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Developing design team working capability: some planning factors emerging from a survey of engineering design courses

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Abstract

The paper discusses some factors related to the planning of team-based design project work with emphasis on the development of student team working capability. This is based on a wider study conducted for the Design Council and Royal Academy of Engineering (RAE) in early 1996. Teamwork is of particular interest to these bodies because:

- *team working experience is mandatory for gaining Chartered Engineer status*
- *industrialists are increasingly vocal in demanding that undergraduates experience teamwork during their courses and develop a capability in team working*
- *there is evidence that design work, when done in properly established and managed teams, can be more effective in terms of the period of evolution of the product, the potential for innovative thinking, and the reliability of the product.*

A series of semi-structured interviews was held with 15 specialist engineering design lecturers and three Visiting Professors at 12 UK universities. The factors emerging from the interviews were organised using a form of elementary cluster analysis. A modified Delphi technique was then used to clarify these factors. The paper identifies some emerging factors which relate to the planning of team based design work:

- *establishing a university wide perspective on team working capability*
- *the clarity of specific learning objectives relating to team working capability*
- *development factors:*
 - *team selection: size, mix, roles, organisation*
 - *team building*
 - *establishing a team base*
 - *task type, context and degree of multi-dimensionality*
 - *the use of information technology to support team based project work.*

The above are discussed and related to some of the literature in the field.

1.0 Background

This paper discusses some factors related to the planning of team-based design project work with the emphasis on the development of student team working capability. This is based on a broader study conducted for The Design Council and Royal Academy of Engineering (RAE) in 1996. The aim of that study was to benchmark good practice in the development of team working in engineering design undergraduate courses.

The sponsors were interested in this field for three reasons:

Accreditation requirements

Team working experience is a mandatory requirement for gaining Chartered Engineer status.

Industry requirements

Team working practices such as concurrent engineering, simultaneous development, innovation cells etc have been shown to produce a better range of ideas, reduce development time and costs, and speed the process of bringing better products to the market (Lawrence 1996). This, and the growth of small to medium size enterprises (SMEs), has lead to a demand for engineers

who can work constructively in a team with a minimum of training.

pedagogical

There are potential pedagogical advantages in the use of team working:

- motivation can be enhanced (Parlett and King 1970)
- improved idea generation and error cancellation (Peacock 1989)
- dealing with design ambiguity through discussion
- critical thinking can be enhanced through discussion (Gokhale 1995)
- dealing with multi-disciplinary tasks
- dealing with realistic scale projects

These have been described elsewhere (Denton 1993) and are not expanded on in this paper.

2.0 Method

Semi-structured interviews were held with 15 engineering design lecturers and three Visiting Professors at 12 UK universities. The factors emerging were clustered and then clarified using a modified Delphi technique (Guglielmino 1977).

3.0 Findings

This paper aims to discuss only certain areas from the study, specifically some observations on factors to consider in planning:

- establishing a university perspective on team working capability
- clarity of specific learning objectives relating to team working capability
- development factors:
 - team selection: size, mix, roles, organisation
 - team building
 - establishing a team base and working structure
 - task, type, context and degree of multi-dimensionality

These observations, whilst based on a survey of engineering design courses, could be applied to any design course.

4.0 Planning factors

4.1 A university wide perspective and policy

Team working capability is increasingly important to all graduates and is not unique

to one subject. The survey showed that in engineering faculties staff expertise in the development of team working capability was often confined to very small numbers, sometimes down to one or two.

This raises two points: the need to expand staff expertise in team working related pedagogy and the possibility of considering this at a university level rather than small numbers of staff in different departments working independently. University level development was being done in a small number of cases, often embedded in the development of “study skills” and self-review materials. Such work could also have spin-offs in terms of supporting multi-disciplinary project work which is being strongly promoted by the RAE at present.

4.2 Learning aims and objectives

There was strong agreement amongst staff that students should develop team working capability in several contexts. It was also seen as important that some of these should be directly with companies in “live” product development. Staff also felt that students should be able to explain the principles behind successful team work.

Looking more specifically the following were identified as areas from which to develop learning objectives in relation to team working capability.

Becoming a productive team member:

- developing communication skills between specialists and others eg managers/accountants
- flexibility
- co-operation / the ability to reach consensus
- contribute ideas
- problem solving skills
- awareness and sensitivity to the work of team members
- empathy for the expertise of other types of specialist
- accepting responsibility
- reflective / analytical
- sensitive to others in the team
- modify own views in light of the views of others
- perseverance

- accept tasks as determined by the team
- accept help when offered and give help when needed
- positive attitude to team working
- appropriate social skills

Being a leader at appropriate times, all the above, plus:

- personnel and project management skills
- goal setting
- time management
- planning
- task decomposition into sub tasks
- task delegation
- encouragement and support of members

4.3 Development in the development of team working ability

The survey showed that with a few exceptions team working was not being overtly analysed at depth in relation to the development of capability over the whole of a course. To some extent this was pragmatic as the central aim was clearly to develop engineering design capability. Many staff failed to consider the development of team working capability as a written aim, though there was evidence, from interview, that their own experience was drawn into planning team-based exercises.

One factor which emerged from the interviews was the indication of a danger, as modular choice increases, of a loss of cohesion of teaching and learning objectives within any degree. Similarly team work exercises may be simply “bolted on” in order to meet engineering accreditation requirements. These may give experience, but not necessarily develop capability. This emphasises the need for a course overview of objectives and learning methods. Team working capability should be grown over a course as a continuum with proper regard for logical development.

The following factors emerged as being the basis for a framework for considering development:

4.3.1 The team

Team selection

Many selection criteria and strategies have merit but none emerged as consistently reliable predictors of effectiveness. Harmony

is not an objective; some of the best teams were reported as ones where discord was obvious in the early stages. Ease of implementation of a selection strategy, however, is important.

The most frequently used selection method was peer selection by students. This may promote harmony but reduces the potential for a variety of perspectives as such teams tend to be homogeneous in attitudes and experience. Peer selection can be used at the start of a course, but as students progress staff should employ more positive strategies.

Staff selection of team members can simulate the fact that individuals do not self-select in companies. This also enhances the number of perspectives on a task by generating more heterogeneous teams. The most common method used in the survey was random selection, based on registers. This is useful but requires different models in order to prevent the situation where the same students always operate in the same team.

A more positive selection technique was to use staff knowledge of individuals to select for overtly heterogeneous teams. This was rarely done in the survey institutions but some selected on the basis of ability, gender or culture. One institution used a database of student academic marks and design marks to achieve a close match of the average of these marks amongst each team, an interesting application of a database for team selection.

Team size

Two students usually lack the range of opinion and experiences to develop a potentially useful dynamic. Three was seen as a minimum. At the other extreme large teams of students of 20 or 30 were formed to tackle substantial tasks. The task was then subdivided into smaller sub-teams which reported to the whole. Such techniques are well suited to multi-dimensional task potentially covering a range of engineering disciplines, industrial design, business etc.

Team size should match the task. There should be no opportunity for individuals to ‘loaf’. Logically development would indicate

starting with small teams, giving students experience of larger teams as a course progresses. There were exceptions noted when, in very early parts of a course, staff structured large research projects with teams of 30 which were then sub-divided to threes and fours. These experiences were valuable in that they gave students experience of delegation and whole team responsibility.

Sub-tasks in any team activity should be inter-dependent so members have responsibility to the whole. This also limits tendencies by individuals to “loaf”.

Staff indicated a preferred average of 5/7 as the best team size for engineering design projects in years two and three of a course. This was big enough to allow substantial projects to be undertaken, yet small enough for students to manage. Individuals could have their say and “loafing” individuals could be easily identified.

Roles

Roles within a team can be viewed in two basic ways: by task, eg leader, secretary etc or by Belbin style role, eg implementor, innovator etc (Belbin 1981). Briefing students on aspects of team dynamics increases productivity and co-operation (Wilde, in Willmott, Preston and Froggatt 1995), though the survey showed that staff often briefed students only on the design side of the task. Generally staff preferred to allow students to develop their own roles. If roles were assigned it would be to appoint a leader to co-ordinate.

Some staff had experimented with team selection using Belbin or Myers-Briggs methods but found these too complex to be practicable and to have little obvious benefit.

Staff pointed out that students need experience of team leadership and that this is a valuable point in a curriculum vitae. Leadership may be flexible and different people may be in a better position to lead at different times. This also means more individuals may gain experience of leadership.

Team building

Team working does not automatically generate a positive synergy. When teams form they go

through stages in which energy and time has to be put into establishing the team and its direction. This has been described as the stages of forming, storming, norming and performing. Team based projects must give experience of going through these stages and strategies to support members in doing it quickly. There were indications that the more this is done progress through these stages is accelerated.

There are many possible team building methods from mini exercises to outward-bound or even meeting in the local pub! Staff considered that warm-up activities worked best when focused on the task rather than being separate “egg-race” type activities.

A successful strategy identified in a number of institutions was to conduct a team audit. The first meeting introduces members, they list their interests and areas of expertise which can then be cross referenced with the task requirements. The audit can also help clarify the task and identify areas for research. During a project teams must be encouraged to stop and reflect on possible areas of trouble: communications, evaluation, control, decision making, tension reduction, re-integration.

Staff reported that those students with prior industrial experience rated team working capability more highly. Generally direct involvement with industry was highly regarded by students and was an aid to motivation, particularly if “formalised”: ie, students were told to wear suits for presentations etc.

Finally, the survey indicated that a team base, ideally dedicated for the period of the project, greatly improves team building. This was, however, becoming increasingly difficult to achieve due to logistic pressures in institutions.

4.3.2 The task

Task type

Team based design tasks may be of many types: the most obvious is an extended design or design and make task. Teams can also be used for shorter or specific tasks such as research leading to the adoption of individual projects; the analysis of a problem or

generation of a specification; analysis of the development of a product, possibly including interview of company staff; short focused design of specific sub-components etc.

In designing a team based task the following dimensions should be considered:

- time span
- whether within timetable or in 'dedicated' time
- creative/open-ended/divergent or focused/convergent
- magnitude: numbers, time, resources, support
- degree of multi-dimensionality, eg a number of engineering specialities together or also specialities such as management, industrial design etc
- industrial fidelity: whether an industrial focus, aspects simulated by staff or companies involved at various levels leading up to full "live" projects
- focus on whole product or sub-assembly

Staff in the survey indicated that the best projects appeared to be based on a good product identity with a balance of engineering, ergonomics, aesthetics etc. Task should also broaden into interdependent sub-tasks. They also considered abstract "problems" for example egg races may be interesting but do not send out the right messages about engineering.

Task context

In many team based design tasks the context will be entirely focused on the physical output, there may be no commercial considerations. This, however, is very difficult if designing products or even components. Cost, for example, must always be a design consideration.

The survey showed that in the majority of engineering design work staff focused on a product and required students to consider commercial aspects, eventually going as far as business plans. Usually this was based within the institution supported by academic staff. A logical development is to incorporate some external commercial element such as bringing company staff in to assist or "live" product design with a company.

The survey showed that such relationships are not one-way. Companies can gain benefit from "live" projects and can be prepared to pay for the privilege. This shows they are getting benefit and puts pressure on students to deliver.

Staff, however, pointed out a number of limitations in working directly with industry. Firstly company staff need careful briefing on the academic context and its effect on the project. Secondly the aim should be to develop the relationship over time. A single point of staff contact between department/university and company appears to be the most successful method.

Degree of multi-dimensionality of task

As indicated above the RAE is encouraging engineering faculties to develop inter-disciplinary project work. The aim is to prepare students to enter modern company structures and be able to fit into working methods such as concurrent engineering. The survey showed that whilst multi-disciplinary work was done at some point in most university engineering faculties this was often confined to one or more engineering specialisms. To get the full potential benefit from multi-disciplinary work disciplines such as business/management or industrial design need to be integrated; a factor raised by several interviewees.

Those institutions which had involved disciplines beyond engineering in project work tended to find that students often experienced difficulties. These were often based about unhelpful student stereo-types. There was also a frequent assumption that other disciplines were not putting full effort into the project. These attitudes illustrate a potentially serious problem and one that is possibly prevalent in companies themselves. This makes it all the more important that universities address the problem of students being able to work in multi-disciplinary teams. One suggestion made was to start courses with large multi-disciplinary projects which have been carefully structured by staff. This may encourage students to work together before such stereo-types set and may help prevent them forming. This area needs further work.

The language of design, especially engineering drawing and mathematical modelling, can cause problems as the number of disciplines increases. Lawrence (1996) suggests 3D models help when members include non-engineers or designers. The indications are that in multi-disciplinary projects the best results come when members “get physical fast” - ie, use 3D modelling early.

Information Technology

The survey indicated a considerable potential for the use of computer technology and networking in supporting and enhancing design project work, particularly multi-disciplinary design. Data bases and CAD/CAM are already being widely and successfully used. There is, however, considerable potential in the field of remote team working with students from other faculties, institutions and or companies. This would simulate what will increasingly become common industrial practice.

5.0 Conclusions

The survey indicated increasing pressures on universities to develop team working capability in students. Done effectively this could improve the employability of graduates, but universities should also recognise the pedagogical advantages possible in team working. There needs to be university wide development of objectives and support materials. These might include the identification of common objectives; where they are best met; planning frameworks and team performance review frameworks. Similarly there needs to be staff training to expand understanding and expertise in team based teaching and learning.

Planning must address the question of development. The logical end point should be a graduate who has had successful experience of working in substantial multi-disciplinary projects, has team working capability, and who can identify the essential features of effective team working.

There needs to be further work undertaken to identify the causes of student negative stereo-typing and its potential effects on multi-disciplinary work both in universities and subsequently in industry. This should lead to work on methods of alleviating the problem.

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