This item was submitted to [Loughborough's Research Repository](#) by the author.
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

Multi-disciplinary team based project work: planning factors

PLEASE CITE THE PUBLISHED VERSION

PUBLISHER

© Elsevier

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Denton, Howard G.. 2019. "Multi-disciplinary Team Based Project Work: Planning Factors". figshare.
<https://hdl.handle.net/2134/2283>.

This item was submitted to Loughborough's Institutional Repository by the author and is made available under the following Creative Commons Licence conditions.

For the full text of this licence, please go to:
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

Multi-disciplinary team based project work: planning factors

Design Studies 1997, Vol 18, No 2 pp 155-170.

Keywords

teamwork, planning, modelling, engineering design, design education

Synopsis

The paper examines some aspects of the planning and practice of multi-disciplinary team based design project work at undergraduate level. It is based on a survey conducted for The Royal Academy of Engineering and The Design Council (which would be relevant to any design centred work). Pressures internal and external to engineering courses for the adoption of multi-disciplinary team based work are discussed. A number of key factors arising from the survey are addressed. These include: planning and supporting the development of team working capability across a whole university; the development of capability through consideration of task type, size, duration, disciplines involved, team size, roles and selection.

Multi-disciplinary team based project work: planning factors

1.0 Aim

The paper aims to examine some factors involved in the planning and practice of multi-disciplinary team based project work at undergraduate level. These factors were identified from a survey conducted for The Royal Academy of Engineering and The Design Council in 1996.

The significance centres on increasing demands from industry for graduates to be able to work effectively in multi-disciplinary teams. In addition the literature shows there are potential pedagogical advantages.

The paper identifies the background to the area. Specific factors identified in the survey are addressed: planning and supporting the development of team working capability across a whole university; the development of capability through consideration of task type, size, duration and disciplines involved, team size, roles, selection and team building.

Although the focus was multi-disciplinary project work it was considered that the inclusion of mono-disciplinary team work would have relevance as such work can be seen as a part of a continuum in which team working capability is developed.

2.0 Method

The parent survey was based on Bench Marking methodology such has been described by Zairi and Leonard (1994). However, the aim was not to compare one institution with another, as is normal in bench marking, but to compare approaches adopted in a number of courses and institutions. The methodology outlined in Zairi and Leonard was modified into one which used two phases. Firstly a number of research questions derived from initial reading were used to generate a schedule used in series of semi-structured interviews with staff in Engineering Design departments. Documentary data was collected on course structures. The combined data from interviews and documents was then analysed. Secondly a modified Delphi technique (Guglielmino 1977) was used to clarify points raised in the initial analysis.

Data was collected from fifteen academic staff and three Visiting Professors from twelve United Kingdom (UK) universities. These were identified on the basis of advice from The Royal Academy of Engineering as being staff involved in developing aspects of team-based working in engineering design. The interviews were structured around a number of research questions but staff were encouraged to add points which they felt relevant to the central aim. The initial questions centred on:

- What examples of multi-disciplinary team work can be found?
- What disciplines are involved?
- What indicators are there of the value of these projects? How are they evaluated?
- How significant is the project in terms of assessment?
- What other team work experiences are given in an engineering design context over the course?
- How are individuals assessed in relation to team work skills?
- What limits / limitations are evident?
- Is there a coherent path for the development of team work skills in students in each institution?

- Is there any specific training in team work skills? How is it structured and how was it informed?
- Why is team work used?
- Is team work used in work other than design projects?
- How are student teams selected?
- Are there any team work experiences given which are separate from engineering design eg outward bound type activities or management type exercises which focus on team work?

The interviews were treated as a rolling programme and points raised which had not been identified initially were then added to the schedule.

Data gathered from the interviews and documents was collated and used to identify a number of key factors. These were explored further in a modified Delphi technique (Guglielmino 1977) in which a open-ended questionnaire was developed with a number of statements in the areas identified. Respondents could register their strength of agreement or disagreement with these statements so giving a quantitative measure of expert feeling. Respondents were also able to add qualitative observations.

3.0 Background

Education at all levels in the UK has traditionally centred on individual academic excellence. Team working has been seen as a capability to be developed on the sports field. Now there are emerging pressures from both industry and educationalists for the development of team working capability within academic coursework at undergraduate level. These pressures centre on the apparent potential in team working methods for better working relationships (Buchanan 1989) and performance (Hewit et al 1990).

In this paper Price's (1995) definition of a team is adopted: "A group of people with a mix of skills who are organised to work together towards an objective that they share".

While most degree programmes involve students in some multi-disciplinary work this paper takes the term to mean the working together of students from different courses and faculties. This may operate at various levels: mechanical and electrical engineers are an obvious combination. They are, nevertheless engineers with a common "language" and culture. A more complex mix would be one or more engineering disciplines with industrial designers and business/management studies students.

Three areas of pressure for the adoption of multi-disciplinary team based work are identified: accreditation; industry requirements; pedagogical.

3.1 Accreditation

The engineering professional institutions require programmes to contain experience of team working for the award of Chartered Engineer status. For example, The Engineering Council in *Standard Routes to Registration* states that accredited courses should develop in students "the ability to work as a member of an engineering team" (p19, 3.3.4 (iv)). In addition the same paper calls for students to experience work in inter-disciplinary teams (p12, 3.1.3).

3.2 Industry requirements

Companies are increasingly using forms of multi-disciplinary team working (concurrent engineering, simultaneous development, innovation cells etc). These techniques have been shown to produce a better range of ideas, reduce development time and so costs, and speed the process of bringing better products to the market (Lawrence 1995).

In addition to the above there are indications of other benefits from team working within companies. Buchanan (1989) showed that, generally, attitudes improve, personal self-confidence grows, people become more tolerant and their confidence in their own ability to learn new skills grows. Buchanan also identified potential limitations. These centred on individuals who found it difficult to adjust to team based work.

The survey noted that companies now frequently ask for references which comment on a student's ability to work in a team. Lack of team working experience may reduce the graduate's employment prospects.

3.3 Pedagogical

Before looking at the pedagogical potential in team based design work it is as well to recognise a central problem: that individuals may be delegated different sub-tasks and so learning within the project is not common to each individual. This would also be the case in individual design work, but in team working the effect is increased.

Some respondents pointed out that, because of the above, team based projects were best used to exercise prior common learning. Others felt that team based projects could be used as vehicles for new learning by containing a 'core' task, the required learning area, which all members addressed.

Interviews and Delphi returns within the survey and further reading identified the following potential pedagogical advantages for the use of team working:

3.3.1 Motivation: Respondents indicated that team working can generate increased levels of student motivation, particularly when the project chosen has direct links to industry. The literature supports this (Parlett and King 1970).

3.3.2 Performance: Peacock (1989) stated that there was evidence that team performance can be 'infinitely' higher than individual. Salomon and Globerson (1989) considered that team work can induce a greater mindfulness as well as helping groups to perform better. Gokhale (1995) considered that collaborative learning fosters the development of critical thinking through discussion, clarification of ideas and the evaluation of other's ideas.

At the most basic level team work brings several minds to bear on a problem. These can act to cancel errors that any individual may make so producing an 'assembly bonus effect' as described by Driskell et al (1987).

a. Synergy. Those who have used 'brainstorming' techniques would probably feel that assembly bonus cannot fully explain the improved flow and breadth of ideas in more 'creative' tasks. The ideas of others can apparently be used to 'leapfrog' to further ideas much as DeBono proposed (1982). Hackman (1983) used the term "synergy" as referring to group phenomena which emerge from interaction and affect how well a group is able to deal with a situation. The popular idea is that the team can generate more than the sum of its individual parts. It is a mistake, however, to see synergy as always a positive effect. When a group initially forms much time and energy is spent establishing relationships and identifying a common aim. This can lead to conflict within the team so that in the early stages of team activity little energy is actually spent on the task itself. This is an important point in academic contexts where teams may operate only for limited periods of time. In contrast a team in an industrial context may tackle a series of tasks over extended periods and so be able to develop into a cohesive and productive unit.

Tuckman (1965) wrote that any team appears to go through stages of:

forming
storming

norming
performing

Only in the last stage is productive work done on the task itself. The earlier stages are important in establishing team identity and preparing for further work. Not all teams progress into the performing stages, but the survey showed that staff found very few undergraduate teams which failed to move into this stage.

b. Idea generation. Team working can improve the range of ideas generated in any given context as indicated above. In addition, the process of working with others means that the individual students gain differing perspectives, helping them to examine their own values and pre-conceptions.

Homogeneous teams such as those typically generated by peer selection tend to be harmonious in the initial phases of the project (Perry and Euler 1988). However, they may lack a range of perspectives which may assist in error cancellation and the development of the type of active discussion which can promote innovative ideas (Hackman1983). Similarly, Bradshaw (1989) noted that teams composed homogeneously of high intellect members did not perform as well as heterogeneous teams.

The selection of teams with a heterogeneous background can promote a wider range of perspectives and active discussion (Hackman1983) but means that the team tends to go more slowly through the forming, storming and norming stages. Experience of forming groups appears to help individuals go through the initial forming stages more quickly and become productive sooner.

c. Dealing with ambiguity: design usually deals with levels of ambiguity and unpredictability. It can be argued that teams are better equipped for dealing with this because of the range of perspectives available. Minneman and Leifer (1993) see ambiguity as a positive aspect of the designer's repertoire. By managing ambiguity, the design team can smooth negotiation and preserve design latitude. While Minneman and Leifer focused specifically on design activity rather than outcomes it may be reasonable to assume that maintaining design latitude would also assist by giving the team more options at any stage of a design process.

d. Critical thinking: Gokhale (1995) reported that collaborative learning in teams fosters the development of critical thinking via the clarification of ideas and the evaluation of other member's ideas.

e. Dealing with multi-disciplinary tasks: team working can enable individuals with a range of knowledge and skills to work together and solve problems or realise opportunities that an individual specialist could not.

f. Dealing with realistic scale projects: more substantial and multi-disciplinary tasks may be set. These can simulate whole product design more effectively, and give the student a better idea of product development in industry. This also means that companies may be more willing to be involved with universities as they are more likely to get something out of project work done by student teams.

4.0 Findings from survey

The survey identified a broad range of factors which influence good practice in the development of multi-disciplinary design team work. This paper focuses on those related to planning and immediate practice. Aspects such as the assessment of team work outputs and team working capability merit separate consideration.

4.1 Planning and supporting the development of team working capability across a whole university

Out of the 12 institutions surveyed within the field of engineering design only three had developed multi-disciplinary team based project work which extended beyond the engineering faculty. These had worked with faculties such as industrial design, art and design and/or business studies. Discussion showed that staff were finding these links difficult to sustain for a number of reasons:

- a. Increasing pressures on staff were limiting their ability to involve themselves in the extra co-ordination identified as being necessary in multi-disciplinary work.
- b. Modularisation of degrees was perceived by staff to limit co-operation across faculties.
- c. Research selectivity pressures were focusing attention away from non-essential curriculum development.

A small number of institutions had recognised team working ability as a factor increasingly important to all graduates. These were developing institution-wide policies or guidelines on team working, often embedded in "study skills" and self-review work. Such guidelines could generate useful materials with commonality across the institution. Such a commonality may, in turn, promote multi-disciplinary work by making some of the materials common and by improved staff communication across faculties.

The survey showed that within engineering design there were very few staff in any one institution with expertise in the field of team based design. Any development of multi-disciplinary work came from their endeavour and in some cases they reported a lack of support by key colleagues. It was reported in some cases that the support of a Visiting Professor (from The Royal Academy of Engineering scheme) helped to overcome planning inertia. Similarly the support of industry, particularly if money was available, could be critical. In turn staff pointed out that industrial personnel often had difficulty appreciating the academic context and time scales; careful briefing of such personnel was necessary in order to gain from these contacts.

4.2 The development of capability

Team working capability cannot be developed from a one-off exercise. An on-going cycle of exercise and evaluation is necessary. It should be noted that while the survey found that all locations visited had developed team based exercises within engineering design there were few that had established multi-disciplinary exercises. One faculty had dropped a multi-disciplinary exercise it had run for a number of years because of the increasing pressures of expansion.

In identifying planning factors to be considered in developing multi-disciplinary team based project work the survey adopted the position that experience of team working within a single discipline would provide a base experience for subsequent multi-disciplinary work. This position appeared to be upheld in discussion with respondents; it was possible to identify the following factors as ones to be considered in planning for team based project work whether in single or multi-disciplinary work:

- task type/dimension, size/ duration and degree of multi-dimensionality
- team size, roles and selection method
- team building

4.3 The task

4.3.1 Type/dimension

The study indicated a variety of task types. Any one task may bridge several types and each type can be seen as a dimension.

a. Research: a team may explore a design brief as far as identifying directions and collecting and collating data. For example, in exploring the design of office seating

engineering students could look at mechanical aspects, ergonomists at the anthropometric data, and art/design students at the form and aesthetics.

b. Focus: staff saw team based projects as being suited to design tasks which were relatively open and allowed a diverse range of directions. Design work which was highly focused, such as machine bearing design work was rarely used except as sub-sets of a larger project.

c. Product: the majority of work looked at products or sub-assemblies. Team working does have the advantage of covering more ground and so making whole-product work more possible.

Respondents highlighted the need for a good product identity in engineering design work. The product should have a balance of engineering, ergonomics, aesthetics etc. In this respect product design is a natural opening for multi-disciplinary team work. While a mono-disciplinary team of, say, mechanical engineers can learn something about ergonomics etc, in industry they will normally work with specialists in these fields.

d. Abstract: another approach is the "Egg race" which is more abstract, typically involving teams of students designing a vehicle to carry a raw egg over a specific course using materials such as balsa wood, wire and rubber bands. Respondents generally felt that such tasks gave the wrong impression of engineering, if used frequently, as they used rapid modelling materials. Egg races were, nevertheless, reported as being valuable if used in appropriate parts of a course.

e. Industry links: industry was involved to varying degrees in all courses. Staff were wary of industrial links in planning, some reporting having difficulties in the past due to the limited sensitivity of some industrialists to the academic context.

Some projects used industry for visits and technical support, but the project was not "live". In other cases the projects were "live" and could be taken on by the company to full production.

f. Production: projects may not be focused on production at all: for example, egg race types. The majority, however, identified the type of production numbers required and students were expected to design with that as a criterion.

g. Design modelling: most projects resulted in design proposals in the form of drawings and reports. Only a limited amount of 3D modelling was seen in specialist engineering design work. This has limitations (Lawrence, 1996) in multi-disciplinary work as is discussed below.

h. Design/make: some projects include some element of construction and probably test. Staff often use such projects to practice elements of Engineering Applications teaching.

4.3.2 Size/duration

The survey identified examples of team based work which spanned from exercises lasting one hour to tasks lasting one academic year. The majority of work was within specific engineering faculties rather than being multi-disciplinary. In all cases a system of development was followed by which students started with small, short team based exercises and used that experience to move onto larger scale work.

An important feature of this work was the supporting structure offered by staff. This varied, in the case of short exercises, from verbal briefings and de-briefings to detailed briefing papers supported by meetings and tutorials at various stages of the exercise. Analysis of briefing paper examples and discussion with staff indicated that the following data was necessary. It should be noted that the following could be used as a framework for planning both mono and multi-disciplinary project work.

Title

include staff responsible and date
objectives of technical and learning objectives
task context
specification of outcome required if appropriate

Personnel

team members
team organisation if appropriate - eg elect a leader
supervising staff and contact numbers / times
company staff if appropriate and contact numbers / times

Structure

time plans
working areas available
supporting lectures / tutorials / materials

Assessment

project outcomes required
assessment requirements eg reports (interim and final), poster/display/3D models, drawings/CAD, prototype
interim assessments/dates
final assessment date
assessment grid to be used by staff
peer assessment sheets (given at the start so they are aware)
weighting of the project in the year scheme
testing/evaluation criteria

The setting of target dates for formal presentations/interviews was regarded as important. These provide opportunities for the team to reflect on progress and practise presenting work. Similarly they can be used to provide impetus especially at the early stages of long term projects. An interim assessment carrying a small percentage of marks a few weeks into a project focuses the team. Similarly a dedicated day or half day at the start of the project can be valuable in getting administrative briefings done, teams established and warmed up and the initial directions established.

Presentations or interviews should be formal and students required to dress appropriately. By stressing this and ideally bringing in industrial clients or simulating them it is possible to give students further practice in preparation for presentations, communications skills, and provide additional motivation.

In planning team based projects it was helpful to identify specific sub-tasks to guide teams in delegating work. It may be more appropriate to do this in early work and leave it to teams in finalist projects. Sub-tasks should be clearly inter-dependent ensuring the team needs to meet frequently to co-ordinate work.

4.3.3 Multi-disciplinary extent

Some institutions had established links with art and design or industrial design departments such as Central Lancashire and Coventry. The study also showed links with other institutions such as the Glasgow University/School of Art link and the Strathclyde/Jordan Hill link.

Respondents identified examples where students introduced to multi-disciplinary exercises in year 3, even after prior experience of team working within a discipline, found working with other engineering specialisms difficult. This was largely due to negative stereo-typing. This was more marked as the range of disciplines broadened.

It may be more appropriate to use multi-disciplinary projects early in a course in order to help students learn to bridge disciplines and to limit the development of negative

stereo-typing. One Visiting Professor (Coventry) suggested starting year one by a large multi-disciplinary project partly in order to limit the building of barriers and to show how the majority of industrial work requires multi-disciplinary teams. The approach used at Cambridge where engineering students do not specialise immediately, and where a multi-disciplinary (within engineering) project is done in year 2, may help students become better inter-disciplinary designers.

As the number and range of disciplines involved increases there can be communication problems. Engineering designers, whether mechanical, electrical, civil etc do have, to some degree, common "languages" of design via drawings to British Standards and mathematical models. Once we include art and design and particularly business students then we can find barriers due to a lack of a common design language. Lawrence (1996) points out that evaluation from multi-disciplinary projects in the USA indicates that best results come when 3D modelling is used as a basic language. He points out that design teams should "get physical fast", ie use 3D modelling early. Cross and Clayburn Cross (1995) and Minneman and Leifer (1993) have underlined the importance of social process within design teams. This supports the need for design studios where members can meet and exchange information and ideas effectively. The survey, in fact, typically found design studios which were lines of drawing stations / CAD stations set up for individual use: this must limit intra-team communication. A studio/team base which enables easy interaction and the exploration of ideas using a variety of modelling techniques including card and foam modelling may go some way to overcoming "language" barriers mentioned above.

The study indicated that the use of multi-disciplinary team based projects is still relatively limited at undergraduate levels, with three institutions out of twelve using them at one point within an engineering degree programme. Discussion with staff indicated that this is largely due to the logistical problems and that increasingly administration driven degree models are making it more difficult for staff to innovate with such projects.

Multi-disciplinary team based project work appears to have a far higher profile at MEng level (UMIST, Sheffield, Hatfield, Strathclyde to mention a few). It appears that because of smaller numbers at this level it is logical for engineering specialisms to get together in the teaching of MEng courses. The limitation is that the degree of multi-dimensionality is restricted to engineering disciplines and is not expanding to art/design, industrial design or business/management.

4.4 The team

4.4.1 Team size

The convention is to start with small, peer-selected teams and progressively give students experience of working in larger and usually more difficult to manage teams. Respondents regarded a pair as being too small. Three is a minimum with 5/6 as being most generally used by respondents. The majority of respondents started with small teams of 3 or 4 in year one. The Cambridge year 2 exercise is interesting in that it develops from year one experience but uses a larger team of 6 which is broken into sub-teams of 2 handling different, but inter-dependent aspects; a clear example of iteration and development. A logical extension of this is the UMIST MEng (year 3) example where a team of 12 complete a project with inter-dependent sub-tasks tackled by sub-teams of two.

The team size should match the task. The individual or sub-team should have tasks which are inter-dependent with the whole team and individuals and sub-teams should realise their responsibility to the whole.

4.4.2 Roles

Roles can be viewed by function; eg leader, secretary or by Belbin (1981) style role; eg implementor, innovator. In general, respondents preferred to allow students to develop their own roles and many reported that students had a preference for 'co-operative' models of organisation rather than having an appointed leader. If roles were assigned by staff it would be to appoint a leader. Note that employers may be expecting to see evidence of prospective employees having had the experience of leading a team at some point.

It is interesting that in Japan roles are not closely defined (Preston, from survey interview and Saba, 1989). Such an approach attempts not to constrain and may help to prevent the defence of a 'territory' which, anecdotally at least, has been a major problem within relatively rigid and complex hierarchical company structures in the UK in the past.

Respondents who had used role based selection tools such as Belbin or Myers-Briggs (Dekker, 1993) generally found them too complex to use in such academic contexts (Hodkinson et al 1994). Belbin's work was based on long term general office/administrative teams and not design. Respondents did feel that leadership was important but that it must be flexible and that different people will be in a better position to lead at different times. This also means that a number of individuals gain experience of team leadership in a project.

Leadership roles may also be exercised in vertical teams - where, for example, final year students work with second year students. The aim being to set standards for the "junior" members and to provide leadership experience for the "senior". This technique is sometimes referred to as 'proctoring' (Button and Sims 1990) but this technique was not well regarded by the majority of respondents (for example Thompson, 1991). It was criticised as potentially limiting student access to experienced engineering design staff at critical times in their development. This should not be the case, as the proctors should be supporting the normal academic staffing ratio, not replacing staff.

4.4.3 Team selection

Many selection strategies have merit but discussion showed that none has emerged as a consistently reliable predictor of effectiveness. Harmony is not an objective, indeed respondents indicated that some of the best teams were those where discord was obvious in the early stages ('storming' in Tuckman 1965, see 3.3.2a above). Ease of implementation, however, is important.

The most frequently used selection method was peer selection by students. This is easy for staff to implement and tends to promote harmony but reduces the potential for a variety of perspectives. Students must, at least later in a course, experience working with others with whom they do not normally work. This can then be extended to students from other courses and, ideally, students from other cultures or institutions.

Staff selection can emphasise the fact that individuals do not self-select in companies. Staff can also use focused criteria. The most common method used was random, based on registers. This usually provides a heterogeneous team but suffers from potential cultural bias such as a number of Singhs working together. Used frequently the same individuals tend to work together and lose opportunities to practice the knitting of the team together. This can be solved by different selection patterns from the register.

Once staff have more information on students a variety of methods can be used to construct groups in order to promote discussion and learning potential. Factors to consider are ability, gender, culture, creativity, interests etc. The survey indicated that such focused methods are rarely applied because of the extra staff work load it causes. One exception is the Bath year 3 Group Design Project. Here staff allocate team members on the basis of a matrix of the students academic and design marks so that the average marks of each team are as close as possible in these two areas. This

means that teams should have similar academic and design expertise and be fairly matched.

Cambridge uses a data base to select students for teams, the criteria being to ensure that team members lived conveniently close together in an otherwise spread out student community. This assists meetings and general co-ordination. Once set up such a data base could be used to record marks and other data which could then be used for more sophisticated methods of team selection.

In relation to gender Morley (1995) pointed out that generally females prefer co-operative/social working and males individual/competitive. Competition and co-operation are not mutually exclusive, but need a balance. Ideally good co-operation internal to the team can be supported by a degree of inter-team competition. The competition must be focused outside. Some respondents noted that highly competitive male sportsmen often could not co-operate within a project team.

4.4.4 Team building

Design work does not normally have a clear and immediate problem; a team needs to reach a shared understanding (Cross and Clyburn Cross 1995). Part of the educational process must be for teams to go through the stages of forming in reaching a shared understanding. "Warm-up" techniques are often used to accelerate these early stages. Many methods are possible including short exercises such as the common management type games or short design exercises such as a tower/bridge made from straws etc.

The warm-up does not need to be separate from the main task. Sheffield and Hatfield used team audits in which members spend some time examining their areas of interest and knowledge and comparing these with the task. This can help the team to identify what expertise they have and what they need to gain together with introducing members to each other. Team audit work can be developed by encouraging students to focus on 6 possible areas of trouble: communications, evaluation, control, decision making, tension reduction and reintegration. Wilde (reported in Willmot, Preston & Froggat 1995) indicated that simply enlightening design workshop participants on aspects of team dynamics increased subsequent productivity and co-operation.

One aspect of warming up is that of shared adversity. This is usually found in military team contexts and outward bound type management training courses. It can, however, be of value to engineering design teams, particularly before long term and multi-disciplinary projects where the time investment may pay off. Glasgow School of Art use a "management week-end" in year 3 in which students complete a series of short team exercises in the mountains. Sheffield use a hill walking exercise to bond students selected for MEng in year 3. Professor Ridgeway is of the opinion that the more arduous the exercise the better the bonding appears to be. Similarly Price (1995), in an industrial context, considers that to develop an effective team appears to require struggle by members.

Team building takes time and appears to detract from the subject topic. This may be a reason why some staff reject team working. This returns us to a point made earlier that staff need to develop a broader staff understanding of team working methodologies within engineering faculties.

A team base, consisting of a table and some display space, can be a valuable tool in developing the team, especially if that base is dedicated for that team's use only. A base provides a focus and can encourage more effective meeting and discussion. Teams may bring in kettles and also use display boards to communicate thinking through the team. Strathclyde has a useful studio area which is used exclusively by Product Design Engineering students, but the pressures of expansion make such provision an increasingly rare luxury. In multi-disciplinary teams a base in one discipline area can cause problems and should ideally be located in a neutral area. If a base is not possible a general studio base in which a series of notice boards are

available for use by teams can go some way to acting as a focus for messages and progress. As indicated above this purpose could also be met by computer networking.

5.0 Discussion

The aim of the paper was to examine factors involved in planning for team based project work. The impetus came from a perceived increasing demand for capability in this area at undergraduate level. The survey confirmed that staff were now regularly asked to report on this in student references. It also supports the literature in terms of team-based work leading to increased motivation. The survey did not, however, focus on examining the range and quality of work produced in relation to individual project work. Staff report that students do, however, gain experience and some capability in working in teams (mono or multi-disciplinary) and that handling large scale projects has been valuable. A logical direction for further work is to look at confirming claims in the literature for increased quality of design thinking (3.3.2b, c, d).

In all cases staff felt that team based project work had been successful, but these were staff with a specific interest in the field. The literature makes it clear that there are many potential pitfalls in team-based work. Staff need to be very aware of these if planning is to be effective. It was clear that, in the majority of engineering departments, the number of staff with interest and experience of planning for team working is very small. This does lead to concern. Team working capability needs to be developed progressively over a degree programme and is not a straightforward topic. The survey showed that apparently logical methods such as working in small mono-disciplinary teams first and building to multi-disciplinary teams in the final year may not be as effective as first thought (4.3.3). It was apparent that the expansion in Higher Education in the UK, together with modularisation, has led to a situation in which staff are reluctant to engage in the planning required for multi-disciplinary work, which would have to be very thorough and time consuming.

In planning multi-disciplinary team-based work staff would have to be sensitive to the need for appropriate "languages" for design and the planning and management of product development. It was apparent that students in multi-disciplinary teams had difficulty with appropriate communications and this was compounded by the building of negative stereo-typing of students on other courses. There were indications that a team base where appropriate modelling languages could be employed and teams enabled to communicate easily would be an effective strategy for staff. However, the pressures of expansion were making the establishment of such facilities difficult. This is clearly a potentially useful area for further research.

The growth of multi-disciplinary team working at MEng level, albeit for pragmatic reasons does mean that lessons may be learned and translated to undergraduate work. The examples seen in the survey, however, were focused on teams of engineers from different specialisms; there was little work involving other disciplines. Nevertheless, the simpler logistics at this level may make Masters course useful test-beds.

6.0 Conclusion

The survey focused on staff in engineering design departments who were reported by peers as having interesting perspectives on the question of multi-disciplinary team working. It revealed that these people were a disturbingly small number and that they often felt isolated in engineering faculties. Various internal and external pressures limited their ability to develop student capability in multi-disciplinary team working. The literature and those Visiting Professors involved in the survey make it very clear that capability in multi-disciplinary team working can be a key to good, rapid and cost effective product design. Universities need to recognise the importance of the above and the pedagogical potential.

References

- Belbin R M** *Management teams: why they succeed or fail* Butterworth-Heinemann, Oxford, (1981)
- Bradshaw, D.** (1989). *Higher Education, Personal Qualities and Employment: Teamwork*. Oxford Review of Education. 15, 1, 55-71.
- Button B L and Sims R** Proctoring at Nottingham Polytechnic. *SEFI News*, Engineering Education section (June 1990) p 11.
- Buchanan D A** High Performance: New Boundaries of Acceptability in Worker Control. In Sauter, Hurrell and Cooper (eds). *Job Control and Worker Health*. John Wiley pp255-268 (1989)
- Cross N and Clayburn Cross A** Observations of teamwork and social processes in design *Design Studies* Vol16 (1995) pp143-170
- De Bono E** De Bono's Thinking Course'. Bath, Pitman Press, British Broadcasting Corporation (1982).
- Driskell J E, Hogan R and Salas E** Personality and Group Performance *Group Processes and Intergroup Relations* 9. *Review of Personality and Social Psychology* (1987)
- Gokhale A A** Collaborative learning enhances critical thinking *Journal of Technology Education* (electronic version) Vol 7 No 1 (1995)
- Guglielmino L M** *Development of the self-directed learning readiness scale* Unpublished PhD thesis, Athens, Georgia, USA (1977)
- Hackman J R** *A Normative Model of Work Team Effectiveness* Technical Report No 2. Research Project on Group Effectiveness. Office of Naval Research Code 442 Yale School of Organizational Management (1983).
- Hodkinson M, Paine R and Podmore G** Team projects and peer assessment in action Proceedings of the *National Conference on Product Design Education*, Bournemouth, July (1994)
- Lawrence, P.** Corporate Design Foundation www pages at <http://www.cdf.org> (1996)
- Morley I E** *Why engineers choose engineering* A report for The Smallpeice Trust (1995)
- Minneman S L and Leifer L J** Group engineering design practice: the social construction of a technical reality *Proceedings of the International Conference on Engineering Design*. ICED '93. The Hague, August 17-19 1993, pp 301 - 310
- Parlett M R and King J G** Concentrated Study: A Pedagogic Innovation Observed *Research into Higher Education Monographs* (1970)
- Peacock R** An industrialist's view Conference papers *Second National Conference DATER*, Loughborough(1989)
- Perry, C. and Euler, T.** (1988). *Simulations as Action Learning Exercises: Implications for Conducting and Evaluating Business and Economic Simulations*. *Simulation/Games for Learning*. 18, 3, September, 177-187.

Price F C Engineering success using teamwork *Proceedings of the Institution of Mechanical Engineers*, London (1995)

Saba, S. (1989). *The Japanese Style of Doing Business*. Royal Society for the Arts Journal. CXXXVIII, 5399 October 715-722.

Salomon G and Globerson T When Teams do not Function the way they ought to *International Journal of Educational Research* Vol13 No 1 (1989) pp 89-98

SEED *Compendium of engineering design projects* Hodgson Press, London, (1988) ISBN 0 948673 04 4

The Engineering Council *Standard Routes to Registration*. Policy Statements, second edition. 1990

Thompson G Examiners' responsibilities. *Proceedings of SEED '91*. UMIST June 1991 pp 29 - 32

Tuckman B W Developmental Sequence in Small Groups *Psychological Bulletin* Vol 63 No 6 (1965) pp 384-399

Willmot P, Preston M E and Froggat S The constitution of effective engineering design teams *Second National Conference on Product Design*, Coventry University July 1995

Zairi M and Leonard P *Practical Benchmarking: the complete guide* Chapman Hall, London (1994)