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Virtual collaborative learning for building design

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A building design project that requires civil engineering students in the UK and architectural students in Canada to collaborate virtually has been implemented at universities in the two countries. The aims were to obtain a greater understanding of the process, strategies and expected outcomes for a more effective implementation of problem-based learning to hone communication and teamwork skills. Data were obtained from a series of interviews with 23 students from seven groups, assessment results of 249 participating and non-participating students, and student evaluation. The findings suggest that the professional ethos of the groups and the consequent building of trust is the greatest factor in supporting successful collaborations. This has been found to be able to overcome many barriers related to technology and differences of culture, language, time zone and tasks. However, the activity did not seem to have any impact on student performance, but has improved the project management skills of participating students. The activity has also contributed positively to increasing student satisfaction. Several lessons for future implementation are presented, before limitations and further research are described.

1. Introduction

Increasing competition and shortage of resources have encouraged the use of globally distributed teams in the design and development of construction projects. Communication over a distance has further exaggerated the challenge and complexity of collaboration between multidisciplinary and fragmented parties involved in the projects. Nevertheless, seamless communication and harmonious relationships between parties are considered the key requisites to more effective and efficient delivery to achieve better project outcomes (Korkmaz and Singh, 2012). Built environment (BE) professionals are expected to work in globally dispersed teams across different time zones and cultures (RAE, 2007), and communication and teamwork skills are therefore now the key skills that employers seek in future BE graduates. Royal Academy of Engineering reports, for example, indicate that employers emphasise the importance of combined technical skills with social and interpersonal skills that meet industry needs (Lamb *et al.*, 2010; Spinks *et al.*, 2006). Students are well aware of this increased need, and value opportunities to learn these employability skills, which can offer them a competitive advantage in the job market. For higher educational institutions, this represents a challenge as well as an opportunity to incorporate virtual collaborative learning into the curricula, which will not only equip students with important employability skills but also enhance their engagement and experience. As an emerging area, it is not fully understood how BE educators can do this and what impact virtual collaboration has on student performance and experience.

A research project has been initiated to address this challenge by conducting a quasi-experimental explorative study of a multidisciplinary, distanced collaboration in a building design project that simulates real industry practice to address the

questions of what factors influence the success of virtual collaborative learning and the impact of this on student performance and experience. The project involved groups of students in two BE departments: one in the UK and the other in Canada. The students formed groups comprising civil/structural engineering students in the UK and architecture students in Canada. The groups worked on the project, based on a real case study, for a whole academic year (September 2011 to May 2012). This paper reports the findings of this investigation, which were obtained from a database of qualitative and quantitative data, including: interviews with 23 participants from seven groups; individual and group marks of 249 (participating and non-participating) students in the first and second phases of the project; and student evaluation obtained from module questionnaire survey. The following section presents a synthesis of relevant literature in team-based learning.

2. Collaborative learning in design projects

Collaborative learning is a term that encompasses all team-based, project-based and problem-based learning approaches in which learners work together in a small group to achieve a common objective (Becerik-Gerber *et al.*, 2012; Dillenbourg, 1999). In BE education, collaborative learning is not new and has been a part of BE courses around the world (Shrivastava, 2013; Tucker and Rollo, 2006). Barry *et al.* (2012) describe the development of the capstone design course in Purdue University, which has been team taught since the early 1960s. There are some recent examples, such as Bhandari *et al.* (2011), Peterson *et al.* (2011), Soibelman *et al.* (2011), Wolcott *et al.* (2011), Korkmaz (2012) and Stanford *et al.* (2013). Their implementation varies considerably with different objects of design (e.g. building, road and other infrastructure projects), supporting technologies (synchronous and asynchronous), composition (e.g. single discipline with participants from one course, multiple disciplines with participants from different courses) and locations of team members (e.g. co-located, distributed), previous training (e.g. on the use of collaborative technologies and software, such as AutoCAD) and education levels (e.g. undergraduate or postgraduate). Some design projects were implemented within one institution, which makes possible regular offline communication between students (e.g. Barry *et al.*, 2012; Tucker and Rollo, 2006). However, there are fewer examples of collaborative learning that involves collaboration between geographically distributed multidisciplinary members from two or more institutions, such as Fruchter (1999), Hussein and Peña-Mora (1999), O'Brien *et al.* (2003) and Becerik-Gerber *et al.* (2012).

Fruchter (1999) developed a multidisciplinary and geographically distributed learning environment involving six universities with information technology toolkits to support collaborative working across six iterations. Hussein and Peña-Mora (1999) conducted an experiment for assessing the interaction between members of geographically distributed teams and their supporting collaborative technologies. They highlighted four major considerations in the development of collaborative learning environments, namely technology infrastructure, group dynamics, incentives and evaluation and feedback. O'Brien *et al.* (2003) implemented a collaborative design course involving graduate students from two institutions with emphasis on the development of process designs for the integration of technology into the work of a multidisciplinary design team. Becerik-Gerber *et al.* (2012) describe the experiences, learning outcomes and lessons learnt from a collaborative design course with students from two institutions, which involved virtual collaboration between distributed team members.

In most of these studies, questionnaire surveys were administered to obtained students' opinions of their experience and the effectiveness of the process. However, as the surveys were administered to a limited number and cohort of students, the effectiveness of the approaches and impact on student performance and skills over a longer period of time is difficult to assess (Becerik-Gerber *et al.*, 2012). Given the variability of their implementations and focuses, lessons learnt are often not directly applicable and comparable for a different context. Furthermore, O'Brien *et al.* (2003) and Becerik-Gerber *et al.* (2012) found that remote collaboration is not always successful and is often less effective than face-to-face offline meetings. Therefore, a greater understanding of barriers to collaboration in geographically distributed teams, the mechanisms and strategies that facilitate the implementation process and the impact on student performance is required for a more effective implementation of this distributed collaborative learning. As stated previously, this study aimed to contribute knowledge in this area by addressing two key research questions: what are the factors influencing the success of virtual collaborative learning, and what is the impact on student performance and experience? As an initial point to address these questions, the following section explains a model for virtual collaborative learning.

3. A model of virtual collaborative learning

When two or more people are collaborating to achieve a common project objective, they are engaged in a communication in which effectiveness relies on the success of bridging the 'transactional distance' between these parties. 'Transactional distance' is defined as the psychological distance that exists between people when communicating (Barrett, 2002: p. 36), and is noticed particularly in online environments because it can be increased by the lack of responsiveness of the environment (or of others within the environment) and transparency of the medium (Wheeler, 2007: pp. 111–112). The theory of transactional distance addresses the psychological

separation between two people in any dialogue (in the examples given by Moore (1993) between tutor and student), and can be described as a series of constraints of which the technology and geographical distance are only additional elements that arise when that communication is mediated by means of technology. Furthermore, the theory argues that many of these constraints exist in face-to-face communication, such as the personalities and philosophies of the participants, their skill at communication and the content of the dialogue (Moore, 1993: pp. 28–30). For example, 'nodding, smiling and other non-verbal behaviours such as eye contact and gaze' are behaviours that reduce transactional distance in that they create a sense of rapport between two people (Wheeler, 2007: p. 111). Defining the sets of characteristics that give rise to transactional distance in such a way is useful in an analysis of virtual teamwork in that it normalises the problems and complexities that arise in these forms of activities. The recognition that psychological distance occurs when people are meeting face to face as well as when mediated by technology means that, although distanced communication introduces technological constraints and geographical distance, these only act to increase a separation that already exists. The technological constraints of the technology are therefore only those that tend to be focused on by participants, because they are ones to which we are not accustomed, and are not necessarily the dominant ones (Childs, 2010: p. 54).

The finding of the literature review and the theory of transactional distance has been adopted to inform the development of a model of virtual collaborative learning, presented in Figure 1. The input, process, output model summarises the combination of issues related to inputs of learning, process of learning, and outputs or impact within the virtual collaboration environment. In this model, the notion of transactional distance constitutes the 'input' to the act of collaboration, indicating a range of barriers or distances that need to be overcome to form an effective collaboration. 'Process' within the model is the adaptation and activities that act on the input. Here, the students adopt a set of behaviours and activities that bridge this separation. The model groups these processes under the heading of 'alignment strategies', which refer to either the students' observations of how the two groups are aligned, or the process by which they brought the two groups into greater alignment. Peer assessment (using an online Web-PA system, see Wilkinson and Lamb (2010) for a description) and tutor intervention provide a 'behavioural control' or 'moderator' to student performance, and are essential elements of the project. Of utmost importance is the level of 'trust', which represents a distinct influence on the process with a two-way arrow. This indicates its impact on the success of the collaboration process, which in turn will enhance the level of trust (or reduce the level of trust, if the process is unsuccessful). The final state is the 'output'; here the outputs that the students and educators valued were the impact the activity had on a range of 'short-term' and 'long-term' aspects, such as employability and personal development, and their performance. 'Short-term' aspects were assessed immediately during and after the process when the students' works or presentations are marked, and from the student evaluation by means of a module questionnaire survey. The model demonstrates the interplay between different influences of virtual

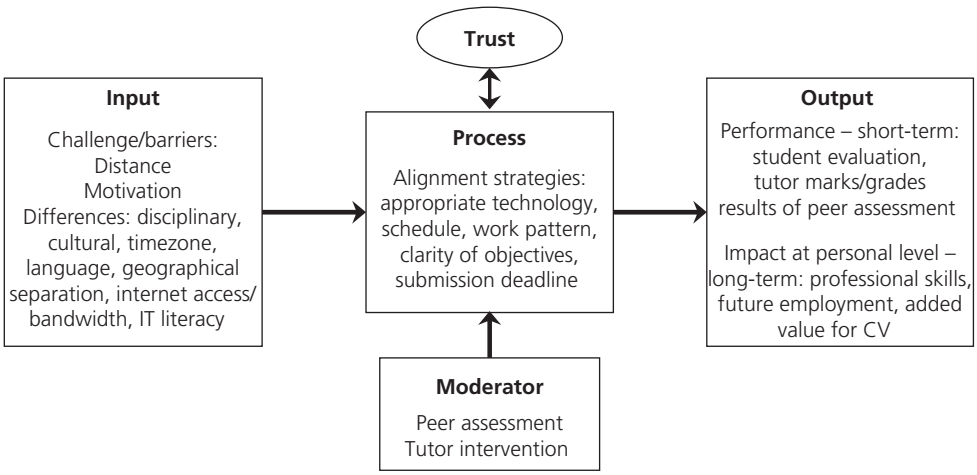

Figure 1. A model of virtual collaborative learning (after Soetanto *et al.*, 2012 with modifications)

collaborative learning effectiveness for possible intervention strategies and is considered a framework to guide the research process.

4. Design task and procedure of group work

In the collaborative design project, which lasted one academic year, students worked in groups to undertake tasks that were derived to meet the requirements of a project brief. The brief was developed by the tutors involved, based on a future plan of a new academic building. The key requirement of the brief was to develop new accommodation for academic activities, which must be flexible, sustainable and adaptable to meet the demands of new ways of teaching, learning and research. The brief included: a description of the purposes of the building; requirements of facilities (e.g. rooms, area, environmental aspects); site location and constraints (relationships with the existing buildings, roads and facilities in the surrounding area); requirements of group formation and work process (regular meetings, group leadership, meeting minutes); assessment of tasks with detailed requirements for two project phases (i.e. a conceptual design phase in the first term and a detailed design and tendering phase in the second term); and online peer assessment using the Web-PA system. In addition to these, design guidance on building standards, structural design codes, posters and presentations were also provided.

The UK students studied civil and structural engineering, whereas the Canadian students studied architecture. Groups of four students were formed in each participating university. After reviewing the tasks in the project brief, each group was asked to identify their relevant technical skills, people management skills (such as leadership, teamwork, communication) and previous experience, and then develop one A2-sized poster to showcase these skills and other attributes. The groups reviewed posters developed by the groups in the other institution, for negotiating and agreeing with a counterpart group for the formation of a team with the strongest complementary skills and experience.

The teams in the same location conducted weekly meetings, and appointed a leader and secretary. These roles were rotated every 5 weeks, so that each member had the opportunity to undertake the responsibilities. They also held regular meetings with their counterparts in the other institutions. They communicated through various means, but commonly used Dropbox for file sharing, Skype and e-mail for synchronous and asynchronous communication. The minutes of the meetings were assessed as a part of the overall module mark. The assessment of the conceptual design phase was weighted 40%, and the detailed design and tendering phase 60% of the overall module mark. The marking scheme combined individual and group marks for each task. The individual marks were derived from the assessment of the task that the individual was responsible for. The group marks were peer-assessed using the Web-PA system, which provides a moderation mechanism to consider an individual's contribution fairly.

5. Research methods

The research consisted of both quantitative and qualitative research methods as this mixed approach was considered to be an effective way to conduct an explorative study in that both in-depth 'rich' data could be gained from the interviews and large-scale data could be gathered from conducting the surveys across the whole cohort. Furthermore, the two alternative methods of data capture would provide triangulation for the findings (Merriam, 1998: p. 204). Data were collected from a series of interviews, a module evaluation questionnaire and marks for both participating and non-participating students. Non-participating students were those students on the same module who had opted to work co-located with students from the same institution, and were used as a 'control group' for comparison. Data collection was guided by the model of virtual collaborative learning (Figure 1), in order to capture a number of important aspects of virtual collaboration (e.g. barriers, trust, alignment strategies, outputs and impacts) throughout two project phases. In particular, the interviews were intended to explore behaviours and practices that led to 'successful' and 'not successful' collaborations.

5.1 Group interviews

The interviews with 23 participating students from seven groups (for the purposes of the analysis, named groups A, B, C, D, E, F and G) were intended to interrogate issues and problems encountered and to provide understanding of the context within which the project took place. The unstructured interviews were conducted with the groups at different times during the course of the project. The students were asked general and specific questions regarding their project. General questions were asked concerning how the students were getting on with the project, and any issues that may have prevented their work. Specific questions covered aspects such as collaborative technologies used, the interaction between distributed teams, issues of trust and barriers to collaboration, guided by the model in Figure 1. Interviewing students in their group enabled the capture of richer, more comprehensive and objective views of their experience, as one issue raised could be discussed with the others during the conversation. One group interview lasted approximately one half-hour. The interviews were recorded and then transcribed verbatim.

5.2 Assessment results

The marking scheme for the project combined group and individual marks. The group mark was derived from the group formation tasks (including the poster, written report on group strategy and time management), presentations, group report structure and teamwork. The group mark was then peer-assessed.

An individual mark was obtained from the assessment of tasks that each student was responsible for. Group and individual marks were obtained from each phase that will allow comparisons between the first and second phases to identify any improvements. Individual and group marks of 249 (35 participating and 214 non-participating) students were obtained for the first and second phases in the UK institution. To address the question of what was the impact on student performance of conducting the exercise with distanced teams, the *t* test was used to compare the performance of participating and non-participating students (as a control group), and their performance in the first and second phases.

5.3 Module evaluation questionnaire

As part of university policy, the delivery of teaching, learning and support services is monitored through the administration of a module evaluation questionnaire to both participating and non-participating students during the last session of the academic year. The questionnaire assessed different aspects of the module, including the performance of the tutor, module delivery, provision of information, supports to learning, timing of classes and coursework release and submission, assessment and feedback. The anonymous responses obtained were analysed quantitatively. For the purpose of student evaluation, one statement (judged to be the most telling) was chosen as the key criterion. This was 'the overall quality of this module is satisfactory'. The students were asked to indicate their level of agreement on a five-point scale representing 'definitely agree', 'mostly agree', 'neither disagree nor agree', 'mostly disagree' and 'definitely disagree' against this statement. As this criterion used in the questionnaire was identical in the previous and current academic years, the responses obtained can be compared, and provide a useful indicator of how the virtual collaboration has impacted the student evaluation.

6. Results and discussions

The seven groups that were analysed for their experience of virtual teamwork were assigned the categories 'successful' and 'not successful' collaborations, with the intention of observing differences in behaviour and practice between the two types of group. In reality, the collaborations did not sit at the end of these two polarities, but on a continuum. The placing within these groups was determined by the researchers based on two criteria: whether the students themselves identified particular issues with their working relationship with the other team, and whether the number of quotes referring to distances and differences or those that referred to alignments predominated. In all, groups A, D, E and G were characterised as 'successful' collaborations; groups B and C as 'not successful'. Group F, lying in the middle of these, was characterised as partly successful. In the transcript, the groups' descriptions of their experiences were broken down into discrete statements, which were then manually coded. Statements assigned the same code were grouped together into a single category and the experience they described was synthesised to identify common traits. Each category was then placed into either input (distancing factors), trust, process (alignment factors) or output (performance and impact factors) clusters as shown in Figure 1. These clusters and their subsidiary categories, with accompanying descriptions, are shown below and summarised in Figure 2.

6.1 Distancing factors

Some distancing factors were common to all groups, some only to specific groups. The distancing characteristic that was common to all groups was the 'mismatched schedules'. Because of the timetable of activities, the Canadian students began their activities before the UK students, and ended before them too.

The distancing factors affecting only some groups included 'technology', 'disciplinary difference', 'task difference' and 'differences in standards' between the two countries. The groups that found technological issues had problems with internet connections and encountered frustrations with not being able to conduct multipoint communication in Skype. Another factor creating distance was the different disciplines involved (i.e. architecture and civil engineering). One group noted that some of the issues they were encountering were no different from those that their colleagues engaged in face-to-face collaboration with UK-based architects were facing. Groups reported that the students in Canada had been set very different tasks. However, only one group had encountered any confusion due to different standards across the two countries.

6.2 Trust and professional ethos in distanced collaboration

The single factor that all those collaborations that were unsuccessful had in common, and was different to those collaborations that were successful, was the attitude to professional behaviour displayed (in their perception) by the team at the other end. Both groups B and C had experienced problems with their experience of the work ethos of the team at the other end. Conversely, group F admitted that the fault lay on both sides, neither side always meeting their commitments on time, which they attributed to the mismatch in schedules. This failure to meet commitments was despite an excellent start as far as project management practice is concerned, in that they shared expectations and goals, and overall their opinion of the group at the other end was positive. One area in which even some of the successful groups struggled was in the attitude to different goals and tasks. As the students observed, a professional outlook requires people to make efforts to meet the objectives of other members of the organisation, not just their own. However, not all groups worked towards a common goal of completing the project, instead they focused on their

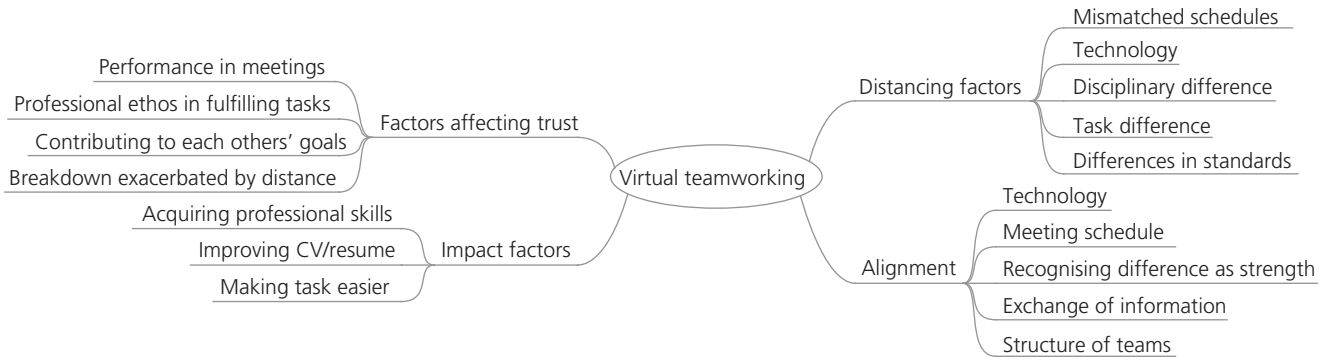

Figure 2. A summary of the different influences on virtual teamwork identified from the interviews with the learners

own individual objectives. Others did not struggle to achieve this higher level of collaboration, for example group G reported that they would: 'find some stuff on sustainability that might be of interest to them (their counterpart team), and put it in, have a look at it, might be interesting. Just help them out, we are a group at the end of the day'.

The consequence of a lack of professional ethos had a greater impact due to the distanced nature of the collaboration, because the students had no recourse to alternative supportive forms of interaction. Although the distanced nature of the interaction is not a problem for those with a successful collaboration, it permits a range of additional concerns to arise when communication is taking place within an unsuccessful collaboration. For example, for group B, the fact that they only met for an hour a week, and the work at the other side could not be constantly monitored, became an issue. The increasing lack of trust was noted by the other team with an unsuccessful collaboration (group C), and was responded to by a similar desire to reciprocate with the withholding of information. It was specifically the distanced nature of the collaboration that exacerbated this breakdown in trust; because the other team could not be observed outside of the brief Skype meetings, this meant that there was an opportunity for doubts and suspicions to develop further.

The root of this breakdown in trust was essentially a failure to produce work to time. The successful collaborations built trust on the basis of a cycle of incrementally increased fulfilment of tasks. When the majority of the collaboration is successful, and the perception of the team at one end is that the team at the other is taking a professional approach to their work, then other distancing factors become less problematical. For example, technological problems, such as internet interruptions, are overlooked or adjusted to in successful collaboration; in unsuccessful ones, it is identified as disruptive. Even mismatches in task briefs were more easily overcome, or overcome with more confidence, if both groups of students behaved with a professional attitude, as were mismatches in schedules. This finding suggests two cycles, one of increasing trust and commitment, and one of diminishing trust and commitment to the collaboration, which is depicted in Figures 3 and 4.

6.3 Alignment factors that predominated

No single alignment factors were identified across all the groups; the most common factor noted by most of the groups was the technological platforms adopted. All groups used Skype for regular synchronous communication and Dropbox for sharing of information. E-mail correspondence was used by all the groups to schedule meetings and notify the other group of when information was loaded to Dropbox, and e-mail was

Figure 3. A cycle of decreasing collaboration in virtual teamworking

Figure 4. A cycle of increasing collaboration in virtual teamworking

still the preferred technology for communicating important and detailed information. The students' familiarity with videoconferencing greatly aided this alignment. For many students, the use of Skype was very natural, to the extent that one group referred to meeting this way as face to face (by 'unsuccessful' group B). It seems that technical alignment, for this cohort of students, is a given, and on its own does not enable effective collaboration.

Another alignment factor commonly referred to by the groups was the creation of an aligned schedule of tasks and meetings. A typical schedule for meeting was a Skype call once a week, sometimes twice. The more successful collaborations adopted the flexibility of additional meetings when required. Flexibility was also important for the meeting structure and length. Adjusting the type of contact depending on the need and the project phase was also a factor employed by the successful groups, and being able to make decisions about how to solve problems and make decisions (i.e. meta-decision-making) is widely recognised as a highly useful practice in effective collaborations. Having a process by which the collaboration can come to a decision about the length of meetings and appropriate schedules for these appears to have made a difference to these groups.

A factor that indicated a positive position on collaboration, and one adopted by the majority of groups, was that of recognising the complementary nature of the two skills sets (i.e. architecture and civil engineering), and how the overall collaboration was stronger as a consequence of this and, as noted above, provision of help in achieving the other party's goals (as explained earlier) is an indicator of a highly successful collaboration. Examples of this collaborative attitude towards the exchange of information are close attention to the information given by the other group, clarity of requests for information, offering of information and provision of an amount of information above the required minimum in the expectation that it may be of use.

Arranging meetings through Skype with the other end did not appear to be particularly problematical for the groups. More problematical were the difficulties in arranging all of the near side team to be able to attend the meeting. This was particularly difficult for group F because they were part-time students. The groups found different solutions to the complexity of having two groups of four people all collaborating. One solution was to structure the activities so that only one person works with their opposite member to complete that task. Another solution was to appoint a single person, or two people, to represent each group at the meetings and have them coordinate the activity with their co-located groups. A third solution was to break down into more detail the tasks between the two groups, so that individual members could work more independently. This third strategy, however, undermines the very idea of team collaboration. Commonly, the students immediately split their tasks into several chunks of work that was to be shared with the individual members.

6.4 Performance and impact

Most of the participants referred to the fact that they had been drawn to doing the collaborative activity because they thought it would be interesting. In addition, the ability to work with other nationalities at a distance was thought to be an intrinsic part of their professional career as civil engineers, and this activity would provide a work-like experience that would prepare them for this sort of activity. Typical statements were 'It gives you a simulated experience of working in the industry' (group F) and 'it shows you a picture into a real life, for example architects will give you a design whatever' (group G). That it would look good on their CVs was also an attractive prospect for most of the participants; the experience was particularly prized because it was thought to be a rare one, and so it would give them a greater competitive advantage when looking for work. Finally, one group (but only one) commented that actually conducting this collaboration at a distance, rather than with another local group of architects, was preferable because it was actually easier. Group F commented 'It is probably easier. Some of the groups I've spoken to that are working with other UK students, they seem to have more problems than we do.'

The analysis of assessment results suggests that there are no significant differences in individual and group marks between participating and non-participating students, and between the first and second phases. However, participating students appear to be better in developing a plan for monitoring,

controlling and coordinating their work with the other team members (t test, $p = 0{\cdot}054$). In this task, each member must submit a report outlining the tasks that they will undertake during their assignment, and how this work will be monitored and controlled so that it coordinates with the rest of the team.

The analysis of the key indicator of student evaluation indicates that overall satisfaction with the module from both participating and non-participating students had actually increased. In particular, the proportion of students who chose 'definitely agree' or 'mostly agree' responses on a statement of 'the overall quality of this module is satisfactory' had increased from 64% to 81%, an increase of 17% from the previous year. While it may be difficult to delineate different factors contributing to this significant increase, the activity and other planned improvements resulting from the project implementation (including unintentionally greater attention and effort from all staff involved) have undoubtedly contributed to this increased level of satisfaction.

7. Conclusion

A model of virtual collaborative learning has been developed to explore factors that may influence the effectiveness of virtual teamwork through a simulated learning environment where students work on a real case study project. The analysis of the interviews, student performance and evaluation indicates a set of key considerations regarding the barriers, success factors and outcomes/impacts that occur when teams work across distances, described as follows.

- The mismatching in schedules at the two sites, the perceived difference in the tasks set and the fact that the team was a virtual one did not have an impact on the teams that were collaborating successfully. Those teams that collaborated successfully managed to work around these issues effectively with little problem. Thus, the virtual teamwork mode was not a barrier to teamwork.
- The single greatest factor in supporting successful collaborations was the professional ethos of the groups and the consequent building of trust. Students who completed tasks on time and performed effectively in meetings built trust and increased the collaborative nature of the teamwork. Attitude to collaboration was therefore the defining variable in whether a collaboration was effective. As all groups chose the same technologies and some were successful and some were not, the technology does not appear to be a defining variable.
- Effective collaborative teams also display meta-decision-making processes and openly and frequently share information. All teams had a regular schedule of meetings; however, only the most collaborative teams adopted the flexibility to add additional meetings when these were required, and would vary the style and length of meetings to meet the needs. Also, only the most effective collaborators shared all information 'just in case' rather than keeping information to the level of that demanded.
- Students felt that the activity would have a positive impact on their employability as they obtained an international collaboration experience. That there were no significant differences in performance between participating and non-participating students, and between first and second phases, was somewhat surprising; however, participating students appear to have learnt from the first phase to develop a better plan for monitoring, controlling and coordinating their work with others in the second phase. That is, the experience of virtual collaboration has elevated participating students' project management skills. The activity has also contributed positively to increasing student satisfaction.

Specific lessons that need to be considered when incorporating virtual teamwork activities into a course are as follows.

- Students from either site are made more aware of the importance of meeting deadlines and fulfilling task requirements. In addition, schedules and tasks must match as closely as possible. Meeting the objectives of the group at the other end must be integrated into the objectives of the group at the near end (through peer assessment or some form of sharing of marks).
- Virtual teamwork can be successful and can be problem free. Most students have the familiarity and experience with the required technologies to be able to make effective choices regarding them and the use of them.
- Raising awareness of the importance of information exchange and meta-decision-making will make collaborations more effective in the future.
- To ensure that a 'genuine collaboration' takes place, the assignment tasks should be designed, based on a higher (i.e. reciprocal) level of task interdependency.
- If virtual teamwork is optional for future cohorts, emphasising the preparation that this provides for international working in the construction industry, and the value potential employers will place on it, will encourage future uptake.

The research presented here has several limitations. First, the findings were obtained from one round of project activity (in one academic year), which does not allow further examination of their validity and reliability. Second, other performance measures (such as assessments from industry practitioners) and data over longer time series would need to be examined to assess the impact and their relationships with the influencing factors. Third, inferences to the general (practitioners')

population should be drawn with caution, as practitioners may have more experience, and there are other influences in the workplace. Despite these limitations, the research has provided insights into factors that allow successful collaborations, and the impacts of virtual collaborative learning. Future research should examine the findings with larger datasets, including several rounds of project implementation, performance data over longer time series. Future research should also assess the validity of skills obtained from this activity to industry practice.

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REFERENCES

Barrett S (2002) Overcoming transactional distance as a barrier to effective communication over the internet. *International Educational Journal* **3(4)**: 34–42 (Educational Research Conference 2002 Special Issue).

Barry BE, Drnevich VP, Irfanoglu A and Bullock D (2012) Summary of developments in the civil engineering capstone course at Purdue University. *Journal of Professional Issues in Engineering Education and Practice* **138(1)**: 95–98.

Becerik-Gerber B, Ku K and Jazizadeh F (2012) BIM-enabled virtual and collaborative construction engineering and management. *Journal of Professional Issues in Engineering Education and Practice* **138(3)**: 234–245.

Bhandari A, Ong SK and Steward BL (2011) Student learning in a multidisciplinary sustainable engineering course. *Journal of Professional Issues in Engineering Education and Practice* **137(2)**: 86–93.

Childs M (2010) Analysis and description of education employing technological platforms: Terminology, features and models. In *Interprofessional E-Learning and Collaborative Work: Practices and Technologies* (Clouder L and Bromage A (eds.)). IGI Global, Hershey, PA, USA, pp. 46–60.

Dillenbourg P (1999) What do you mean by collaborative learning? In *Collaborative-learning: Cognitive and Computational Approaches* (Dillenbourgh P (ed.)). Elsevier, Oxford, UK, pp. 1–19.

Fruchter R (1999) A/E/C teamwork: a collaborative design and learning space. *Journal of Computing in Civil Engineering* **13(4)**: 261–269.

Hussein KM and Peña-Mora F (1999) Frameworks for interaction support in distributed learning environments. *Journal of Computing in Civil Engineering* **13(4)**: 291–302.

Korkmaz S (2012) Case-based and collaborative-learning techniques to teach delivery of sustainable buildings. *Journal of Professional Issues in Engineering Education and Practice* **138(2)**: 139–144.

Korkmaz S and Singh A (2012) Impact of team characteristics in learning sustainable built environment practices. *Journal of Professional Issues in Engineering Education and Practice* **138(4)**: 289–295.

Lamb F, Arlett C, Dales R *et al*. (2010) *Engineering Graduates for Industry*. The Royal Academy of Engineering, London, UK.

Merriam SB (1998) *Qualitative Research and Case Study Applications in Education,* 2nd edn. Josey-Bass, San Francisco, CA, USA.

Moore MG (1993) Theory of transactional distance. In *Theoretical Principles of Distance Education* (Keegan D (ed.)). Routledge, London, UK, pp. 22–38.

O'Brien W, Soibelman L and Elvin G (2003) Collaborative design processes: an active- and reflective-learning course in multidisciplinary collaboration. *Journal of Construction Education* **8(2)**: 78–93.

Peterson F, Hartmann T, Fruchter R and Fischer M (2011) Teaching construction project management with BIM support: experience and lessons learned. *Automation in Construction* **20(2)**: 115–125.

RAE (Royal Academy of Engineering) (2007) *Educating Engineers for the 21st Century*. The Royal Academy of Engineering, London, UK.

Shrivastava GS (2013) ASCE vision 2025 and the capstone design project. *Journal of Professional Issues in Engineering Education and Practice* (Forum) **139(1)**: 5–11.

Soetanto R, Childs M, Poh P, Austin S and Hao J (2012) Global multidisciplinary learning in construction education: lessons from virtual collaboration of building design teams. *Civil Engineering Dimension* **14(3)**: 173–181.

Soibelman L, Sacks R, Akinci B *et al*. (2011) Preparing civil engineers for international collaboration in construction management. *Journal of Professional Issues in Engineering Education and Practice* **137(3)**: 141–150.

Spinks N, Silburn N and Birchall D (2006) *Educating Engineers for the 21st Century: the Industry View*. A study carried out by Henley Management College for The Royal Academy of Engineering, London, UK.

Stanford MS, Benson LC, Alluri P *et al*. (2013) Evaluating student and faculty outcomes for a real-world capstone project with sustainability considerations. *Journal of Professional Issues in Engineering Education and Practice* **139(2)**: 123–133.

Tucker R and Rollo J (2006) Teaching and learning in collaborative group design projects. *Architectural Engineering and Design Management* **2(1–2)**: 19–30.

Wheeler S (2007) The influence of communication technologies and approaches to study on transactional distance in blended learning. *Association for Learning Technology Journal* **15(2)**: 103–117.

Wilkinson N and Lamb F (2010) *WebPA Online Peer Assessment: Resource Pack*. Loughborough University, UK. See http://www.webpa.ac.uk/files/WebPA_resource_pack-low-res.pdf (accessed 07/01/2013).

Wolcott M, Brown S, King M *et al*. (2011) Model for faculty, student, and practitioner development in sustainability engineering through an integrated design experience. *Journal of Professional Issues in Engineering Education and Practice* **137(2)**: 94–101.