The idea of Facebook is very interesting. I am actually looking to see how it is going to pan out.

¶58:

¶59: L02: I am not familiar with it at all. I have never looked at it on the web. So I am...

¶60:

¶61: I: Anyway, when you start working with them, the interns, what is going to be the nature of the relationship you are going to have with them? What kind of working relationship are you going to expect to have with them?

¶62:

¶63: L02: I am not sure what you mean.

¶64:

¶65: I: Right, at the moment your working relationship with the students as it stands is that of a professor and a student, isn't it? That is the relationship, when you start working with them as interns, what will be the nature of the relationship?

¶66:

¶67: L02: Well, I am hoping it will be more like... err. I mean I have research students; hopefully it will be more informal like along those lines. We will be able to talk about things really. So relaxed. [Laughter I and L02]. I do not want any tensions between us so...

¶68:

¶69: I: And from your own perspective... from your point of view, what are some of the positive outcomes that the interns can derive from working on this project?

¶70:

¶71: L02: From the interns point of view? Err hopefully they will have a better understanding of mathematics, that is one thing. And they will feel better of that… but I guess it is an experience of worth having... It will be an experience they can all carry forward in getting into other jobs. It will advantage them when they come to get a job afterwards.

¶72:

¶73: I: In relation to that, if you could be a bit more specific, other than the subject knowledge what sort of skills will they probably acquire to take with them when they get into the work place?

¶74:

¶75: L02: They would have the confidence to work through things on their own. There will be problem solving eventually. That is the sort of thing you have to do in a lot of jobs. You know you are giving a task and you have to go away to give out to carry it through. And so having the maturity to do it on your own, something that has to be acquired. Hopefully they will be one step ahead of the game.

¶76:

¶77: I: What barriers to successful outcomes of the module design do you sort of envisage?

¶78:

¶79: L02: What barriers? [I: Yeah] I don't know.

¶80:

¶81: I: Yeah

¶82:

¶83: L02: I don't know. I suppose, I have a slightly fear that they won't be able to...I mean we are hoping that they are going to come up with good ideas but may be they won't. So there is a fear that the ideas won't there. I am not sure that that is what you are asking really. [Laughter]

¶84:

¶85: I: Well it is more less a good answer.

¶86:

¶87: I: Are there any particular things you think need to be in place for the module design process and the subsequent delivery of the module to work well?

¶88:

¶89: L02: Any particular things to be in place? You mean specifically to with how the module is going to be delivered for it to work well?

¶90:

¶91: I: Yeah

¶92:

¶93: L02: For it to work well. I don't think...apart from good set of lecture notes and I am not sure how many preconceptions they ... I am not really sure what you are getting at.

¶94:

¶95: I: The project director obviously is Tony and of course the whole... what I am trying to get at is that are there any resources perhaps you need to make the course design process work well that perhaps you don't have.

¶96:

¶97: L02: I still can think of anything. I think we have...unless those students suddenly start wanting to... I am afraid I haven't look at it yet. You gave me these links to these videos if the students wanted to make some videos. We have presumably access to ... we may not have it in the department we have access to that sort of thing. [Listen to this Segment again] Within the university? Within the University? [L02: Yeah] I would have thought we have pretty much at hand everything we are likely to need.

¶98:

¶99: I: And err...Time will tell

¶100:

¶101: L02: Time will tell

¶102:

¶103: I: Okay. How would you know that what the interns have been involved in have been successful or not?

¶104:

¶105: L02: Presumable with the interns. The problem with this module, Complex Variables, is the there is a clear... Some people don't engage with the module and there is a very high failure rate. But there is also a very high success rate. So we have these two disparate groups taking the module. I think the whole thing will be a success...we can smooth things out. I think the reason, in the past we have tried, oh we, I have made the module easier than it was because tying to get these weaker students on board but has had the effective of making the students who do engage get very high marks. So ideally you want to be able to make the module slightly harder but still… I think all the students who come to this university should be able to do reasonable well on this module if they can actually get down and work. So we will find the way of delivering the module so that we can engage the students so that we don't see these marginal failures. That will be the sort of measure we are looking for. To say haven't got, I don't know, say twenty percent failure that we have put through a number of years. [Listen Again]

¶106:

¶107: I: And if it was not successful, or if some aspects of it were not successful, how would you know other than the achievement?

¶108:

¶109: L02: We will presumably survey the students of their opinions so we will get some feedback. If we start using Facebook for instance we can get feedback on what the students think of it. Again we may well have written material prepared by the interns in a more friendly style. Again we will gain feedback. That is as far as I am concerned. We will ask them, apart from the actual results.

¶110:

¶111: I: If you were not involved in the project at the moment, what do you think it will take to persuade you that it is worthwhile to get involved?

¶112:

¶113: L02: If I wasn't involved? [Laughter: I & L2]. [Silence] I am trying to think what SK said to me when we he first mentioned it. I can't remember. I am not sure I have a good answer to that one.

¶114:

¶115: I: Did you volunteer to be part of it or were you co-opted into it?

¶116:

¶117: L02: Well I was asked to do it, yes. But I suppose, it was part of the reason for getting involved was what I said about the fact that that historically there has been quite a high failure rate and it did seem an opportunity to try and do something about it. So I guess to answer your question may be that is what it is, yeah. There has to be some identifiable thing you could work on. May be. So if somebody has been lecturing a module for which historically everything is fine, they probably won't, possibly won't want to get involved. I suppose there is a sort of certain pressure from the university I think, to improve well update teaching methods. I am not sure is always appropriate but there is a pressure there I think.

¶118:

¶119: I: And obviously you have been teaching for many years, because when we started you mentioned, you are very experienced.

¶120:

¶121: L02: Thirty-six, Thirty-Five, that is an estimate [Laughter: I]. I can't work it out its too long.

¶122:

¶123: I: As a professor, no one can question your knowledge. [Laughter: I & L02]. What could you possibly learn from working with the interns?

¶124:

¶125: L02: Nothing about the mathematics, I hope, or I am failing. It's been a long time since I was twenty-one or whatever. People have different attitudes and expectations now. So I can hopefully learn something about what they want out of the university careers more than I did. What they want to get out of the whole degree course and specifically what they want to see when they go to a module. More about the younger people attitudes I think.

¶126:

¶127: I: That is quite interesting even though I am much younger than you are and yet I can't even understand some of the things they get up to. The last few questions. What professional development opportunities do you think your working relationship with the interns could provide you? I suppose you have touched on this a bit from what you have just said. You said you might learn a bit about people's attitude that sort of thing. Are there any other professional development opportunities that...

¶128:

¶129: L02: Professional development opportunities? That sounds a bit grand for...[Laughter I & L02]. Nothing particular springs to mind from what I have just said.

¶130:

¶131: I: Right. Err obviously within the university, there are staff professional development activities going on from time to time and some staff do attend. What sort of professional development activities does the university offer? The professional development department; what sort of activities do they offer that you may have attended already?

¶132:

¶133: L02: Are you just asking factually or...

¶134:

¶135: I: Factually. For example, I have been on a course where they trained me as a graduate student on how to teach. That is an example the sort of thing I am asking for.

¶136:

¶137: L02: Well, I have been to many over the years. I was talking about one today. In fact that was L05 asking. There is one that is...what is it called? Recruitment and Selection Training, which you are supposed to go to before you interview people, which is why L05 was asking. And I have been on that and Probationer Supervisors and things like that. The ones that I have been that are quite useful are the ones that acquaint you with the university regulations and the way the university does things. I find those useful. The ones that I will say are not useful are the ones you mentioned where they are trying to tell you about teaching because it is just too general.

¶138:

¶139: I: Ah and when you say general are you therefore saying mathematics is a unique subject with its...

¶140:

¶141: L02: I am sure it's not just mathematics. I am sure every subject has elements that are very unique. To actually try and have blanket thing that is going to cover all subject areas, it is difficult to see how useful it could be. I mean there are certain things… The only things you can learn are common sense like talk to students, don't talk to the wall. [Laughter]. Things like this so… I am probably a bit sceptical about that sort of thing. May be more than I should be. [Laughter I & L02]

¶142:

¶143: I: To what extent do you see the interns you've recruited either as experts or novices learning mathematics? Again you may have touched on this from the earlier questions.

¶144:

¶145: L02: Do I think they are experts or novices?

¶146:

¶147: I: Yeah. To what extent do you see them either as experts or novices? Learning mathematics?

¶148:

¶149: L02: Sorry clarify the question. Are you asking about experts or novices in mathematics or methods for learning and teaching mathematics? In mathematics? They are definitely not experts. I don't think they are novices either. So well I suppose they are experts if you compare them to the general population. In terms of being trained to be mathematician, I think they are long way from being experts. So I don't know. So we are in the middle. [Laughter]

¶150: L02]

¶151:

¶152: I: That leads me to my last question. What does being a mathematician at university mean to you?

¶153:

¶154: L02: What does being a mathematician in my position or in their position?

¶155:

¶156: I: Or their position. You can cover both. Lets start with you first.

¶157:

¶158: L02: What does it mean to me? It gives me the chance to do something I enjoy doing. Well I always think the reason people do maths degrees is because it is a training in, well training is a wrong word, they get the chance to stretch their minds in a way that is valued by employers. So I don't think for the majority they do it because they particular want to have a career in mathematics. It is true most of them don't want a career in mathematics but they do appreciate that by being tested in that way they can actually then be held in a good light by potential employers. So it is to their advantage to do it. I am absolutely convinced that a lot of them are not interested in mathematics you just have to talk to them. But err...a lot of them are but there is a lot of them aren't. So I think it is more along the lines of what the degree can do for them than what the mathematics can do for them is why they come to university. That is their sort of reason for doing it.

¶159:

¶160: I: And as a professor in mathematics, you've already said you enjoy mathematics anyway. You are a mathematician because you enjoy. But what is your working day like as a mathematician other than lecturing?

¶161:

¶162: L02: What do you mean what is like? You mean how much time do I spend doing other things?

¶163:

¶164: I: Say if you are not teaching and you are not doing administrative duties, what is the nature of ... Take away teaching and admins.

¶165:

¶166: L02: It's just research basically which is... I don't have much time as I would like but that is the rest of the time. That is the most enjoyable bit. The teaching comes second. Sometimes close second. [Laughter: I & L02]. The admin rarely comes in very close. I think most people who are employed as university level mathematicians, it is because it is an opportunity to do research and have the freedom to do it. I will be surprised if many people will say anything different. I think some people enjoy the teaching aspects more than others. I am one of the ones who enjoy it. I think there are some who don't. They are prepared to put up with it.

¶167:

¶168: I: Thank you very much.

APPENDIX Z A PRE-INTERNSHIP STAFF EMAIL SURVEY

Name of Staff: L03

Created On: 15/01/2016 01:09:07

Created By: F K Duah

Modified On: 15/01/2016 01:09:07

Modified By: F K Duah

Size: 3 KB

¶1: [Name of Staff – L03]

¶2: 24 June 2011

¶3:

¶4:

¶5: Q1. What personal benefits do you expect the student interns to gain from their engagement with staff in redesigning the two courses, Vector Spaces and Complex Variables?

¶6:

¶7: A chance to work closely with mentors in their department, get to know staff better, have staff members they can approach about other questions or concerns related to their study or careers, e.g. letters of recommendation, advice, etc.

¶8Experience undertaking a fairly open-ended assignment, setting goals and priorities, teamwork.

¶9:

¶10:

¶11:

¶12: Q2. What additional mathematical knowledge and expertise, over and above course requirements, could the student interns gain from working with staff as partners?

¶13:

¶14: A much better understanding of what it is that staff are hoping that students will learn from a module and why.

¶15:

¶16:

¶17: Q3. What barriers do you think could arise and possibly make an impact on the contribution the student interns make to the course redesign process?

¶18:

¶19: Technological hang-ups, administrative barriers to changes in module structure

¶20:

¶21: Q4. Describe the nature of the working relationship you expect to develop between yourself and the student interns as they assume their role full time.

¶22:

¶23: I expect to meet with the interns basically every day during their time over the summer. The goal is for them to have a chance to talk both the project and any other concerns over in an unstructured, informal environment and also for them to feel that the staff know and care they are there every day working on the project.

¶24:

¶25:

¶26:

¶27: Q5. What professional development benefits do you personally expect to gain from the partnership between staff and the student interns in the course redesign process?

¶28:

¶29: I don't think I will get much credit from my involvement. Maybe some general good feeling from other members of the project.

APPENDIX AA A POST-INTERNSHIP STAFF INTERVIEW TRANSCRIPT

Name of Staff: L02

Created On: 15/01/2016 01:07:54

Created By: F K Duah

Modified On: 15/01/2016 01:07:54

Modified By: F K Duah

Size: 9 KB

I: Interviewer

P: L02

¶1: [Start of recording − audio file DM200004L02]

¶2:

¶3: I: Right, thank you for helping me. The first question that I have is: How would you describe your experience of the six-week summer internship, of the students who worked with you to re-design resources for Complex Variables?

¶4:

¶5: P: How would I describe...

¶6:

¶7: I: Describe your experience.

¶8:

¶9: P: My experience of it?

¶10:

¶11: I: Yes, your experience.

¶12:

¶13: P: Well, it was fruitful. I suppose, first of all, because... It remains to be seen, I suppose, how the resources will benefit the future students, because they developed those videos and hand-outs. But certainly, yeah. It was obviously fruitful for me, because it focused my attention on certain parts of the lecture notes that had deficiencies, shall we say, and I was able to improve them. So, there definitely was a direct benefit, even if the resources turned out to be not very good for whatever reason, which I'm not saying they will do. But we don't yet know how they're going to be received, the resources. I mean, I'd like to see the videos, for example. They look fine to me. But I suppose, it's how the students react to them that's the main thing.

¶14:

¶15: I: Ok, thank you for that answer. What surprised you most about the role played by at least the two students that you worked with?

¶16:

¶17: P: Surprised me most?

¶18:

¶19: I: Yeah.

¶20:

¶21: P: I really can't think of anything that surprised me.

¶22:

¶23: I: Ok. Obviously, you probably didn't find anything surprising. But we were hoping that there were some surprises that you might be able to talk about. But if there weren't any, that is all well and good.

¶24:

¶25: P: I certainly can't think of anything surprising. No. I think I'll have to pass on that one.

¶26:

¶27: I: That's fine. In what ways do you think the two student interns who worked on Complex Variables benefited from the internship experience?

¶28:

¶29: P: Well, they certainly know a lot more about Complex Variables than they did before. I think they gained an appreciation of the depth they needed to go into things to understand them properly. So, hopefully that will benefit them in their final years. Obviously, they gained skills as well. I'm sure they gained skills just from writing documents in LaTeX and producing these videos. They didn't know how to do these things before.

¶30:

¶31: I: Ok. Could you describe any instances, if there are any, of when the students gained insights into some aspects of Complex Variables?

¶32:

¶33: P: Well, there was one instance, where they told me they were talking about the definition of a limit, and I don't think they appreciated what it meant when we were talking about it has to give the same answer when you came from every direction into a limit point. It was only when I produced a little video that − actually I did it − I think they fully appreciated it. So, I think that's an example.

¶34:

¶35: I: Ok. Have you benefited from the staff-student partnership in the course re-design process? Obviously, you've touched on this before.

¶36:

¶37: P: Well, as I said, I think the lecture notes are definitely better than they were. There were some bits that I probably did realise needed improving, but there were other bits that I hadn't appreciated that they weren't being understood. So, I needed to be sat down and told, "We don't understand what that means." So, I think that is the main thing. I have a better appreciation now of what was causing problems.

¶38:

¶39: I: But socially, have you benefited?

¶40:

¶41: P: Socially?

¶42:

¶43: I: Yeah.

¶44:

¶45: P: Well, I enjoyed interacting with them. Does that count as a benefit?

¶46:

¶47: I: Right. You know the afternoon tea breaks − at least, I saw you at them a couple of times. How did you find the afternoon tea break experience?

¶48:

¶49: P: Well, ok, I guess. I wouldn't say... I had nothing against it, but at the same time, it wasn't something that I felt I... I felt too old, really, when I was there. I was probably the oldest. It was for the younger generation.

¶50:

¶51: I: Ok. If you were running the simple project, would you have done things differently?

¶52:

¶53: P: Well, I undoubtedly would have done. I definitely feel sometimes that there are too many people involved. There's this phrase − too many cooks spoil the broth. When it was first brought up, I thought it would be more me and the interns, basically. And I think they did get confused sometimes, because there were different people providing inputs on the subject matter. Well, that had benefits as well, I suppose. But a lot of the time, I wasn't sure... I had the feeling, sometimes, that maybe it would have been better if I hadn't had quite as many people telling me what was right and what was wrong. I think that was possibly the main thing. I did feel that there were possibly too many people involved.

¶54:

¶55: I: Right, that's fine. What is your view on whether other staff in the school would be interested in doing what you've done?

¶56:

¶57: P: I'd imagine that some − I won't mention any names − would be very much against it. Well, like most things, I think there would be people who would be quite happy and encouraged by such things and other people who want complete control over what they're doing. I don't want to name names, but I think there will be a very... It's not something that everybody would be comfortable with, I know that.

¶58:

¶59: I: But would you try to persuade them that it's worth doing?

¶60:

¶61: P: I think I'd wait and see what happens with... You know, when we have the leaders interacting with the next level of undergraduates on the module.

¶62:

¶63: I: Ok. Thank you for that answer. How do you intend to modify lectures to incorporate the peer support scheme that is obviously about to start and also to incorporate the additional resources − the videos and the hand-outs − into your teaching of Complex Variables?

¶64:

¶65: P: In detail... Well, to be honest, I haven't thought about it in detail of what I will be changing. I am going to be trying to bike up lectures more, which will inevitably... It means there's less time in lectures, I think. That will mean that some of the things will have to be done in tutorials, which will be bringing in these hand-outs and the videos. I haven't decided yet whether I... I don't think I'll actually use the videos in lectures. I think they will just take up too much time, basically. Funnily enough, I actually watched them all this morning, just to remind me of what they all had done. There's a lot of material there. I think it would take too much out of lectures to actually use them directly. But the main thing is going to be back-up for the sub-set of students. So the thing is to make sure it's catalogued in an easy and accessible way that if there's a problem with this bit of the lecture notes, then there's this extra thing there. So, it's more to do with establishing these links between the lectures and the tutorials and the additional material, rather than actually using it directly in the things themselves.

¶66:

¶67: I: How important is it that students take full advantage of the resources, all the resources that have been produced for Complex Variables?

¶68:

¶69: P: How important is it? I'm not sure what you're getting at.

¶70:

¶71: I: Obviously, the resources are available, and you've said that you probably intend to create links between lectures, tutorials and the resources, so that if students are having problems with some aspects, they know where to go. But if students do not make use of these resources, are there any implications for them?

¶72:

¶73: P: I intend to... There is a big... Well, as it is now − a completely self-contained thing where the stuff I produce in lectures and tutorials will be, in some sense, all they need to know. It's going to be there for the people. The other stuff is going to be there for the people who need it. Hopefully, it'll make it − well, these leaders groups and the videos particularly − more accessible to students who otherwise wouldn't have engaged. Maybe that's what it is. That's the important aspect. Because in the past, there's been a very marked break between a lot of students who just find the module very straightforward and a group of students − a large group of students − who don't really engage and get terrible marks. That's the reason why all this was done in the first place − for this module, anyway − to get these students engaged. So, for that group of students, it's going to be important. Hopefully this will get them working.

¶74:

¶75: I: So, how would it be possible for us to identify − or for you to identify − some of these who are "at risk" students?

¶76:

¶77: P: Well, we're going to have a class test, for a start, which we haven't had before. The student leaders − I thought that was part of their function − to actually try and engage with this group of students and find out who is either struggling or not willing to take the final step and actually participate. Hopefully by having somebody nearer their own situation, they'll be able to do more than I can.

¶78:

¶79: I: Do you think there are aspects of the simple project that could be used during the training sessions for new lecturers?

¶80:

¶81: P: I'm not sure if that can be done directly. As I said before, it is actually very useful to talk to students about the content − the detailed content −of a module. That's maybe getting away a bit from what you meant.

¶82:

¶83: I: I don't think you are getting away from what I meant.

¶84:

¶85: P: But if that aspect could somehow be made more widely available, I think that could only be beneficial.

¶86:

¶87: I: That's right. So, my understanding of what you've just said is: During the training sessions of new lecturers, perhaps they should be made aware that it's important that they talk to the students or they −

¶88:

¶89: P: Well, yeah. Or even somehow arrange sessions where they do talk to the students. But I suppose, I was thinking particularly about... It benefited me, because it was literally the detail that I found important. If you're training in a training session, you're not going to be going into the detail of a particular module. Again, it depends how it works out. But obviously, some of these things, like the student leaders and having these extra resources, could be brought to new lecturers' attention. But I wouldn't say it was exactly integrated with the simple project.

¶90:

¶91: I: Right. There are a couple of questions about teaching. And the reason why I'm asking these questions is because we thought that the students have what we are beginning to describe as either "tacit knowledge" or some kind of intuitive ideas about teaching. So, we wanted to explore your own ideas about teaching, so that we can tie them in. So, the question I have for you now is: How were you taught mathematics at university?

¶92:

¶93: P: How was I taught it?

¶94:

¶95: I: Yeah.

¶96:

¶97: P: I guess in a way that it was, "This is what you need to know. Go away and find out about it." When I was at university, we had very little interaction with the staff. The staff member would stand up there and recite a few things, but I think basically you were expected to find out the things for yourself. That's just the way it was. I think everybody of my age had a similar experience. But then, there was only 5% of people going to university at that time, so maybe it worked. And that's why it worked. For instance, I didn't have a single tutorial in the whole of my time at university. Well, I suppose I just accepted it and I didn't think anything about it.

¶98:

¶99: I: I guess in those days, you couldn't question your lecturer anyway. Right. So, how is your teaching now similar to or different from the way you were taught at university?

¶100:

¶101: P: I doubt if there are many similarities at all. Obviously, the formal lecture part is, in some senses, similar I guess. No, even that's not true, I think, because in those days, the lecturer just stood at the board and wrote at 100 miles an hour. That just wouldn't happen these days. Not very often, anyway. Apart from that, there are very few similarities, I would say.

¶102:

¶103: I: But are there any differences that you can touch on?

¶104:

¶105: P: Well, I suppose I can only speak for myself, of course. I always now provide notes, in which the students fill in gaps, for instance. And that would never have happened − well, never in my experience, that never would have happened − in those days. We had no tutorials. We actually have a lot more... Obviously then, you could go and see the lecturer, but very few people did. Now, there's a lot more contact between the staff and the students − trying to find out what their differences are. I suppose, it's a general change in attitude of trying to teach, I suppose, rather than just saying, "This is the material. If you want to pass the exam, you've got to find out about it."

¶106:

¶107: I: Ok. And I think this is probably the last question.

¶108:

¶109: P: That was quick.

¶110:

¶111: I: Your duties as an academic include researching teaching. What does teaching mean to you? Or what constitutes teaching? If somebody says, "What does teaching at the university involve?", what would you say?

¶112:

¶113: P: I'm not sure I understand the question.

¶114:

¶115: I: Ok. What does preparing for teaching... For you, what does it entail? There are some difficult questions in here.

¶116:

¶117: P: I'm still not sure really what you're getting at.

¶118:

¶119: I: Ok. We want to try to explore the idea about what pedagogy is. Obviously, pedagogy and teaching are the same. So, if I said to you, "Ok, tomorrow you're going to go and lecture; we have a lecture tomorrow," what is involved in planning for that teaching session? What response would you give?

¶120:

¶121: P: Well, you'd have to start with some material you want to convey, so you'd look at the syllabus − if you want to call it that. I just see a ... and try to put it over. I don't have any ground theory on working to it. I just try to put it over in the best way I can, and that'll depend on the material. Sometimes, you're required to do some theory, and that's quite detailed. You have to try to think of ways of how you're going to explain the difficult points. And other times, you're trying to think of good, illustrative examples.

¶122:

¶123: I: I think you've answered the question. The last time I interviewed you, I asked a similar question and I asked it in relation to professional development. One of the things you said was some of the training that the people offer in the Professional Development Centre or, say, from the Teaching Centre are not quite useful, which is understandable, because for somebody to train someone to teach mathematics, surely they must have some knowledge and understanding of how mathematics is supposed to be taught. So, the question I have for you now is: Do you think you need... Not just you. Do you think as a mathematics teacher in the university that you need pedagogical training?

¶124:

¶125: P: Specifically in how to teach mathematics?

¶126:

¶127: I: Yes.

¶128:

¶129: P: Well, I would hesitate to... I mean, it's sort of trying to put everybody into the same category. To some people, it comes naturally − in some sense −how to explain things in an easy way. I'm convinced a lot of it is common sense. If you've got common sense, you'll find a way through. It's thinking about how to do these things for yourself that often leads to the best way of doing it for you, because everybody is different. Probably the best way is just to watch two or three different people and see what they do. Different styles. If you're starting out, that is probably the way to go. I'm always a bit suspicious of formal training, I must admit, of how to do these things. As I say, a lot of it's common sense. You're just drawing on your own experience. But certainly watching other people who are good lecturers or are recognised as good lecturers − not according to them themselves − can only be beneficial. I don't know if that answers your question.

¶130:

¶131: I: Thank you very much. It does answer my question quite well and I really appreciate this. I'm having to turn the recorder off.

¶132:

¶133: [End of recording − audio file DM200004PL02]

APPENDIX BB COURSE DESIGN OBSERVATION FIELD NOTES

Fieldnotes ID: FNPR3, Week 3

Created On: 15/01/2016 01:12:23

Created By: F K Duah

Modified On: 16/04/2016 18:25:01

Modified By: F K Duah

Size: 4 KB

PR: Postgraduate Researcher (F K Duah)

VA: Visiting Academic

S01, S02, S03, and S04 are references to the Student Interns.

¶1: Date Entry

¶2: 18 July 2011 S01: I am sick and tired of it. It's boring. S01 was beginning to see…how lecturers might feel when producing problem sheets for their classes. S01 has almost finished producing Latex files for solutions to seven problem sheets and at this pointing he was getting tired "with typing". He puts his hands on his eyes and rubs them against his eyes.

¶3:

¶4: At lunchtime, a visitor from Australia visited the project office and joined the interns for afternoon tea.

¶5: VA: "Tell me about the work you have been doing"

¶6: PR: One of the interns stated that they have been redesign two modules VS an CV

¶7: VA: "Why these modules?"

¶8: An intern response: "Students find them difficult"

¶9: S04: What we include in the supplementary material are at the lecturer's discretions. We talk to the lectures but sometimes the they don't mind. We drew ideas from focus groups.

¶10: We have produced: videos, restructure notes, made links between problem sheets and lecture notes and extra problem sheets. The problem sheets are similar but slight different to exam questions. Harder examples

¶11: VA: “Will they use extra examples”?

¶12: VA: How do other lecturers run their tutorials?

¶13: Intern: Different lecturer do different things in their tutorials

¶14: A discussion of the purpose of a tutorial ensued

¶15: S04: It’s a good idea for one lecturer to sit in another lecturer’s to see how they teach.

¶16: S04: There is this lecture, he writes down the notes word for word.

¶17: S02: I have learned more during the internship than I did

¶18: S03: I have learned more during the internship than I did

¶19: 19 July 2011 PR: Today all the interns were focused on their individual activities. There were very little interactions in the sense as envisaged by Wenger (1998). At tea break, 3pm, S02 had a worksheet with the function, $f\,(\mathrm{z}) = 1/z(z+2)$ on it.

¶20:

¶21: L03 poses the question: Shall I show you how I will do this? She followed through with a discussion which appeared to pose even more difficulty for at least two of the interns.

¶22: S02 suddenly exclaimed: “When I am down there I understand. When I come up here, I don’t understand”.

¶23:

¶24: PR: This was because L03 seems to want to take the lead in sharing her mathematical content knowledge and use mathematical language she thinks the students understand but they don’t. At times she appears, not on purpose, to confuse the students although for politeness they often agree with her. L03 persevered in her explanation and eventually S04 said:” I think I have learnt something”. L03’s enthusiasm and willingness to share her knowledge aren’t probably bad things.

¶25: 20 July 2011 S03 and S02 engaged in discussions relating to feedback on worksheets they have produced. They are standing at the door ready to go. S02: “It’s quite disheartening when you go up there and they tell you what you’ve done is wrong.”

¶26:

¶27: S02: I am quite pleased with how it is at the moment. (PR: Referring to the handout she produced on Laurent series for which she had received feedback yesterday.)

¶28:

¶29: S04: Basis. What is a basis? What does that help me achieve".

¶30: [PR: Given that S04, had completed the module, and has been successful, that is passed, this statement suggests that are aspects of Vector Spaces that he does not understand. It will be useful to revisit this to check his understand. It is possible that in relation to Vector Spaces, his understand would have improved and his knowledge increased as a result of getting involved in the module redesign.]

¶31: S01 responded to the question posed by S04: Vectors that are all independent of each other.

¶32: S04: "I don't get what that helps me to do"

¶33: S01: "I do get where you are coming from though"

¶34: S02: "I am very proud of it"

¶35:

¶36: [PR: Explore the discussion on Kernel and diagonalization of a matrix when you can]

¶37:

¶38: 21 July 2011 Interview with VA.

¶39: VA: "Why screen cast?"

¶40: Some sort of video and tutorials, seen one on university VLE, person talking, listen to at your own pace. Some of the interns claim to have seen L5's video. L9 produced a one off video lecture when she could not attend lectures and the students liked the video and have commented upon this many times.

¶41: The interns suggested that the advantage of the video is that you can stop and think about something…

¶42: S04 you can switch off

¶43: S02: Will be of benefit if not done every lecture

¶44: S04: Students who don't attendance because of videos, it is their own fault.

¶45: VA: Why not video camera?

¶46: S03: Same as screencast

¶47: S04: Not wanting to see the person

¶48: VA: Why produce your own videos?

¶49: S03: Different notation, Content too much, content in the module not in the video, content in the video not in the module

¶50: S04: Own pace, what notation should b used for consistency with notes.

¶51: S02: Modules with the same name may be different in different universities.

¶52:

¶53: 22 July 2011 PR: There was a discussion about eigenvectors and eigenvalues which I should follow up using the notes taken.

¶54:

¶55: PR: I joined the afternoon tea break at 3:30pm. Much discussion had taken place prior to my arrival. Explore what might have gone on before I arrived.

APPENDIX CC INTERNS AND FOCUS GROUP DATA CODING FRAME

Name	References	Modified On	Created By
1_00 ISSUES ON LEARNING AND TEACHING	148	15/01/2016 03:24	F K Duah
1_01 TEACHING APPROACH	24	03/01/2017 12:26	F K Duah
1_01_01 Pedagogy	16	15/01/2016 03:25	F K Duah
1_01_02 Relationship	8	03/04/2016 01:49	F K Duah
1_02 LEARNING RESOURCE AND ENVIRONMENT	101	03/01/2017 12:29	F K Duah
1_02_01 Learning material	62	18/01/2016 16:12	F K Duah
1_02_02 Lectures and tutorials	40	15/01/2016 03:28	F K Duah
1_04 ASSESSMENT	23	03/01/2017 01:30	F K Duah
1_04_01 Formative assessment	3	15/01/2016 03:27	F K Duah
1_04_02 Summative assessment	20	03/01/2017 01:29	F K Duah
2_00 MUTUAL ENGAGEMENT	70	15/01/2016 03:31	F K Duah
2_01 Relationship and interaction	22	15/01/2016 03:32	F K Duah
2_02 Student voice	17	15/04/2016 23:17	F K Duah
2_03 Negotiation of content and meaning	6	15/01/2016 03:35	F K Duah
2_04 Support and feedback	23	08/04/2016 12:40	F K Duah
2_05 Conflict	2	15/01/2016 03:36	F K Duah
3_00 JOINT ENTERPRISE	43	15/01/2016 03:40	F K Duah
3_01 Motivation to partner	5	23/01/2016 08:02	F K Duah
3_02 Roles and responsibilities	38	15/01/2016 03:42	F K Duah
4_00 SHARED REPETOIRE	50	15/01/2016 03:46	F K Duah
4_01 Stories	20	20/01/2016 22:17	F K Duah
4_02 Products	24	16/04/2016 06:56	F K Duah
4_03 Reflection	6	22/01/2016 04:57	F K Duah
5_00 MODES OF BELONGING	37	15/01/2016 04:27	F K Duah
5_01 Engagement	1	16/04/2016 07:17	F K Duah
5_02 Alignment	22	18/01/2016 02:55	F K Duah
5_03 Imagination	14	18/01/2016 02:57	F K Duah
6_00 IDENTITY TRANSFORMATION	91	15/01/2016 04:34	F K Duah
6_01 Interns' understanding and confidence	38	16/04/2016 09:15	F K Duah
6_02 Interns' personal development	53	16/04/2016 09:15	F K Duah
6_03 Pedagogical and affective impact for staff	-	06/03/2016 02:14	F K Duah
7_00 SUSTAINABILITY	19	15/01/2016 04:45	F K Duah
7_01 Inclusivity	8	16/04/2016 07:25	F K Duah
7_02 Successful collaboration	11	23/01/2016 13:39	F K Duah
8_00 MATHEMATICAL BELIEFS	33	16/04/2016 07:02	F K Duah
8_01 Views on mathematics	6	16/04/2016 12:06	F K Duah
8_02 Being a mathematician	26	15/01/2016 04:24	F K Duah
8_03 Views on Vector Spaces	1	03/11/2016 01:51	F K Duah
9_00 EXPECTATIONS	70	26/03/2016 04:08	F K Duah
9_01 Tensions & Challenges	29	15/01/2016 04:58	F K Duah
9_02 Outcomes	25	23/01/2016 03:37	F K Duah
9_03 Student perspective	9	15/01/2016 04:58	F K Duah
9_04 Relationships	7	01/03/2016 22:03	F K Duah
X10_00 SOURCE OF PEDAGOGIC KNOWLEDGE	-	15/01/2016 04:48	F K Duah

APPENDIX DD STAFF INTERVIEWS CODING FRAME

Name	References	Modified On	Created By
1_00 ISSUES ON LEARNING AND TEACHING	-	15/01/2016 03:24	F K Duah
1_01 TEACHING APPROACH	-	03/01/2017 12:26	F K Duah
1_01_01 Pedagogy	-	15/01/2016 03:25	F K Duah
1_01_02 Relationship	-	03/04/2016 01:49	F K Duah
1_02 LEARNING RESOURCE AND ENVIRONMENT	-	03/01/2017 12:29	F K Duah
1_02_01 Learning material	-	18/01/2016 16:12	F K Duah
1_02_02 Lectures and tutorials	-	15/01/2016 03:28	F K Duah
1_04 ASSESSMENT	-	03/01/2017 01:30	F K Duah
1_04_01 Summative assessment	-	15/01/2016 03:27	F K Duah
1_04_02 Formative assessment	-	03/01/2017 01:29	F K Duah
2_00 MUTUAL ENGAGEMENT	20	15/01/2016 03:31	F K Duah
2_01 Relationship and interaction	7	15/01/2016 03:32	F K Duah
2_02 Student voice	12	15/04/2016 23:17	F K Duah
2_03 Support and feedback	1	08/04/2016 12:40	F K Duah
2_04 Negotiation of content and meaning	-	15/01/2016 03:35	F K Duah
2_05 Conflict	-	15/01/2016 03:36	F K Duah
3_00 JOINT ENTERPRISE	15	15/01/2016 03:40	F K Duah
3_01 Motivation to partner	7	23/01/2016 08:02	F K Duah
3_02 Roles and responsibilities	8	15/01/2016 03:42	F K Duah
4_00 SHARED REPETOIRE	-	15/01/2016 03:46	F K Duah
4_01 Products	-	16/04/2016 06:56	F K Duah
4_02 Reflection	-	22/01/2016 04:57	F K Duah
4_03 Stories	-	20/01/2016 22:17	F K Duah
5_00 MODES OF BELONGING	3	15/01/2016 04:27	F K Duah
5_01 Engagement	2	16/04/2016 07:17	F K Duah
5_02 Alignment	1	18/01/2016 02:55	F K Duah
5_03 Imagination	1-	18/01/2016 02:57	F K Duah
6_00 IDENTITY TRANSFORMATION	58	15/01/2016 04:34	F K Duah
6_01 Interns' understanding and confidence	11	16/04/2016 09:15	F K Duah
6_02 Interns' personal development	27	16/04/2016 09:15	F K Duah
6_03 Pedagogical and affective impact for staff	20	06/03/2016 02:14	F K Duah
7_00 SUSTAINABILITY	44	15/01/2016 04:45	F K Duah
7_01 Inclusivity	38	16/04/2016 07:25	F K Duah
7_02 Successful collaboration	6	23/01/2016 13:39	F K Duah
8_00 MATHEMATICAL BELIEFS	20	16/04/2016 07:02	F K Duah
8_01 Views on mathematics	5	16/04/2016 12:06	F K Duah
8_02 Being a mathematician	12	15/01/2016 04:24	F K Duah
8_03 Views on Vector Spaces	3	03/11/2016 01:51	F K Duah
9_00 EXPECTATIONS	53	26/03/2016 04:08	F K Duah
9_01 Tensions & Challenges	15	15/01/2016 04:58	F K Duah
9_02 Outcomes	23	23/01/2016 03:37	F K Duah
9_03 Student perspective	10	15/01/2016 04:58	F K Duah
9_04 Relationships	5	01/03/2016 22:03	F K Duah
X10_00 SOURCE OF PEDAGOGIC KNOWLEDGE	72	15/01/2016 04:48	F K Duah

APPENDIX EE A PAL PARTICIPANT INTERVIEW TRANSCRIPT

Name: PS05

Created On: 05/01/2016 21:00:37

Created By: F K Duah

Modified On: 15/01/2016 07:15:33

Modified By: F K Duah

Size: 14 KB

I: Interviewer

P: Interviewee (PS05, A PAL participant)

PL04 and PL05 are references to two PAL leaders.

¶1: **[Start of recording - audio file PS05]**

¶2:

¶3: I: Interview being conducted on the 6th of December with PS05.

¶4:

¶5: P: PS05.

¶6:

¶7: I: Ok. Thank you. Thanks very, very much once again, …, for coming.

¶8:

¶9: P: You're welcome.

¶10:

¶11: I: I very much appreciate it. The first question that I have for you is: How many of the mathematics peer support sessions have you attended so far?

¶12:

¶13: P: I've attended all of them apart from one, when I had a clash with a one-off event from another module that I'm studying.

¶14:

¶15: I: Right. So, in other words, you've attended seven out of the eight sessions.

¶16:

¶17: P: If there have been eight so far, then I've gone to seven, yes.

¶18:

¶19: I: Now, obviously, you just said that there was a clash with the timetable. How do you think we could address that kind of problem so that we don't have those situations?

¶20:

¶21: P: There was nothing the department could really do about that. The clash with another module was a guest speaker coming to give us a communication skills workshop, and the department obviously had no idea when those sessions were going to be and quite how the timetable was going to look. I don't think there's anything you could do to prevent that happening in the future.

¶22:

¶23: I: Ok, thank you very much. Do you go to the peer support session alone or with a friend?

¶24:

¶25: P: I know some of the people in the session, so I have course mates who I attend with. But I suppose I make my way there on foot. I don't really walk with anyone.

¶26:

¶27: I: Right. Now, would you have gone there... Would you have preferred to go with your friends if you were given that opportunity?

¶28:

¶29: P: 2 I don't really mind who I attend the peer support sessions with, because I find them useful for me in their own right, regardless of who else is there with me at that point. I ended up choosing a different peer support session than my course mates because of the way my timetable was different to theirs, and I picked the one that was most suitable for me.

¶30:

¶31: I: Alright. So, why do you choose to go to the mathematics peer support sessions?

¶32:

¶33: P: Well, I go because I might like further clarification of some of the material the lecturer has raised in the lectures, or the chance to work through additional examples and have those examples explained to me in perhaps a clearer, more detailed way than the lecturer can provide due to the time constraints on his lectures.

¶34:

¶35: I: Right. Now, are there any other reasons, for example social reasons, as to why you go to the peer support sessions, apart from the academic ones?

¶36:

¶37: P: I quite like our PAL leaders. I enjoy having a chat with them, mostly related to work whenever we're there. But I go mostly because it'll help my mathematical understanding and improve my chances of passing the end-of-module exam.

¶38:

¶39: I: Right. So, in terms of chatting with the student leaders, are there any things that you talk about that don't relate to mathematics?

¶40:

¶41: P: We occasionally talk about different modules and how we're getting on with particular modules that we're studying at the moment. They perhaps mention if there are any particularly good modules or good lecturers to be watching out for in the future. Stuff like that, really. Just mostly maths-related chat about possible options in the future sort of thing.

¶42:

¶43: I: Ok. Tell me about some aspects of mathematics, some aspects of the mathematics peer support sessions, that you enjoy.

¶44:

¶45: P: They're structured well in that often, everybody in the group gets a chance to contribute to the peer sessions. It's slightly more informal than a lecture. Perhaps that creates an environment where we feel quite encouraged to contribute, to bounce ideas about, bounce ideas off each other and that's good. Also, well, the amount of working out that gets provided is useful - from my point of view - in being able to logically see all the steps involved with a particular calculation or process. I just find most of it very useful, really.

¶46:

¶47: I: And do you enjoy doing mathematics with other students?

¶48:

¶49: P: Yeah, I definitely do. I'm studying Maths Education at the moment, and we've touched on social constructivism, which is the idea obviously that people learn maths a lot better when they bounce ideas off each other. And I think a large part of that is true. Maths doesn't have to be a solitary experience. You can very much work well - and perhaps even be motivated to do better maths - in a group of people. So, I think it works well. I do enjoy doing maths in a group, yes.

¶50:

¶51: I: So, do you think social constructivism has a role to play within the peer support scheme that we're running at the moment?

¶52:

¶53: P: I think so, yeah. I feel as if it can motivate students to generate ideas and share them within the group, improving not only their mathematical knowledge, but others' as well.

¶54:

¶55: I: Right. I'm going to probe a little bit more about the student leaders. You talked about the fact that you enjoy working with other students as a result of social constructivism. But do you enjoy working with the particular, the particular student leaders, who have been assigned to you?

¶56:

¶57: P: Yeah, yeah, I do. They're very friendly, very helpful. They're obviously very knowledgeable and very approachable. If we have any problems, they've told us we can e-mail them and they can go away and spend some time thinking about how best to answer our questions. I get on very well with both of them, and that's one of the reasons why I enjoy the session so much, because I almost feel as if I were friends with the student leaders, which is sort of the point.

¶58:

¶59: I: And what you said - both of them. Which two are you talking about?

¶60:

¶61: P: My two student leaders at the moment are PL04 and PL05.

¶62:

¶63: I: Ok, thank you very much. How do the student leaders, the third years who provide peer support, work with you when you are in the session?

¶64:

¶65: P: What they do often is recap the lecture material, ask us if we have any particular queries about any of the processes, talk through with us which steps we should follow in order to complete a question and ask us to contribute with working out or explaining parts of the procedures on the board to not only them, but to the other people in the group, as well.

¶66:

¶67: I: Ok. Think about the last session that you went to. Can you take me through how the session unfolded? From the time you entered to the time you finished, what actually happened during the session?

¶68:

¶69: P: So, the last session that we had, I turned up perhaps a couple of minutes late, because I had a lecture in another part of the campus. But I showed up and strangely there were only about three or four other people apart from the leaders in the session at that time. I welcomed the leaders and said hello to everybody else who was in the PAL session. The student leaders kicked off by saying, "Today, we're going to talk about the Gram-Schmidt Process. Do all of you know what the Gram-Schmidt Process is and what the steps are which are involved in the Gram-Schmidt Process?" And if any of us didn't, they gave us a quick recap of the Gram-Schmidt Process, then referred us to questions on Problem Sheet 6, I think it was, where we would have to use the Gram-Schmidt Process to construct an orthonormal basis of some sort and wrote the information on the board. They then asked us to provide the steps necessary to complete the question and generate the correct answer. We threw ideas out and they told us if they thought those steps were correct or whether we needed to have a re-think about how we were approaching the problem. Then once we as a group agreed and knew what we were doing, they put the corresponding steps on the board, so that we could all copy it down. We worked through that example and perhaps another one afterwards to make sure we perfectly understood what was going on with the question. And this process took up most of the student leader session time, so by the time we had completed a couple of questions thoroughly, we then agreed that that had been a productive session and that we would meet again at the same time and same place next week.

¶70:

¶71: I: Ok, thank you. That's quite detailed. Thank you for that. But I just wanted to know about the use of the board. Do you get opportunities to go up to the board to present yourselves as students or is it just the student leaders?

¶72:

¶73: P: Oh, are we talking now about the most recent session that I had or in any of the sessions?

¶74:

¶75: I: Any session.

¶76:

¶77: P: In previous student leader sessions, we've been encouraged to write stuff up on the board if we feel we're confident enough and can give a suitable explanation to the people in our group. That particular session I just talked about with the Gram-Schmidt Process - none of us did. But that was because we were understanding the material from our seats and we felt as though none of us needed to go up on to the board to explain it, and that we couldn't explain it in fact better than the student leaders could, anyway.

¶78:

¶79: I: Ok, thank you very much. Describe the way in which the mathematics peer support sessions differ from going to normal tutorials, for example.

¶80:

¶81: P: I think - and this is my personal opinion - that the tutorials are more formal than the student leader sessions. That's because the tutorials still feel somewhat like a lecture with more examples than a lecture, for sure. But very structured, in that the lecturer or the postgrad students will be up at the front explaining how to do something or watching us to make sure we know what we're doing and we're doing it. But there's less opportunity for conferring and generally sharing ideas. That's the sort of thing that comes out in the student leader session - how well we understand the material and how good we are at communicating it to others in the group, sharing ideas as I've said and generally working together slightly more to come to a consensus or a solution to problems.

¶82:

¶83: I: Ok, thank you. Tell me something that you have learned by going to a mathematics peer support session. I know you've spoken about Gram-Schmidt already. But this is supposed to be very specific. It may well be that you may give a different example from Gram-Schmidt. Tell me about any specific example of something you've learned or perhaps you didn't know at all but at the end of the student leader session you said, "Really, I've got this."

¶84:

¶85: P: There was a student leader session where we tackled some sample questions from previous Vector Spaces in-class tests. During that session, I developed a greater understanding of how to successfully complete questions off of the in-class tests in the past, for example, questions about proving that a certain map was well-defined and linear in the rationals, and questions relating to that map. There were additional questions about how to generate the basis of an infinitely large eigenspace for a given map, for example, which we also went through in the same student leader session. And I became more comfortable with how to approach those problems. And in fact, when a similar, yet slightly different question came up in my exact Vector Spaces in-class test, I felt a lot more equipped to answer it and did in fact get most of the marks on that question.

¶86:

¶87: I: Ok, thank you. Tell me how you prepare, if anything at all, in advance of going to the mathematics peer support sessions?

¶88:

¶89: P: Our peer support sessions are on a Thursday, which happens to be the day after my Vector Spaces tutorial time on a Wednesday. As such, round about Tuesday or Wednesday I will have attempted three or four - maybe more - questions off of the current problem sheet for Vector Spaces. And by that point, I either know that I can answer the questions satisfactorily or that I have a problem with a particular question and need to raise it in the peer session. So, on Thursday, I would often go equipped with knowledge of what I'd like to raise or points that I'd like further clarification or explanation of by the student leaders. I'd then put those questions to the leaders if they did indeed ask for material that we'd like them to go over during the session.

¶90:

¶91: I: Ok. What do you talk about on mathematics peer support sessions with your friends outside the session, outside the session time.

¶92:

¶93: P: That's a good question. We discuss how confident we're feeling with the Vector Spaces material, any areas that we particularly have difficulties understanding at the moment. But generally, a lot of our chat about the student sessions is that they're very useful and we come away with a greater understanding of the topic as a whole and they're very beneficial to improving our education and mathematical understanding so far.

¶94:

¶95: I: Ok. And do you talk about the peer support sessions with your friends who are not necessarily doing mathematics?

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¶97: P: Not so much. I sort of leave the maths talk to my course mates, and if I'm speaking to other people, I would talk to them about completely unrelated, non-course-based topics.

¶98:

¶99: I: Do the student leaders ever contact you - I'm sure I know what the answer will be - or do you contact them outside the peer support session and why?

¶100:

¶101: P:Well, PL05 or PL04 do in fact e-mail most weeks to say, "We're having a session this week at this time and this place, where we..." Either their e-mail says, "We'll be going over such-and-such a topic in our peer session this week," or their e-mails say, "We would like you to come to us with any information of topics that you don't understand, so that we can help you to understand them." And as such, I've e-mailed them back saying, "I don't particularly understand X topic in Vector Spaces. Could you please go over this in our session this week? Thanks very much." And they've often replied saying, "Yes, that's not a problem. We'll cover that in the sessions. See you then." So, yes, we do e-mail outside of our sessions weekly.

¶102:

¶103: I: So, apart from the e-mail as a means of communication, do they use other forms of communication?

¶104:

¶105: P: Not really. But I have bumped into both of them just around the Schofield Building and in the Maths Centre every now and then. But that's sort of been by accident - same place, same time kind of thing.

¶106:

¶107: I: What - if anything - in terms of your study habits has changed by going to the mathematics peer support sessions?

¶108:

¶109: P: I suppose I have a greater motivation to complete lots of the problems off of the Vector Spaces problem sheets, because I now feel as though I can get additional explanation and clarification if I don't know how to do a particular problem. So, it's more worth my while to try a wide variety of questions, so that I can learn as much as I can, either from the lecturers or the tutorials or the peer sessions. I suppose it's been all good, then, in terms of just getting me trying more questions more often.

¶110:

¶111: I: Do you think the peer support sessions make you work harder or less hard?

¶112:

¶113: P: Work harder, definitely, because I'm more motivated to get a better grasp on the material that's being covered, and also so that I can make a positive contribution to the peer sessions once a week.

¶114:

¶115: I: And in what ways has going to the mathematics peer support sessions changed the way you think about the mathematics you are studying?

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¶117: P: Do you mean other maths modules, or the way I think about this particular module, Vector Spaces?

¶118:

¶119: I: The way you think about mathematics in general.

¶120:

¶121: P: How the student peer sessions -

¶122:

¶123: I: Change the way that you think about mathematics, the mathematics that you're studying. First of all, let's focus on the mathematics as in Vector Spaces first, and then perhaps explore mathematics in general.

¶124:

¶125: P: The peer sessions have helped me take a more relational view of Vector Spaces. I can better see the connections between all the separate sections of the module that I'm studying. I have - as I said - a better overview. I feel as though I know how everything fits in better. I can understand and apply one week's worth of knowledge to another week's. I can sort of build upon my past knowledge of Vector Spaces and develop my sort of concept image of Vector Spaces more and more with each peer session that I attend. In terms of "How have the peer sessions developed my mathematical understanding in general," I guess they've helped me to communicate better with others of a similar age or people in a position of authority, as it may be. I guess I have a better understanding of how I should be looking for links between separate sections of maths and sort of drawing together my knowledge into a whole and sort of... I see maths as less disconnected subjects or modules. As a whole, I see it as more of a discipline with overlaps between separate disciplines and sub-sections. So, I guess it's helped me improve my view of maths in general.

¶126:

¶127: I: Ok. Is there anything in particular that you like more of or less of about peer support sessions, in mathematics in general?

¶128:

¶129: P: The peer sessions are pretty good at the moment in their balance of our opportunities to contribute with the peers and the peer leaders having the chance to share their knowledge with us, share their tips and advice on how to do exam questions. I feel as though the setting works. The sort of more informal format works and they're the right sort of length of time and the right sort of pace to be successful in the future.

¶130:

¶131: I: Have you become more or less confident with mathematics by going to the mathematics peer support sessions?

¶132:

¶133: P: Oh, more confident, definitely. Just in general - having been exposed to a variety of questions, knowing the different techniques to tackle them, being able to consolidate and apply my broader knowledge of maths to different situations. It's all improved my confidence an awful lot.

¶134:

¶135: I: Ok. Just in relation to that question - do you think there are any specific aspects of Vector Spaces that you are now more confident with as a result of attending the sessions? You may have answered this already.

¶136:

¶137: P: Certainly with regard to the typical questions which come up in exams, how to apply certain procedures, such as the Gram-Schmidt, effectively without forgetting the steps or confusing the algorithm, typical tips and tricks to use when asked to prove a certain theorem or property of a map, for example. Generally how to go about constructing and tackling answers to questions.

¶138:

¶139: I: Now, obviously you've talked about how you've become more confident with mathematics. But as a person... So, we're forgetting about the mathematics. As a person. As a person, how has going to the peer support sessions impacted on you, your confidence as an individual, as a person? In other words, your confidence here. I'm not looking in relation to mathematics itself, but as an individual involved in the community.

¶140:

¶141: P: I’ve touched briefly on how I feel my communication skills have improved and that obviously is not limited to just maths. I feel more confident talking to people in generally explaining my thought process. I also feel as though it's improved my work ethic. I'm perhaps now more committed to completing all my tasks quickly, but also effectively. I have better time management skills. I can... I feel as though I could solve a greater variety of tasks in real life and not just in maths. I think it's been great.

¶142:

¶143: I: We're almost there. We're getting to the end of it. Next year, would you like to become a student leader?

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¶145: P: Yeah, pretty much. I think it's a very good opportunity and a very valuable resource for people in the second year. And I feel as though I have something to contribute and something to share, perhaps to help out the year below me in terms of understanding some of their difficult modules in the second year.

¶146:

¶147: I: And would you do things the same or differently to the student leaders of your session?

¶148:

¶149: P: I would pretty much do it the same. It works very well at the moment and if it's improved my confidence and my competence in maths and outside of maths, then I feel as though "If it isn't broke, why would you try and fix it?" kind of thing. I guess I could add my own personal experience of going through the process, which is something the current student leaders can't add, because this is obviously a new scheme. Perhaps that's something new I could contribute, though, if I was to be a student leader for next year.

¶150:

¶151: I: Now, obviously you... I'm sure you're excited about the opportunities to become a student leader next year. But would you encourage your peers, your friends, to also take part in the scheme for next year?

¶152:

¶153: P: I'd discuss it with them. I'd try and point out whether they feel as though they've learned anything from the process and if so, whether they think it's a useful resource for the year below to have. And I'd mention that they could easily contribute themselves towards helping other people learn and that that's a valuable endeavour in its own right, regardless of any other benefits associated with being a student peer leader.

¶154:

¶155: I: Right. In what ways do the student leaders act as role models for you?

¶156:

¶157: P: I guess they're obviously clever, because they've made it on to the third year, which means that they know what they're doing with maths. They've obviously worked to deadlines, completed questions, revised hard to pass their exams. They - by taking part in this programme - show willing to help others, compassion for other people, empathy with the fact that we may be having problems in specific modules. They always turn up to the peer sessions on time with a completed set of resources or, at the very least, knowledge of the topic that we're going to cover, so that they can pass on the information to us. I don't know. Their entire approach is very professional and very helpful.

¶158:

¶159: I: Thank you. Just a couple more questions. This is the first year that we've run the mathematics peer support. You've seen it in practice. Do you think we should have done things differently?

¶160:

¶161: P: What do you mean by that question? Do you mean in terms of advertising it to students?

¶162:

¶163: I: Yeah, things like that. You know, it could be about advertising, it could be about scheduling, it could be about timetabling, it could be about the classroom environment. Anything that you think, because remember, we're looking for ways to improve things.

¶164:

¶165: P: Of course.

¶166:

¶167: I: Right, so, this question is about... It's an opportunity for you to think about how things could be done better, if you think there is, or there are.

¶168:

¶169: P: Well, I think what works well about the entire scheme at the moment is the way that the peer sessions are scheduled for the day after our tutorial time. I think that's a valuable point and one that should be continued onwards, so that we've had a chance to tackle problem questions and get clarification during tutorials, and then the peer session builds upon that some more. I think the more informal setting, the small groups, the ease of communication with the peer leaders and with each other is valuable. I know that at the start of the second year, we all went to a presentation about enhancing our second-year experience, at which point the simple project was mentioned and we were made aware that we would be taking part in these peer schemes. So, I suppose that was good advertising. I suppose not everybody attended that presentation, though.

¶170:

¶171: I: So, what could be done differently? You've talked about the things that are working quite well.

¶172:

¶173: P: The good stuff. Now it's going on to the useful stuff, the suggestions for improving.

¶174:

¶175: I: Yeah, that is very good, if you can come up with any.

¶176:

¶177: P: I guess making students aware that such a resource is going to be available to them and that they don't in fact have to struggle with these modules on their own. I'm trying to think of a good way for advertising beyond what you've done already. E-mails to student accounts I suppose is worth doing, because at some point, everybody has got to check their student account. Posters in the maths department. Would that be a possibility?

¶178:

¶179: I: Yes. Do you think posters were put around to tell people that this scheme is running? Did you see any?

¶180:

¶181: P: I don't remember seeing any. I wasn't really looking for them, at the same time, but perhaps somewhere near the coursework office to catch people's attention every time they go there, and perhaps even then, so that the first-year students who go there to hand in their coursework read those posters beforehand and are aware that they are going to get this resource next year, so that they don't go crazy and panic about how difficult their second-year experience is going to be.

¶182:

¶183: I: Ok. Now, you've already spoken about communication - how your communication has improved and other things. But this question is trying to... The question I'm going to ask you now is trying to find out what non-mathematical skills you may have acquired. So, the question is: Talk about any non-mathematical skills - besides what you've said already, you've told me already - you think you have learned, which you think would be useful in other aspects of your life or your future career? Now, remember, you already talked about communication. Right?

¶184:

¶185: P: I've talked in great depth about a lot of things already.

¶186:

¶187: I: That's right, that's right. That is, if you can remember any, any additional points, non-mathematical.

¶188:

¶189: P: Beyond better communication and working to deadlines effectively, what else have I gained from the experience? I suppose taking part in this and participating in goodwill shows that I'm keen to challenge myself. I take new opportunities and try and get the maximum possible benefit from them. And I'm not afraid of investigating different ways to approach a task or solve a problem. I suppose that's all I can add to what I said before.

¶190:

¶191: I: Thank you. This year, we are offering support for Vector Spaces and Complex Variables. Which modules would you have preferred to have peer support for and why?

¶192:

¶193: P: I think the peer support for Vector Spaces is very helpful, because of the increased amount of content in the module compared to what we studied in Linear Algebra last year. And, by default, then, the more challenging nature of what's presented to us, meaning that we would need some additional clarification from time to time on how best to solve problems. I haven't studied Complex Variables yet, so I'm not entirely sure how that's going to work out for me. Based on my current experience... I'm studying Numerical Methods 1 at the moment, which I'm finding to be challenging based on the very general nature of the lecture notes and the possibility that I haven't come across some of the material before in either my first-year studies or pre-university education. As such, I think it would be useful to get a different perspective on the material in Numerical Methods from somebody who is not in fact the lecturer, who has been studying the topic in-depth for several years. So, that would be my only recommendation. But obviously, not everyone takes Numerical Methods and as such, to run a peer support session for that may not be the best use of the third years' time.

¶194:

¶195: I: Ok, thank you. That is quite useful. I'm quite pleased for that answer. And you'll be happy to hear that we're about to finish. Would you like to say anything else about the mathematics peer support?

¶196:

¶197: P: It's very useful. I've enjoyed taking part in it. Long may it continue, really. I've got no bad things to say about it. It's all been very good in my experience and I'm very grateful that this scheme is being trialled and I hope it continues, because I've found it to be very, very useful and invaluable in helping me develop my maths education.

¶198:

¶199: I: Thank you very much, Jack, for coming. I'm now going to stop the recorder. You'll be happy to know that we've spent 35 minutes on the interview, so we've kept to time.

¶200:

¶201: P: Very good.

¶202:

¶203: I: Thank you very, very much once again.

¶204:

¶205: P: No problem.

¶206:

¶207: [End of recording - audio file PS05]

APPENDIX FF A PAL LEADER INTERVIEW TRANSCRIPT

Name: PL02

Created On: 03/01/2016 03:23:59

Created By: F K Duah

Modified On: 15/01/2016 07:13:32

Modified By: F K Duah

Size: 15 KB

I: Interviewer

P: Interviewee, (PL02, A PAL leader)

PL01 is a reference to a different PAL leader.

¶1: 00:32:39[Start of recording audio file WS650016]

¶2:

¶3: I: Ok. This is an interview with PL02. I've already explained to you what this is about. Well, essentially, I'm trying to find out about your experiences with peer support, or student leader sessions, in order to inform the core research process. Ok? It should take us about 30 minutes. As I said, there are about 16 questions. Now, have you enjoyed your role as a student leader?

¶4:

¶5: P: Yeah, I've really enjoyed it. I think it's really allowed me to develop, within both maths and as a person. I think it's been really useful, and I think the atmosphere has been quite laidback, so that it hasn't been too much pressure and we can put in as much work as we want to. And the students have been great, so I think it's been really useful. Yeah, I've really enjoyed it.

¶6:

¶7: I: What are the similarities and differences between the PAL sessions you have run and the usual timetable tutorials you would experience with Vector Spaces and Complex Variables?

¶8:

¶9: P: The ones that I actually went to?

¶10:

¶11: I: Yes, when you were in second year.

¶12:

¶13: P: Ok. I would say the differences were, in tutorials, in Complex Variables... I loved the Complex Variables tutorials. I feel it was really good with the way that he'd do the first question and then we'd get on with our own work. I think the PAL sessions are different, in the sense that we get the students to come up and do the work. We don't do the work on the board for them. We'll give them model solutions, but not... We'll get them interacting. I think it feels a lot more relaxed, I guess, because we're students, so they feel they're allowed to talk amongst each other, they can sort of be a bit more relaxed about it all. It sort of makes the whole ethic of work a bit less pressurised, I think. And then with Vector Spaces, the tutorials were more like us, like L01, doing problems on the board, which I found really useful, because you'd get model solutions from it. But obviously, we'd try to get the students to be the ones that give the model solutions, and then other students can say, "Oh no, I don't think that's right." And we can just be there more as a helping hand, rather than... So it's kind of more student-on-student learning, rather than feeling like it's more in a lecture capacity, I think, which I think has been really good.

¶14:

¶15: I: Ok, so, would you say then, that the tutorials that you attended are... Either for Vector Spaces or Complex Variables, did those tutorials resemble the lecture?

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¶17: P: I wouldn't say they resembled necessarily the lecture. They were more kind of like a lecture, but more example-based. I found them really useful, because it's always good to go through the examples, so you would always expand on what you've learned in the lecture. But I think with the PAL sessions, they're more like interactive. I suppose they put it more like a fun way of learning the subject, rather than... I think tutorials are probably a bit more serious, and students feel like they are a bit more under pressure to get the right solution. But within our PAL sessions, we've always made it clear that if you get it wrong, it doesn't matter. We can get it wrong. They can get it wrong. It's fine.

¶18:

¶19: I: Ok. And for students in which year group do you think PAL sessions can have the most benefit and why?

¶20:

¶21: P:I think introducing them in first year would be really good. I think 1) it would give the students... When you're in first year, you kind of feel like a little fish in a big bowl, so I think sometimes having older students who have been there before in those sessions, I think they would feel like they've got someone to go to, if they need to. Me, personally, I knew someone who was older, which helped, because I knew that if I had any problems, I could talk to them about it. But some students wouldn't necessarily have that connection. So, I think it would be a really good way to get the students interacting with people who have already been in that situation. And then, I think that... I think it's really good in second year as well. I know, obviously, to get it in third year would be really difficult, because a lot of students wouldn't stay on. But I think first and second year would probably be the best years. But I do think the introduction of it in first year would be really useful.

¶22:

¶23: I: Ok. How much, thinking about the PAL sessions, do you find yourself doing outside of the timetable slot?

¶24:

¶25: P: I'd say me and PL01 try and fit in, between half hour-ish slots every week to plan. Sometimes, we will plan from after the last session, see how things go, and plan straight after that what we're going to do the week after. I think a lot of it just flows within the actual session itself, because we always ask if they want help on anything in particular, and if they do, obviously we change what we had planned as that session, obviously because we want to make sure that we facilitate for their needs, rather than just what we had planned to do. So, I would say, probably between half an hour and an hour every week spending to plan. But it's not intense planning. It's not been a like chore. It's just been something like, "Oh, we'll plan the PAL session." It hasn't been anything that's been too bad for us to do, or too time-consuming, I don't think.

¶26:

¶27: I: Could you give an example of the kind of planning that you have done before?

¶28:

¶29: P: Yeah. So, we'll find out where the students are up to, and we'll look at what lecture notes there have been, are there any examples that they might have found difficult, then look at the problem sheets. The problem sheets are a lot determined on what they've covered in their tutorial, so we often pick out a few questions, but sometimes, we can't do that, because they've already done them, and then look at the resources that the students set up in the summer, and just try and piece together different problems and stuff. We often give prizes in our sessions. So, we always pick a question that we think is quite challenging, so we can say, "This is the good first question, so you get a prize for it." And it kind of sets them up. It's kind of like we'd have more of a list of things that we want to cover, and then we just see how it goes within the session.

¶30:

¶31: I: Alright. Describe an example of a mathematics problem or theory that you and your colleagues helped the second-year students to understand.

¶32:

¶33: P: Ok. Well, in our last PAL session before Easter, we wanted to cover Cauchy's integral formula, but the students hadn't actually fully covered it. So, we put a question up on the board, and the students weren't sure how to go about it. So, we thought, "We'll try and talk to them a little bit about it, so then when they do go to their lecture, they're kind of a bit more like 'Oh, yeah, we've seen this.'" It doesn't seem as such a shock to them. And that just kind of happened by coincidence, because we just assumed that they had covered it, but they hadn't. So, we not necessarily taught them it, but we pointed them in the right direction, and they ended up understanding. So, yeah.

¶34:

¶35: I: And did they find it easy, or difficult?

¶36:

¶37: P: Yeah. The solution was written up by one of the students. So, I think once we'd gone through what we went through with them, they sort of understood the concept of it. And then, obviously, when they went to the lecture, it would be back-up to what we had said. So, yeah, I think they would have found that quite useful, I think.

¶38:

¶39: I: Ok. What are your views about the student leader training that was provided by the …….. team?

¶40:

¶41: P: I think it was really good. It was really useful. I don't know if it needed to be as long as it was. I think the day probably could have maybe been cut into half a day. It was more that kind of when we were interacting with each other, because a lot of us already know each other, I don't necessarily think that that was necessary. But I found the actual resources were... I mean, Teaching Centre Staff 1 and Teaching Centre Staff 2 were really good. I thought they were great. And it was nice to see how they interacted with us, because it kind of gave you a backbone of how you should act with the other students when... I don't know. I thought it was really good, the way they presented themselves, and I found that really useful. But I think some of the stuff we did as an icebreaker for us, I don't't' think we really needed, because we kind of all knew each other. And the types of people we were, I don't think it was a problem if someone didn't know anybody. We'd kind of just integrate into each other. So I think they could have maybe been a bit shorter. But I thought they were really useful. And I think the last one, as well, when Tony did the problems, I thought that was really good, because it's kind of what we do tackle within the student leader sessions. And it helped to know how to... Sort of when I was put in the position of the student and I didn't understand, it kind of made you think, "Oh, that's what they feel like," although we already know what they feel like, because we find problems hard, it'd be in front of everybody and it being a like student and you're like, "I don't understand." I thought that was really good. It made you realise what the students would be feeling. So I found L05, his exercises, really good.

¶42:

¶43: I: And when you refer to that example, are you talking about the training that we had in the second semester?

¶44:

¶45: P: Yeah. Just after our exams.

¶46:

¶47: I: Just after the exams. In February.

¶48:

¶49: P: Yeah.

¶50:

¶51: I: So, tell me, then, how helpful did you find the training and was it adequate?

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¶53: P: Yeah, definitely think it was adequate. I definitely think that they covered everything we needed to know. I think it allowed us to go into the first PAL session knowing kind of what we were doing, how we would go about things, if there were any problems. I think all the resources were great. If people had time to go through it all, it was really helpful, especially things like the little icebreaker things that we could do with the students. I think the examples, when they showed us things like the two of the lecturers, one of them would be a the student and the other one would be the student leader, that was really helpful, because it was like, "This is how you should be." I think if we hadn't have had that, we wouldn't have known how to go into the sessions. I think it would have been more sort of like, I think we would have just taken it as, "We just have to be there and the students can just get on with their own stuff." Whereas, I think through the training programme I think we realised, "Oh, we can do this, and we can do that," and it gave us ideas and inspiration for what we could do in our sessions. So, I think it was definitely adequate for what we had to do.

¶54:

¶55: I: Ok. So, how did you make use of the student leader handbook that was given?

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¶57: P: The one that Teaching Centre Staff 1and Teaching Centre Staff 2 gave us? I read through quite a lot of it, especially before the first few PAL sessions, because I think it was always the first few that didn't work quite as well as they did once you've moved on. And it was helpful for icebreaker things, how to overcome any problems, if people won't talk up, how to get them to talk up and stuff. I think that was really useful. So, basically just as a resource to look through and see. I think we probably used it less and less as we'd go on, because you get to know the students and it kind of becomes a bit more natural. But I think to start with, it was a really good resource to look through.

¶58:

¶59: I: Ok. There were certain policies and procedures in the handbook. Do you think you followed all of them?

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¶61: P: Not necessarily. I think it depends on the students you get and how they interact with each other depends on how you have to take the PAL sessions. I think you have to be quite open-minded. I think if you try and follow a structure, it's not always going to work. It's kind of like, when we plan our PAL sessions, we don't always stick to it, because the students might have questions that they might want to have. For example, for this week, we had planned what we were going to do today, but the students might have questions on their class test from last week. So, we've allocated time that we can just help them if they need it. So, I don't think following a structure is necessarily the best... I think it's a good backbone. You know what you're doing and how to go about it. But sometimes, you have to adapt depending on the type of students that you get. Some are really quiet; some are really loud. You will always get the students who really want to go up to the board, which is really useful. But I think trying to follow a structure is just too difficult.

¶62:

¶63: I: In the handbook, there were some forms about reflecting on your sessions and maybe writing up. Do you think you did any reflection on sessions?

¶64:

¶65: P: Not really. I think it was more sort of that me and PL01 would talk about how things wen especially after the first few sessions, because the first few were a bit... We weren't sure how they were going or if the students were enjoying it. We're still getting good attendance, so we thought they must be pleased with how it was going, and I think it was more reflection on like I'd reflect on what I thought of L01, and he'd reflect on what he thought of me. And I think that's quite useful, because we could sort of be constructively critical on "I think you should do this." And I think that was more how we used the reflection, rather than actually writing it down.

¶66:

¶67: I: Ok. Did you communicate with the second-year students outside of the PAL sessions and how?

¶68:

¶69: P: Yeah. We communicated. We created a Facebook group for both Complex Variables and Vector Spaces. We basically added all the students in. We told them if there was anyone who wanted to join our sessions just to add them in. And each week, we'd posted something, reminding them of the session that week, what we were going through that week, did they have any questions. We got good responses. People would Like what we'd written on it or comment on it if there was a question asked. Some students would, when it came to near the exams or nearer class tests, they would post questions on there. So, I felt like that was quite useful. We started off originally by e-mail. But then, when we went to our first PAL session, we said, "Would you be happy for us to set up a Facebook group?" and they were more than happy for that to happen. And I think the students have got Facebook on their phones. They've got it all the time. So, for us to communicate with them like that, it's almost like texting someone. You get a quick response and it was easier than e-mail, which students wouldn't always check. And I suppose, with e-mail, you feel like you have to be more formal, when you write an e-mail back. And the students probably wouldn't really want to do that. I think the Facebook way was so easy. We would write something and students could just click one button to say that they Liked it, which would make us think, "Oh, good, they're pleased with that." Yeah, I think Facebook was really good for us. But obviously, it depends on whether the students agreed to want it or not.

¶70:

¶71: I: Ok. Following a PAL session, have you ever fed any information back to the module leader about his teaching, the learning resources or how students are finding the module?

¶72:

¶73: P: We did do with Vector Spaces. We sort of had a meeting every week with L01, and he would ask, "Have the students flagged up anything?" And we used to tell him, "Oh, the students didn't understand this," or what he could perhaps touch on a little bit more, things like that. We would tell him what examples and stuff the students had problems with and stuff like that. And L02 has always said that we're more than welcome if we wanted to set up a meeting with him, that's absolutely fine. But so far on the course, the students haven't had too many problems. And they've kind of been happy that if we've said "Do you want us to ask L02 or do you need to ask L02?", they've been happy to ask L02 themselves, which has been good. They've been happy to have the student lecturer communication, which has been quite good. So, yeah. But if there have been any problems with things, people have been quite happy to tell the lecturers what's been going on.

¶74:

¶75: I: Ok. Have you ever shared your own experiences of doing either or both of the modules with the second-year students?

¶76:

¶77: P: Yeah, definitely. I think there's a lot of the time when... If a student says, "I can't do this question," for example, I'd look at it and say, "Do you know what? I couldn't do that question when I was..." And I think it kind of helps them to realise that "Oh, ok. The student leaders couldn't do that when they were here." I think it kind of gives them a "They're not on their own" kind of thing. And I'm always open to say, "Oh, I really didn't know or understand this part. But it will become clear when you do this or this." And also, a lot of the times, when you look through the solutions, there's a certain way that the lecturer will do it. But there might have been ways that me or PL01 found that were easier to do the problem. So, we've kind of given them that idea. And if they like it, they take it on board, and if not, they don’t. But yeah, all the time I think we're going through and saying, "Oh, we did this question. We didn't understand this. Do it this way." I think it's quite useful that you've been in their shoes, so you know that you had those problems but you overcome them and now you're a year ahead. I think we did reflect quite a lot on what we did.

¶78:

¶79: I: And describe your relationship with the second-year students in and outside of the timetable PAL sessions?

¶80:

¶81: P: I think if I was to see the students out around campus, we would always say, "Hello, how are you?" I think we've got quite a good relationship. I think we've kind of become friends with the students. I think that's also a reason why we get quite a good turnout every week. I think they feel like we're people that they can come to if they need to. In the PAL sessions, they're always really friendly, really up for just talking. Sometimes we will just have a chat in general. Especially after the exams? "How did it go? How did you find it?" A lot of the time when they were picking modules for the second semester, we had the students asking us loads of questions about it? "What would you recommend? How did you find this?" During revision, some of our students would even ask questions on other modules, like, say, Analysis. So, I kind of feel like we've built up a bit of a friendship with everybody and it's not just based on Vector Spaces and Complex Variables. I think they feel quite happy to come. You know, I saw quite a few of them in the library over the January exams and they'd say, "Oh, we're revising for Analysis" and stuff like that. They'd sort of say, "How did you find this?" But, yeah, I think we've got a really good relationship with our students.

¶82:

¶83: I: So, from what you've just said, some of your discussions with the second-year students also focused on other modules?

¶84:

¶85: P: Yeah.

¶86:

¶87: I: And would you say that there were occasions... Were there occasions when they asked you questions or they asked you for help about how to solve problems in a particular module, for example?

¶88:

¶89: P: Yeah, there could have been, yeah. When they were doing revision for other subjects, if we were around and they'd seen us, they would say, "Do you have any idea how to do this?" or something like that. So, that made me feel like they feel quite comfortable with us. They feel like they can ask us. We've always been very open. Especially on Facebook, we've said, "If you need any help, just contact one of us" or whatever. And PL01 also told the students where we would be when we were revising? "If you need any help with anything, just come and see us." We did have a couple of students pop in and see us and stuff. So, yeah, I think that they feel like they can ask us anything, really.

¶90:

¶91: I: Ok. And how has your role as a student leader impacted on your study of mathematics in your third year?

¶92:

¶93: P: I think it's made me realise mistakes I made in the second year and how I could have best gone about doing some of the stuff. Watching some of the students, they're so up-to-date with everything they're doing on the problem sheets and stuff. I think the PAL sessions are really helping them keep up-to-date with everything. They know where everybody else is kind of at. They might not think themselves to organise a session where they're all with their friends and they all do the problems together. But PAL kind of gives them that straight away. You see the students? They’re sort of talking? "Where are you up to?" I think they're trying to keep up-to-date with it and I think the PAL sessions really help with that. And I think personally, it makes me sort of reflect and think, "That's what I want to do. That's what I need to be doing, keeping up with all the notes, all the lectures and stuff." I think it makes you reflect on how you could have done things better and then hopefully use them in this year to do as best as we can in our last year.

¶94:

¶95: I: Obviously, you're doing BSc.

¶96:

¶97: P: Yeah.

¶98:

¶99: I: So this is your last year?

¶100:

¶101: P: My last year. Yeah.

¶102:

¶103: I: How critical is it that... Ok, let me rephrase it. Do you think the PAL, getting involved as a student leader, has that affected your studies in third year negatively?

¶104:

¶105: P: No. I don't think so. I think that it's taken that hour session, a maximum hour of planning, which I think... It's something that you can take as sort of a break from doing work. Our PAL sessions, for example, this semester are at 1 o'clock on a

Tuesday. We're free from 10 o'clock and we're free until 4 o'clock, so in the bits in between we're just in the MLSC just doing problem sheets and stuff, to be honest. Whereas if we didn't have that session, we might have decided, "Oh, let's go home. We've got such a long time" and you'd get strayed to not necessarily do work. But no, I don't think it's made it negative at all. I think, if anything, it's probably made you realise how you should better yourself, rather than holding you back from doing your own work.

¶106:

¶107: I: Ok. Now, obviously you're in your final year and you'll be leaving soon to find a job, won't you?

¶108:

¶109: P: Yes.

¶110:

¶111: I: So, the question I have for you now is: What non-academic benefits have you gained from your role as a student leader?

¶112:

¶113: P: I think it's made me a bit more of a... I think it's developed me as a person and it's made me realise that you can be there for somebody and it's good to have someone there for you. And I think it's made me realise that I really enjoy helping people. I never really looked at that aspect before. But I think in terms of job-type things, it's sort of made me realise that I really enjoy helping people and I really enjoy being that person that people feel they can come to and they can ask questions. And even if I can't answer them, which happens quite a lot of the time, they're just happy to have someone just to talk to about something. I think that's really made me develop as a person.

¶114:

¶115: I: So, what about your confidence?

¶116:

¶117: P: Yeah, I think it's increased my confidence massively, because obviously I didn't know any of these students before the PAL sessions. And thinking that we've come from that, to sort of becoming friends with the students, I think that's been massive. And obviously, it's only ever really been me and PL01. We did have Magda and Catherine for a short period, as well. But I think when it is just me and PL01, there can be us and up to students. It does feel a bit daunting that you've got to talk in front of all these students. But I think as you progress, you realise how best to talk to them and you just get over that kind of fear. So, yeah, I think it's made me a lot more being able to be confident in front of people that I don't necessarily know that well. So, yeah, I think it's been good.

¶118:

¶119: I: What about your organisational skills?

¶120:

¶121: P: It's helped me be able to sort of be restricted within time, be able to plan something and give it... To say, "We'll spend five minutes on this" and restrict yourself. Like I said, it's quite difficult. You have to be quite flexible. You don't always get through everything we want to get through, but that's more because students have questions. And I think, also, it's made us say, "Oh, we want ten minutes on that." But then, once you actually go through it, it might mean that you need 15 minutes on it, and that it's ok to be a bit more flexible. But yeah, I think it's been really good for organisation. We've had to meet up. We've had to make sure that we get the session planned for the hour. Yeah, I think it's been good.

¶122:

¶123: I: Ok. Do you think you could have run the sessions alone?

¶124:

¶125: P: No. No, I don't think I could have done it without PL01 at all. I think going to the sessions knowing that PL01's going to be there has kind of... It takes the pressure off the one person. If, for example, we get anything wrong, we can kind of just laugh it off and it's fine. Or if one of us doesn't know how to do something as well as the other one, we can kind of bounce off each other. There's often times, where I'll be helping someone with a problem and I'll be like, "I don't understand" and I'll call PL01 over. When we talk through it together, because we work really well together anyway, I think it kind of helps. And I think the students feel a bit more relaxed, rather than there just being one person. I think if you had one person, it would be more like a tutorial- or lecture-type situation, whereas it's a bit more like a group of friends. And I think the students, they can feel the atmosphere as well. So, no, I definitely couldn't have done it without PL01, no.

¶126:

¶127: I: Ok. And how many students, how many student leaders, are appropriate for a group?

¶128:

¶129: P: I'd say two to three. I don't think you need any more than three. I'm sort of judging on about... I think we're supposed to have about 28 students. I think the most we've had is about 21. I think two of us is absolutely fine for that amount of students. I think, obviously, if you go up to 30, I think you would probably need three, just so you can get around the students and make sure that everyone gets as much help as they can. I think too many would probably be too intimidating, I think. But, yeah, two to three.

¶130:

¶131: I: What is the most difficult aspect of being a student leader?

¶132:

¶133: P: Not being able to help, I think. Yeah, I guess, lack of knowledge and understanding. I mean, the thing with the tutorial is that the lecturer knows everything, so they're always able to help. As a student, you know that if you ask a question that you're going to get an answer. Whereas, it always worries me that students are going to ask me a question and I don't know the answer. I think through the PAL sessions, we've learned that that's fine. And that's how we've always run ours. They don't' always know the answer and we don't always know the answer. And I think it makes the students feel better, sometimes, that we don't always know the answer. I think, yeah, that's probably the most difficult part. Not being able to give a student an answer. But obviously, we always tell them, "Ask L02, or we can ask L02 and we can get back to you." So, it works quite well, in that way. But I think, yeah, it's definitely not having the knowledge of a lecturer is difficult, in some senses, when you're asked questions like that.

¶134:

¶135: I: Ok. Have there been sessions where things have gone wrong and how did you handle that?

¶136:

¶137: P: I wouldn't say things have gone wrong. No, I don't think there's ever been anything that's gone wrong in our sessions, no. There might have been a particular problem we've had difficulty with. We did have one session where me and PL01 could not figure out. It was a question asked to us by the student, and it wasn't like a problem sheet question. It was just a general question. We went out to the MLSC to ask[name of a lecturer] to help us, because we just genuinely didn't know the answer. But I don't think it's ever been anything that we've sort of thought, "I can't believe that's happened." It's always flowed really well, I think.

¶138:

¶139: I: And finally, we're almost there. We've got about three minutes to go. The final question: Starting again from scratch, would you do things differently?

¶140:

¶141: P: No, I don't think so. I think there are some aspects I would probably do differently, like the first few sessions? I don't think they went as well as they could have, and I think that was probably more my lack of confidence, sort of being in a situation that I wasn't used to. I think I would probably, maybe sort of put myself out there a little bit more and be a bit more warming to the situation, rather than sort of holding back. I think that was a problem for the first few sessions. But other than that, I think they've gone really well. We've kept up good attendance for the whole time with Vector Spaces and Complex. Yeah, no, I think it's gone really well.

¶142:

¶143: I: Ok. And should the [Project Team], as with everybody... Should they have organised things differently?

¶144:

¶145: P: No, I think they've done it really well. The only problem we did have in some sessions at the beginning was allocating students to the sessions. I mean, we took it on board ourselves. We asked. Everybody was more than happy to do it for us, but we just said, "Oh, we'll take it on board and do it." But I think that was quite difficult, because, obviously, we had to get hold of timetables, we had to get hold of all the students' names and stuff, allocate them into certain slots, which I think was the only difficulty, I think, of overcoming it. When we first did the Complex, the Vector Spaces, we had to go into the lectures and get students to sign their names and when they could do. I think the only problem with that was not all the students were present. I think, sometimes, there were students left out. We did have a couple of students say in our session, "My friend hasn't been allocated a slot." We just said, "Tell them to come to ours and we'll add them to our Facebook group, etc." But I think that was quite difficult. I think we need to make sure that all students are included and, perhaps, that the organisation of groups can be done beforehand, and then maybe we can be the ones that are a bit more flexible? "Oh, I need two people to do this slot," and then we can be the ones that say, "We're free. We can do that," rather than we were sort of picking, putting ourselves in a slot and saying, "What students could do that?" I think that was the most difficult part.

¶146:

¶147: I: Allocation of students.

¶148:

¶149: P: Yeah.

¶150:

¶151: I: So, just to finish off. Obviously, you've mentioned one way that things could be improved. Is there anything that comes to mind? Is there any other thing that comes to mind about how Tony and the rest of the people in the department could do things differently, to ensure that this scheme continues successfully into the future?

¶152:

¶153: P: I think they've done a great job. I really do. I think they've been great. They've had great communication with us and all that. I suppose the only other thing that could potentially be done is maybe during the students' first few lectures, the lecturers could maybe enhance on how important going to the PAL sessions can be. Instead of just being told by us, if it's told by somebody who's maybe a bit more authoritative, it might sort of help the students, to encourage them to come along. I know some sessions have had quite a low turnout of students. I mean, I know, obviously, that it's not compulsory that students come, but I think if it's seen as more compulsory, it might help the attendance. And I think some students don't necessarily not come because they don't want to, but because they're a bit worried of what exactly will happen? you know, are they going to be picked on to answer questions and stuff like that? But that's not what happens. But I don't think they realise that until they're actually in the session and see what's going on. We'd never pick on anybody. We know the students that don't mind coming up to the board. There are often people that volunteer. But if you are going to pick on someone, as such, you know the kind of people that don't mind being... You know, we wouldn't want to pick on someone that really doesn't want to go up to the board. I don't think that's fair, to put them in a situation they don't want to be in. But I think, yeah, a bit more from the lecturers. Not necessarily just the lecturers of that module, but any person from the project to come in and talk to the students and say how good it can be, how useful it can be. It might help them think, "Oh, yeah, I should go," I think, yeah.

¶154:

¶155: I: Ok. Thank you very much. We've come to the end of the interview. It's been about 32 minutes. Thank you.

¶156:

¶157: [End of recording audio file WS650016]

APPENDIX GG PAL PARTICIPANTS INTERVIEWS CODING FRAME

Name	References	Modified On	Created By
1_00 MUTUAL ENGAGEMENT	177	03/01/2016 01:20	F K Duah
1_01 Engagement with PAL	28	15/01/2017 11:59	F K Duah
1_01 (Non) - participation	24	06/01/2016 05:47	F K Duah
1_02 Conflict and Tensions	4	07/01/2016 20:59	F K Duah
1_02 Peer Learning community	40	27/11/2016 21:33	F K Duah
1_02_01 Community	5	08/01/2016 01:41	F K Duah
1_02_02 Communication	35	03/01/2016 01:23	F K Duah
1_03 Mathematical practice	88	03/01/2016 01:29	F K Duah
1_03_1 Focus on example practice	8	03/01/2016 02:55	F K Duah
1_03_2 Hints and scaffolding	5	08/01/2016 01:36	F K Duah
1_03_3 Board Use	8	03/01/2016 02:55	F K Duah
1_03_4 Peer review and feedback	5	03/01/2016 02:55	F K Duah
1_03_5 Group work	14	06/01/2016 03:40	F K Duah
1_03_6 Leaders facilitation strategies	22	08/01/2016 01:59	F K Duah
1_03_7 Reflection	28	03/01/2016 03:05	F K Duah
1_03 Role modelling and mentoring	21	03/01/2016 03:20	F K Duah
2_00 JOINT ENTERPRISE	30	03/01/2016 01:24	F K Duah
2_01 Academic Success	11	03/01/2016 01:25	F K Duah
2_02 Other Academic Reason	19	07/01/2016 01:37	F K Duah
3_00 SHARED REPERTOIRE	45	03/01/2016 01:26	F K Duah
3_01 Formality tutorials and PAL sessions	19	15/01/2017 13:43	F K Duah
3_02 Small group work	12	15/01/2017 13:44	F K Duah
3_03 Peer to peer support	10	15/01/2017 13:46	F K Duah
3_04 View on tertiary mathematics	3	15/01/2017 14:06	F K Duah
3_05 Use of co-created resources	3	15/01/2017 14:01	F K Duah
4_00 IDENTITY TRANSFORMATION	127	03/01/2016 02:57	F K Duah
4_01 Understanding mathematics	60	03/01/2016 03:00	F K Duah
4_02 Mathematical and personal confidence	26	03/01/2016 03:03	F K Duah
4_03 Personal Development	30	03/01/2016 03:04	F K Duah
4_03_01 Changing Study Habits - going over notes	19	06/01/2016 03:37	F K Duah
4_03_02 Academic career	-	30/04/2016 19:21	F K Duah
4_03_03 Communication	2	30/04/2016 01:44	F K Duah
4_03_04 Have become patient	-	30/04/2016 19:10	F K Duah
4_03_05 Organisational skills	-	30/04/2016 12:58	F K Duah
4_03_06 Impact of role as intern and PAL leader	-	30/04/2016 12:28	F K Duah
4_03_07 Socialising	1	08/01/2016 03:58	F K Duah
4_03_08 Team work	2	08/01/2016 03:58	F K Duah

Name	References	Modified On	Created By
4_04 Enjoyment	11	08/01/2016 01:44	F K Duah
5_00 FURTHER DEVELOPMENT OF PAL FOR MATHEMATICS	66	03/01/2016 01:27	F K Duah
5_01 Training for PAL Leaders	8	03/01/2016 01:27	F K Duah
5_02 Courses Requiring PAL	22	07/01/2016 02:09	F K Duah
5_03 Keep Uniqueness of PAL	11	08/01/2016 04:09	F K Duah
5_04 Promote PAL with Evidence of Effectiveness	4	08/01/2016 03:56	F K Duah
5_05 Scheduling and attendance	-	30/04/2016 13:24	F K Duah

APPENDIX HH PAL LEADERS INTERVIEWS CODING FRAME

Name	References	Modified On	Created By
1_00 MUTUAL ENGAGEMENT	97	03/01/2016 01:20	F K Duah
1_01 Engagement with PAL	28	15/01/2017 11:59	F K Duah
1_01 (Non) - participation	-	06/01/2016 05:47	F K Duah
1_02 Conflict and Tensions	-	07/01/2016 20:59	F K Duah
1_02 Peer Learning community	11	27/11/2016 21:33	F K Duah
1_02_1 Community	-	08/01/2016 01:41	F K Duah
1_02_2 Communication	11	03/01/2016 01:23	F K Duah
1_03 Mathematical practice	50	03/01/2016 01:29	F K Duah
1_03_1 Focus on example practice	2	03/01/2016 02:55	F K Duah
1_03_2 Hints and scaffolding	1	08/01/2016 01:36	F K Duah
1_03_3 Board Use	-	03/01/2016 02:55	F K Duah
1_03_4 Peer review and feedback	-	03/01/2016 02:55	F K Duah
1_03_5 Group work	-	06/01/2016 03:40	F K Duah
1_03_6 Leaders facilitation strategies	-	08/01/2016 01:59	F K Duah
1_03_8 Reflection	47	03/01/2016 03:05	F K Duah
1_04 Brokering	13	03/01/2016 03:20	F K Duah
1_05 Role modelling and mentoring	24	04/01/2016 16:50	F K Duah
2_00 JOINT ENTERPRISE	-	03/01/2016 01:24	F K Duah
2_01 Academic Success	-	03/01/2016 01:25	F K Duah
2_02 Other Academic Reason	-	07/01/2016 01:37	F K Duah
3_00 SHARED REPERTOIRE	27	03/01/2016 01:26	F K Duah
3_01 Formality tutorials and PAL sessions	15	15/01/2017 13:43	F K Duah
3_02 Small group work	2	15/01/2017 13:44	F K Duah
3_03 Peer to peer support	5	15/01/2017 13:46	F K Duah
3_04 View on tertiary mathematics	-	15/01/2017 14:06	F K Duah
3_05 Use of co-created resources	-	15/01/2017 14:01	F K Duah
3_06 PAL handbook	5	30/04/2016 13:16	F K Duah
4_00 IDENTITY TRANSFORMATION	46	03/01/2016 02:57	F K Duah
4_01 Understanding mathematics	8	03/01/2016 03:00	F K Duah
4_02 Mathematical and personal confidence	4	03/01/2016 03:03	F K Duah
4_03 Personal Development	24	03/01/2016 03:04	F K Duah
4_03_1 Changing Study Habits - going over notes	12	06/01/2016 03:37	F K Duah
4_03_2 Academic career	1	30/04/2016 19:21	F K Duah
4_03_3 Communication	2	30/04/2016 01:44	F K Duah
4_03_4 Have become patient	1	30/04/2016 19:10	F K Duah
4_03_5 Organisational skills	2	30/04/2016 12:58	F K Duah
4_03_6 Impact of role as intern and PAL leader	3	30/04/2016 12:28	F K Duah

Name	References	Modified On	Created By
4_03_7 Socialising	2	08/01/2016 03:58	F K Duah
4_03_8 Team work	1	08/01/2016 03:58	F K Duah
4_04 Enjoyment	11	08/01/2016 01:44	F K Duah
5_00 FURTHER DEVELOPMENT OF PAL MATHEMATICS	68	03/01/2016 01:27	F K Duah
5_01 Training for PAL Leaders	33	03/01/2016 01:27	F K Duah
5_02 Courses Requiring PAL	15	07/01/2016 02:09	F K Duah
5_03 Keep Uniqueness of PAL	8	08/01/2016 04:09	F K Duah
5_04 Promote PAL with Evidence of Effectiveness	5	08/01/2016 03:56	F K Duah
5_05 Scheduling and attendance	7	30/04/2016 13:24	F K Duah

REFERENCES

Ahern, K. J. (1999). Ten tips for reflexive bracketing. *Qualitative health research*, *9*(3), 407-411.

America Educational Research Association(AERA). (2000). *Ethical standards of AERA*. Washington, DC: American Educational Research Association.

Arendale, D. R. (1994). Understanding the supplemental instruction model. *New Directions for Learning and Teaching*, 60, 11-21.

Arendale, D. R. (2001). Supplemental Instruction (SI) : *Review of research concerning the effectiveness of SI from the University of Missouri-Kansas City and Other Institutions from across the United States*. Retrieved 1 February 2012, from http://a.web.umkc.edu/arendaled/DAincreaseefficiencySI97.pdf

Astin, A. W. (1999). Student involvement: A developmental theory for higher education. *Journal of College Student Development, 40*(5), 518-529.

Basit, T. N. (2010). *Conducting research in educational context*. London: Continuum.

Berger, J. B., & Milem, J. F. (1999). The role of student involvement and perceptions of integration in a causal model of student persistence. *Research in Higher Education*, *40*(6), 641-664.

Biggs, J. B. (1978), Individual and group differences in study processes. *British Journal of Educational Psychology*, *48*, 266–279

Biza, I., & Vande Hey, E. (2015). Improving statistical skills through students' participation in the development of resources. *International Journal of Mathematical Education in Science and Technology*,*46*(2), 163-186.

Biza, I., Jaworski, B., & Hemmi, K. (2014). Communities in university mathematics. *Research in Mathematics Education*, *16*(2), 161-176.

Bovill, C. (2014). An investigation of co-created curricula within higher education in the UK, Ireland and the USA. *Innovations in Education and Teaching International*, *51*(1), 15-25.

Bovill, C., & Felten, P. (2016). Cultivating student–staff partnerships through research and practice. . *International Journal for Academic Development, 16*(2), 133-145.

Bovill, C., Cook-Sather, A., & Felten, P. (2011). Students as co-creators of teaching approaches, course design, and curricula: implications for academic developers. *International Journal for Academic Development, 16*(2), 133-145.

Bovill, C., Cook-Sather, A., Felten, P., Millard, L., & Moore-Cherry, N. (2016). Addressing potential challenges in co-creating learning and teaching: overcoming resistance, navigating institutional norms and ensuring inclusivity in student–staff partnerships. *Higher Education*, *71*(2), 195-208.

Boyer, E. L.(1990). *Scholarship reconsidered: Priorities of the professoriate*. Princeton, NJ: Cargie Foundation for Advancement of Teaching.

Boylan, M. (2010). Ecologies of participation in school classrooms. *Teaching and Teacher Education*, *26*(1), 61-70.

Brannen, J. (2005). Mixing methods: The entry of qualitative and quantitative approaches into the research process. *International Journal of Social Research Methodology, 8*(3), 173-184.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77-101.

British Educational Research Association (BERA). (2004). *Revised ethical guidelines for educational research*. Southwell: British Educational Research Association.

Brousseau, G. (1997). *Theory of didactical situations in mathematics*. Translation from French: M. Cooper, N. Balacheff, R. Sutherland & V. Warfield.

Brown, J. S., & Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. *Organization Science*, *2*(1), 40-57.

Brown, J. W., & Churchill, R. V. (2014). *Complex variables with applications* (9th ed.), New York, NY:McGraw-Hill.

Brown, M., Macrae, S., Rodd, M., & Wiliam, D. (2005). *Student Experiences of Undergraduate Mathematics*: ESRC Report Ref. No. R000238564 (obtainable upon request from the ESRC).

Bryman, A. (2008). *Social Research Methods*. Oxford: Oxford University Press.

Burmeister, S. L., Carter, J. M., Hockenberger, L. R., Kenney, P. A., McLaren, A., & Nice, D. L. (1994). Supplemental Instruction sessions in college algebra and calculus. *New Directions for Learning and Teaching*, 60, 53-61.

Burmeister, S. L., Kenney, P. A., & Nice, D. L. (1996). Analysis of effectiveness of supplemental instruction (SI) sessions for college algebra, calculus, and statistics.*CBMS Issues in Mathematics Education*,*6*, 146-154.

Capstick, S. (2004). *Benefits and shortcomings of peer assisted learning (PAL) in higher education: an appraisal by students*: Bournemouth: Bournemouth University.

Capstick, S., & Fleming, H. (2002). Peer assisted learning in an undergradaute hospitality course : Second year students supporting first year students in group learning. *Journal of Hospitality, Leisure, Sport and Tourism*, *1*(1), 69-75.

Carini, R. M., Kuh, G. D., & Klein, S. P. (2006). Student engagement and student learning: Testing and linkages. *Research in Higher Education, 47(1)*, 1-32.

Cheng, D., & Walters, M. (2009). Peer-assisted learning in mathematics: An observational study of student success. *Journal of Peer Learning*, *2*(1), 23-39.

Chevallard, Y. (1999). L'analyse des pratiques enseignantes en théorie anthropologique du didactique [The analysis of teaching practice in the anthropological theory of the didactic]. *Recherches en Didactique des Mathématiques*, 19, 221–266.

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE Bulletin*, *3* (7).

Clark, B. R. (1960). The "cooling-out" function in higher education. *American Journal of Sociology*, *65*(6), 569-576.

Coe, E. M., McDougall, A., & McKeown, N. B. (1999). Is peer assisted learning of benefit to undergraduate chemists? *University Chemistry Education*, *3*, 2.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Abingdon, Oxon: Routledge.

Confrey, J. (1990). Chapter 8: What constructivism implies for teaching. *Journal for Research in Mathematics Education. Monograph, 4*, 107-210.

Congos, D. H., & Schoeps, N. (1993). Does supplemental instruction really work and what is it anyway?. *Studies in Higher Education, 18*(2), 165-176.

Congos, D. H., & Schoeps, N. (1999). Methods to determine the impact of SI programs on colleges and universities. *Journal of College Student Retention: Research, Theory & Practice, 1*(1), 59-82.

Cook-Sather, A. (2008). What you get is looking in a mirror, only better: Inviting students to reflect (on) college teaching. *Reflective Practice, 9*(4), 473-483.

Cook-Sather, A. (2011a). Layered learning: Student consultants deepening classroom and life lessons. *Educational Action Research, 19*(1), 41-57.

Cook-Sather, A. (2011b). Teaching and learning together: College faculty and undergraduates co-create a professional development model. *To improve the academy, 29*, 219-232.

Cook-Sather, A. (2012). Amplifying student voices in higher education: Democratizing learning and teaching through changing the acoustic on a college campus. *Revista de Educación, 359*, 184.

Cook-Sather, A. (2014). Student-faculty partnership in explorations of pedagogical practice: a threshold concept in academic development. *International Journal for Academic Development, 19*(3), 186-198.

Cook-Sather, A., Bovill, C., & Felten, P. (2014). *Engaging students as partners in learning and teaching: A guide for faculty*. San Francisco:John Wiley & Sons.

Cooper, B. (1990). PGCE students and investigational approaches in secondary maths. *Research Papers in Education. 5*(2), (1990): 127-151.

Corti, L. (1993, 1 May 2011). Using diaries in social research. *Social Research Update* Retrieved from http://sru.soc.surrey.ac.uk/SRU2.html

Cox, A. (2005). What are communities of practice? A comparative review of four seminal works. *Journal of Information Science, 31*(6), 527-540.

Cox, M. D., & Sorenson, D. L. (1999). Student collaboration in faculty development: Connecting directly to the learning revolution. *To improve the academy, 18*, 97-127.

Crawford, K. (2012). Rethinking the student/teacher nexus: students as consultants on teaching in higher education. In M. Neary, H. Stevenson, L. Bell (Eds.) *Towards teaching in public reshaping the modern university*, 52-67. London: Continuum

Creswell, J. W. (2008). *Educational research : Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Upper Saddle River, NJ: Person Education.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA:Sage.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing amongst five approaches* (3^{rd} Ed.). Thousand Oaks, CA:Sage.

Croft, T., & Grove, M. (2006). Mathematics support: Support for the specialists mathematician and the more able. *MSOR Connections, 6*(2), 1-5

Croft, T., Solomon, Y., & Bright, D. (2007). *Developing academic support for mathematics undergraduates - the students' views*. Paper presented at the CETL-MSOR Conference, University of Birmingham, 22-27.

Danenhower, P. (2000). *Learning and teaching Complex Analysis at two British Columbia universities* (Unpublished PhD Thesis). Simon Fraser University, Burnaby: BC. Retrieved from http://www.collectionscanada.gc.ca/

Daskalogianni, K., & Simpson, A. (2002). "Cooling off"– the phenomenon of a problematic transition from school to university. *Proceedings of the Second International Conference on Teaching Mathematics at the Undergraduate Level*, July 1-6, (pp.103-10). Crete, Greece

Davis, R. B. (1990). *Constructivist Views on the Teaching and Learning of Mathematics. Journal for Research in Mathematics Education: Monograph No. 4*. National Council of Teachers of Mathematics, 1906 Association Drive, Reston, VA 22091.

Dawson, P., van der Meer, Skalicky, J., Cowley, K. (2014). On the effectiveness of supplemental instruction: A systematic review of Supplemental Instruction and Peer-Assisted Study Sessions literature between 2001 and 2010. *Review of Educational Review*. 84 (4), 609-639

Delpish, A., Darby, A., Holmes, A., Knight-McKenna, M., Mihans, R., King, C., & Felten, P. (2010). Equalizing voices: Student-faculty partnership in course design. In C. Werder, & M. M. Otis (Eds.) *Engaging student voices in the study of teaching and learning*, 96-114, Sterlin, VA:Stylus.

Denzin, N K.; & Lincoln, Y. S., (Eds). (2005).*The Sage Handbook of Qualitative Research (3rd ed.).* Thousand Oaks, CA: Sage.

Dobbie, M. & Joyce, S. (2009a). Peer-assisted learning in account: A qualitative assessment. *Asian Social Science, 4*(3), 18-25.

Dobbie, M. & Joyce, S. (2009b). Does peer-assisted learning improve student marks in Accounting? *Asian Social Science, 5*(10), 3-9.

Duah, F., Croft, T., & Inglis M. (2014). Can peer assisted learning be effective in undergraduate mathematics? *International Journal of Mathematical Education in Science and Technology*, *45*(4), 552-565.

Entwistle, N. J., & Ramsden, P. (1983). *Understanding student learning.* London: Croom Helm.

Ernest, P. (1997). The Epistemological Basis of Qualitative Research in Mathematics Education: A Postmodern Perspective. *Journal for Research in Mathematics Education. Monograph*, 22-177.

Fayowski, V., & MacMillan, P. D. (2008). An evaluation of the Supplemental Instruction programme in a first year calculus course. *International Mathematical Education in Science and Techonology, 39*(1), 843-855.

Flint, A., & O'Hara, M. (2013). Communities of practice and 'student voice': engaging with student representatives at the faculty level. *Student Engagement and Experience Journal*, *2*(1).

Freire, P. (1970). *Pedagogy of the oppressed*. New York: Continuum

Fuller, A. (2007). Crititiquing theories of learning and Communities of Practice. In J. Hughes, N. Jewson, & L. Unwin, (Eds.). *Communities of Practice*: *Critical Perspectives*, (pp. 17-29). London, Routledge.

Goldschmid, B., & Goldschmid, M. L. (1976). Peer teaching in higher education: a review. *Higher Education, 5*(1), 9-33.

Goodsell, A., Maher, M., and Tinto, V. (1992), *Collaborative learning: A sourcebook for higher education*, University Park, PA: National Center on Postsecondary Teaching, Learning and Assessment.

Goos, M. E., & Bennison, A. (2008). Developing a communal identity as beginning teachers of mathematics: Emergence of an online community of practice. *Journal of Mathematics Teacher Education*, *11*(1), 41-60.

Gorard, S, (2010). Research design, as independent of methods. In Teddlie, C (ed.) & Tashakkori, A (Ed.). *Sage Handbook of Mixed Methods,* (pp. 237-252*).* Thousand Oaths, CA:Sage

Goulding, M., Hatch, G., & Rodd, M. (2003). Undergraduate mathematics experience: its significance in secondary mathematics teacher preparation. *Journal of Mathematics Teacher Education*, *6*(4), 361-393.

Gratton, C., & Jones, I. (2010). *Research methods for sports studies*. London: Routledge.

Graven, M. (2004). Investigating mathematics teacher learning within an in-service community of practice: The centrality of confidence. *Educational Studies in Mathematics*, *57*(2), 177-211.

Gray, D. E. (2013). *Doing research in the real world*. London:Sage.

Green, P. (2005). Spaces of Influence: A framework for analysis of individual contribution within communities of practice. *Higher Education Research & Development. 24*(4), 293 – 307

Grove, M., Croft, T., Kyle, J., & Lawson, D. (2015).*Transitions in undergraduate mathematics education*. The University of Birmingham with The Higher Education Academy.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The handbook of qualitative research* (pp. 105–117). Thousand Oaks, CA: Sage

Gueudet, G. (2008). Investigating the secondary–tertiary transition. *Educational studies in mathematics*, *67*(3), 237-254.

Hagstrom, F., Olson, J.; and Cross, C. (2014). The student observer program at Carleton College: Three perspectives on supporting good teaching, *Teaching* *and Learning Together in Higher Education*: Issue. 13 (2014), http://repository.brynmawr.edu/tlthe/vol1/iss13/8

Handley, K., Sturdy, A., Fincham, R., & Clark, T. (2006). Within and beyond communities of practice: making sense of learning through participation, identity and practice. *Journal of Management Studies*,*43*(3), 641-653.

Harding, A., Engelbrecht, J., & Verwey, A. (2011). Implementing supplemental instruction for a large group in mathematics. *International Mathematical Education in Science and Technology*, *42*(1), 847-856

Hawkes, T., & Savage, M. (2000). *Measuring the mathematics problem.* London: Engineering Council.

Healey, M., Bovill, C., & Jenkins, A. (2015) Students as partners in learning. In J. Lea, (Ed.), *Enhancing Learning and Teaching in Higher Education: Engaging with the dimensions of practice.* Milton Keynes: Open University Press:, pp. 141-172.

Healey, M., Flint, A., & Harrington, K. (2014). *Engagement through partnership: students as partners in learning and teaching in higher education*. York: Higher Education Academy.

Healey, M., O'Connor, K. M., & Broadfoot, P. (2010). Reflections on engaging students in the process and product of strategy development for learning, teaching, and assessment: an institutional case study. *International Journal for Academic Development*, *15*(1), 19-32.

Hemmi, K. (2006). *Approaching proof in a community of mathematical practice (Doctoral Thesis)*. Department of Mathematics, Stockholm University, Stockholm.

Hensen, K. A., & Shelley, M. C. (2003). The impact of supplemental instruction: Results from a large, public, Midwestern university.*Journal of College Student Development*,*44*(2), 250-259.

Hernandez-Martinez, P., Williams, J., Black, L., Davis, P., Pampaka, M., & Wake, G. (2011). Students' views on their transition from school to college mathematics: rethinking ‘transition’as an issue of identity. *Research in Mathematics Education*, *13*(2), 119-130.

High Education Funding Council (HEFCE) (2016). *Review of information about learning and teaching, and the student experience*. Bristol:HEFCE.

Higher Education Academy (HEA). (2010). Student engagement. Retrieved from http://www.heacademy.ac.uk/student-engagement.

Howe, K. R. (1988). Against the quantitative-qualitative incompatibility thesis or dogmas die hard. *Educational researcher*, *17*(8), 10-16.

Hoyles, C., Newman, K., & Noss, R. (2001). Changing patterns of transition from school to university mathematics. *International Journal of Mathematical Education in Science and Technology*, *32*(6), 829-845.

Hurley, M., & Gilbert, M. (2008). Basic supplemental instruction model. In M. E. Stone & G. Jacobs (Eds.), *Supplemental instruction: Improving first-year student success in high-risk courses* (Monograph). Columbia, SC: University of South Carolina

Hutchings, P. (2005). *Building pedagogical intelligence*. Carnegie perspectives: The Carnegie Foundation for the Advancement of Teaching. Retrieved from http://www.carnegiefoundation.org/perspectives/building-pedagogical-intelligence

Iannone, P., & Nardi, E. (2005). On the pedagogical insight of mathematicians: ‘Interaction’and ‘transition from the concrete to the abstract’.*The Journal of Mathematical Behavior*, *24*(2), 191-215.

Iannone, P., & Simpson, A. (Eds.). (2012b). *Mapping university mathematics assessment practices*. Norwich: University of East Anglia.

Jaworski, B. (2010). The practice of (university) mathematics teaching: Mediational inquiry in a community of pratice or an activity system. In *Proceedings of the Sixth Congress of the European Society for Research in Mathematics Education. WG 2. January 28th-February 1st 2009, Lyon (France)*. Institut National de Recherche Pedagogique.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*,*33*(7), 14-26.

Jones, I., & Alcock, L. (2014). Peer assessment without assessment criteria. *Studies in Higher Education*, *39*(10), 1774-1787.

Joubert, J. (n.d.). To teach is to learn twice. Wikipedia: *The Free Encyclopedia*. Retrieved from http://en.wikipedia.org/wiki/Joseph_Joubert

Kajander, A., & Lovric, M. (2005). Transition from secondary to tertiary mathematics: McMaster University experience. *International Journal of Mathematical Education in Science and Technology, 36*(2-3), 149-160.

Kane, S., & Sinka, I. (2011).*Good practice in undergraduate peer support: a guide for those interested in the establishment and development of undergraduate mathematics peer support in higher education institutions*. Birmingham:The Maths, Stats & OR Network.

Kanes, C., & Lerman, S. (2008). Analysing concepts of Communities of Practice. In A. Watson & P. Winbourne (Eds.)*, New Directions for Situated Cognition in Mathematics Education* (pp. 303-328). New York, NY: Springer US.

Kay, J., Marshall, P. M., & Norton, T. (2007). *Enhancing the student experience*. London: 1994 Group of Universities.

Keenan, C. (2014). *Mapping student-led peer learning in the UK*. York: The Higher Education Academy.

Kemmis, S., & Wilkinson, M. (1998). Participatory action research and the study of practice. In Atweh, B., Kemmis, S., & Weeks, P. (Eds.). *Action research in practice: Partnerships for social justice in education*, 21-36., London: Routledge.

Kenney, P. A., & Kallison, J. M. (1994). Research studies on the effectiveness of Supplemental Instruction in mathematics. *New directions for teaching and learning*, 60, 75-82.

King, A.(2008). In vivo coding. In L. M. Given (Ed.). *The Sage encyclopedia of qualitative research methods*. (pp. 473-474). Sage Publications.

Kreuger, R. A. (2002). *Designing and conducting focus groups interviews*. Retrieved from http://www.eiu.edu/~ihec/Krueger-FocusGroupInterviews.pdf

Kuh, G. D. (1995). The other curriculum: Out-of-class experiences associated with student learning and personal development. *The Journal of Higher Education*, 123-155.

Kuh, G. D. (2009). What student affairs professionals need to know about student engagement. *Journal of College Student Development*, *50*(6), 683-706.

Kuh, G. D., & Vesper, N. (1997). A comparison of student experiences with good practices in undergraduate education between 1990 and 1994. *The Review of Higher Education*, *21*(1), 43-61.

Kuh, G.D., Kinzie, J., Schuh, J.H., & Whitt, E.J. (2005). Never let it rest: Lessons about student success from high-performing colleges and universities. *Change:The Magazine of Higher Learning*, *37*(4), 44-51.

Kuhn, T. S. (1970). *The structure of scientific revolutions.* Chicago, IL :University of Chicago.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lawson, D. (2015) Progression within mathematics degree programmes. In M. Grove, T. Croft, J. Kyle, & D. Lawson (Eds.). *Transitions in undergraduate mathematics education*. The University of Birmingham with The Higher Education Academy.

Lewis, D., O'Brien, M., Rogan, S., & Shorten, B. (2005). Do students benefit from supplemental instruction? Evidence from a first year statistics subject in economics and business. *University of Wollongong Economics Working Paper Series WP 05–21*, September.New South Wales, Australia: University of Wollongong.

Li, L. C., Grimshaw, J. M., Nielsen, C., Judd, M., Coyte, P. C., & Graham, I. D. (2009). Evolution of Wenger's concept of community of practice. *Implementation science*, *4*(1), 11-19

Lin, A. C. (1998). Bridging positivist and interpretivist approaches to qualitative methods. *Policy Studies Journal*, *26*(1), 162-180.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA:Sage.

Little, S. (Ed.). (2012). *Staff-student partnerships in higher education*. London: Continuum.

Loughlin, W., Gregory, S. J., Harrison, G., & Lodge, J. (2013). Beyond the first year experience in science: Identifying the need for a supportive learning and teaching environment for second year science Students. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 21*(4), 13-26.

Malm, J., Bryngfors, L., & Mörner, L. L. (2011). Improving student success in difficult engineering education courses through Supplemental Instruction (SI) – what is the impact of the degree of SI attendance? *Journal of Peer Learning,4*(1), 16-23.

Malm, J., Bryngfors, L., & Mörner, L. L. (2012). Supplemental Instruction for improving first year results in engineering studies. *Studies in Higher Education*, *37*(6), 655-666.

Maracci, M. (2008). Combining different theoretical perspectives for analyzing students' difficulties in vector spaces theory. *ZDM*, *40*(2), 265-276.

Martin, D., & Arendale, D. (1994). *Review of research concerning the effectiveness of SI from the University of Missouri-Kansas City and other institutions from across the United States*. Paper presented at the Annual Conference of the Freshman Year Experience (Columbia, SC, February 1994). Retrieved from http://www.eric.ed.gov/ERICWebPortal/d etail?accno=ED457797

Marton, F. (1994).On the structure of awareness. In Dall'Alba, G., Bowden, J., & Walsh, E. (Ed.) (1994). *Phenomenographic Research: Variations in Method*.

Marton, F., & Säljö, R. (1976). On qualitative differences in learning: I—Outcome and process. *British journal of educational psychology*, *46*(1), 4-11.

Maxwell, S. (2004). *Qualitative Research Design: An interactive approach*. Thousand Oaks, CA: Sage.

McBurnie, J. E., Campbell, M., & West, J. (2012). Avoiding the second year slump: A transition framework for students progressing through university. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International)*, *20*(2), 14-24.

McCarthy, A., Smuts, B., & Cosser, M. (1997). Assessing the effectiveness of supplemental instruction: A critique and a case study. *Studies in Higher Education*, *22*(2), 221-231.

McMillan, J. H. (2004). *Educational research: Fundamentals for the consumer* (4th ed.). Boston, MA: Pearson Education.

Mihans, R., Long, D. T., & Felten, P. (2008). Power and expertise: Student-faculty collaboration in course design and the scholarship of learning and teaching.

International Journal for the Scholarship of Teaching and Learning, *2*(2). Retrieved from https://doi.org/10.20429/ijsotl.2008.020216

Miles, A. C., Polovina-Vukovic, D., Littlejohn, D., & Marini, A. (2010). *The effectiveness of peer-assisted study sessions (PASS) program in enhancing student academic success at Carleton University*. Toronto: Higher Education Quality Council of Ontario.

Miles, M. B., & Huberman, M. A. (1994). *Qualitative data analysis* (2nd ed.). Newbury Park, CA: Sage.

Mittendorff, K., Geijsel, F., Hoeve, A., de Laat, M., & Nieuwenhuis, L. (2006). Communities of practice as stimulating forces for collective learning. *Journal of Workplace Learning*, *18*(5), 298-312.

Moore, N., & Gilmartin, M. (2010). Teaching for better learning: A blended learning pilot project with first-year geography undergraduates. *Journal of Geography in Higher Education*, *34*(3), 327-344.

Myers, M. D. (2008). *Qualitative Research in Business & Management*. London: Sage

Odi, M. (2008). Personal Communication. 10 July 2016.

O'Donoghue, T. (2007). *Planning your qualitative research project: An introduction to interpretivist research in education*. Abingdon, Oxon: Routledge.

Ogden, P., Thompson, D., Russell, A., & Simons, C. (2003). Supplemental instruction: Short-and long-term impact. *Journal of Developmental Education*, *26*(3), 2-7.

Pace, C. R. (1995). From good practices to good products: Relating good practices in undergraduate education to student achievement. *Paper presented at the 35th Association for Institutional Research Annual Forum*. Boston, 28-31 May.

Paloyo, A. R., Rogan, S., & Siminski, P. (2016). The effect of supplemental instruction on academic performance: An encouragement design experiment. *Economics of Education Review*, *55*, 57-69.

Parkinson, M. (2009). The effect of peer assisted learning support (PALS) on performance in mathematics and chemistry. *Innovations in Education and Teaching International*, *46*(4), 381-392.

Parsons, S., Croft, T., & Harrison, M. (2009). Does students' confidence in their ability in mathematics matter? *Teaching Mathematics and its Applications, 28*(2), 53-68.

Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students* (Vol. 2). K. A. Feldman (Ed.). San Francisco, CA: Jossey-Bass.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). London:Sage.

Peterfreund, A. R., Rath, K. A., Xenos, S. P., & Bayliss, F. (2008). The impact of supplemental instruction on students in STEM courses: Results from San Francisco State University. *Journal of College Student Retention: Research, Theory & Practice, 9*(4), 487-503.

Piaget, J. (1972). *The psychology of the child*. New York, NY: Basic Books.

Porter, A. (2008). What comes into your mind when I use the words 'student representation'. *Brookes eJournal of Learning and Teaching, 2*(3). Retrieved from http://bejlt.brookes.ac.uk

Pritchard, D. (2015). Lectures and transition: from bottles to bonfires?. In Grove, M., Croft, T., Kyle, J., & Lawson, D. (ed.).*Transitions in undergraduate mathematics education*. The University of Birmingham with The Higher Education Academy.

Quality Assurance Agency for Higher Education (QAA). (2012). Chapter B5: Student engagement. *UK quality code for higher education:[Internet]*. Gloucester: QAA. Retrieved from http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/quality-code-part-b

Ramsden, P. (1988). Context and strategy. In Schmeck, R. R. (Ed.) *Learning strategies and learning styles* (pp. 159-184). Springer US.

Rapke, T. (2016). A process of students and their instructor developing a final closed-book mathematics exam. *Research in Mathematics Education, 18*(1), 27-42.

Rath, K. A., Peterfreund, A., Bayliss, F., Runquist, E., & Simonis, U. (2011). Impact of supplemental instruction in entry-level chemistry courses at a midsized public university. *Journal of Chemical Education, 89*(4), 449-455.

Resnick, L. B .(1991). Shared cognition: Thinking as a social practice. In L. B. Resnick, B. Lauren B. Levine, M. John, S.D. Teasley (Eds.). *Perspectives on socially shared cognition*. , (pp. 1-20). Washington, DC, US: American Psychological Association.

Richardson, P., Schatz, A., & Owen, T. R. (1973). *Student involvement in course design.* Syracuse, NY: Syracuse University.

Roberts, J. (2006). Limits to communities of practice. *Journal of Management Studies*, *43*(3), 623-639.

Robson, C. (2011). *Real world research*. Chichester: Wiley.

Sale, J. E., Lohfeld, L. H., & Brazil, K. (2002). Revisiting the quantitative-qualitative debate: Implications for mixed-methods research.*Quality and quantity*, *36*(1), 43-53.

Sandover, S., Partridge, L., Dunne, E., & Burkill, S. (2012). Undergraduate researchers change learning and teaching: A case study of two universities in Australia and the UK. *CUR Quarterly*, *33*(1), 33-39.

Scandrett, E. O'Leary, T. & Martinez, T. (2005): Learning environmental justice through dialogue. In *Making knowledge work: Building sustainable communities through partnerships*. Paper presented at Univerity of Stirling, 25-28 October 2005. Stirling:University of Stirling.

Scandrett, E. O'Leary, T. & Martinez, T. (2005): Learning environmental justice through dialogue. In *Making knowledge work: Building sustainable communities through partnerships*. Paper presented at Univerity of Stirling, 25-28 October 2005. Stirling:University of Stirling.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, *3*(3), 265-283.

Schoenfeld, A. H. (1999). Looking toward the 21st century: Challenges of educational theory and practice. *Educational researcher*, *28*(7), 4-14.

Scotish Educational Research Association (SERA). (2005). *Ethical guidelines for educational research*. Edinburgh: Scottish Educational Research Association.

Shemmings, D. (2006). ‘Quantifying’qualitative data: an illustrative example of the use of Q methodology in psychosocial research. *Qualitative Research in Psychology*, *3*(2), 147-165.

Smithson, J. (2000). Using and analysing focus groups: Limitations and possibilities. *International Journal of Social Research Methodology, 3*(2), 103 - 119.

Solomon, Y, & Croft, T. (2015). Understanding undergraduate disengagement from mathematics: Addressing alienation. *International Journal of Educational Research*, *79*, 267-276.

Solomon, Y, Croft, T. & Lawson, D. (2010). Safety in numbers: mathematics support centres and their derivatives as social space. *Studies in Higher Education*, *35* (4), 421-431.

Solomon, Y. (2007). Not belonging? What makes a functional learner identity in undergraduate mathematics? *Studies in Higher Education*, *31*(1), 79-96.

Solomon, Y., Croft, T., Duah, F., & Lawson, D. (2014). Reshaping understandings of teaching – learning relationships in undergraduate mathematics: An activity theory analysis of the role and impact of student internships. *Learning, Culture and Social Interaction*.

Steffe, L. P. (1991). The constructivist teaching experiment: Illustrations and implications. In Von Glasersfeld, E. (Ed.) *Radical constructivism in mathematics education* (Vol. 7), (pp. 177-194). Springer Netherlands.

Stout, M. L., & McDaniel, A. J. (2006). Benefits to supplemental instruction leaders. *New Directions for Teaching and Learning*, 106, 55-62.

Stout, M. L., & McDaniel, A. J. (2006). Benefits to supplemental instruction leaders. *New Directions for Learning and teaching*,106, 55-62.

Strauss, A. L. (1987). *Qualitative analysis for social sciences*. Cambridge: Cambridge University Press.

Strauss, A., & Corbin, J. (1990).*Basics of qualitative research* (Vol. 15). Newbury Park, CA: Sage.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research*.2nd Ed. Thousand Oaks, CA:Sage

Tall, D. (2008). The transition to formal thinking in mathematics. *Mathematics Education Research Journal*, *20*(2), 5-24.

Thompson, S., Milsom,C., Zaitseva, E., Stewart, M., Darwent,S., Yorke, M. (2013). *The Forgotten Year? Tackling the Second Year Slump* York: The Higher Education Academy.

Topping, K. J. (2005). Trends in peer learning. *Educational Psychology*, *25*(6), 631-645.

Topping, K. J. (2009). Peer assessment. *Theory into practice*, *48*(1), 20-27.

Topping, K., Miller, D., Murray, P., & Conlin, N. (2011). Implementation integrity in peer tutoring of mathematics. *Educational Psychology*, *31*(5), 575-593.

Trochim, W. M. (2006). Research methods knowledge base. Retrieved from 1 January 2012, http://www.socialresearchmethods.net/kb/sampnon.php

Trouche, L. (2005). Instrumental genesis, individual and social aspects. In D. Guin, K. Ruthven, L. Trouche *The didactical challenge of symbolic calculators.* (pp. 197-230). Springer US.

Trowler, V. (2010). *Student engagement literature review*. York: The Higher Education Academy.

University of Manchester. (2012). Peer assisted study sessions. Retrieved 1 January 2012, from http://www.tlso.manchester.ac.uk/students-as-partners/peersupport/pass/

University of Missouri-Kansas City (UMKC) (2017). What is Supplemental Instruction. Retrieved 22 June 2017, from http://info.umkc.edu/si/

University of Wollongong (2016). Pass programme results. Retrieved 1 January 2012, from http://www.uow.edu.au/student/services/pass/evaluation/index.html

Usher, R. (1996). A critique of the neglected epistemological assumptions of educational research. In D. Scot and R. Usher (Eds.) *Understanding educational research*, (pp.9-32). London:Routledge.

Von Glasersfeld, E. (1990). Chapter 2. An exposition of constructivism: Why some like it radical. *Journal for Research in Mathematics Education. Monograph*, *4*, 19-29.

Vygotsky, L. (1978). *Mind and society: Interaction between learning and development* , (pp. 79-91). Cambridge, MA: Harvard University Press.

Warfield, V. M. (2013). *Invitation to didactique* (Vol. 30). Springer Science & Business Media.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Wenger, E. (2000). Communities of practice and social learning systems. *Organisation*, *7*(2) 225-246.

Wenger, E., McDermott, R., & Snyder, W. M. (2002). *Cultivating communities of practice*. Boston, MA: Harvard Business School Press.

Werder, C., & Otis, M. M. (Eds.). (2011). *Engaging student voices in the study of learning and teaching*. Sterling, VA: Stylus.

Wertsch, J. V. (1991). A sociocultural approach to socially shared cognition. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Ed). *Perspectives on socially shared cognition*, *2*, 63-82.

Williams, J. (2015). Mathematics education and the transition into higher education – Transmaths demands better learning-teaching dialogue. In M. Gove, T. Croft, J. Kyle & D. Lawson (Eds.). *Transitions in undergraduate mathematics education*, (pp 25-37). Birmignham: University of Birmingham.

Williams, J., Alder, D., Cook, J., Whinney, M., O'Connell, R., Duffin, W., & King, P. (2010). Students and staff as educational partners in the development of quality-assured online resources for medical education. In S. Little (Ed.) *Staff-student partnerships in higher education*, (pp. 76-91). London: Bloomsbury.

Wilson, V. (1997). Focus groups: a useful qualitative method for educational research. *British Educational Research Journal, 23*(2), 209-224.

Winsløw, C., Barquero, B., De Vleeschouwer, M., & Hardy, N. (2014). An institutional approach to university mathematics education: from dual vector spaces to questioning the world.*Research in Mathematics Education*,*16*(2), 95-111.

Zerger, S (2008). Basic supplemental instruction model. In M. E. Stone & G. Jacobs (Eds.), *Supplemental instruction: Improving first-year student success in high-risk courses* (Monograph).

Zerger, S., Clark-Unite, C., & Smith, L. (2006). How supplemental instruction benefits faculty, administration, and institutions. *New Directions for Learning and teaching, 106*, 63-72.