Team-Based Design for Design and Technology Teachers

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Schools and universities are under pressure to develop team working capability in pupils and students. This pressure comes from (a) industry and commerce, as there are strong indications that well-designed team working improves performance (Hoerr, 1989; Saba, 1989) and working relationships (Buchanan, 1989); and (b) education, as there is evidence that cooperative work can support learning generally (Cowie & Rudduck, 1988).

This article reviews some of the relevant literature. The development of team-based design capability is illustrated over the four years of teacher training in Design and Technology at Loughborough University in the United Kingdom. Finally, issues in developing team-based design capability in schools are identified. In this article a *team* is defined as a number of individuals cooperating in the production of a single outcome; a *group* as individuals cooperating, but producing individual outcomes.

Background

Companies are increasingly using multidisciplinary team working. This has been shown to produce a better range of ideas and reduce development time and costs. Buchanan (1989) showed that, with some exceptions, attitudes improve and self-confidence grows. Recognition of the potential value of team working in industry has meant pressure on universities and schools to give students team-based work experience. There are also broad educational reasons:

Motivation: Team working can generate increased levels of student motivation, particularly when the project chosen has direct links to industry (Denton, 1992, 1997a).

Performance: Team performance can be higher than the sum of individual efforts

(Peacock, 1989). Gokhale (1995) considered how collaborative learning develops critical thinking through discussion, clarification of ideas, and the evaluation of other's ideas. Team working brings several minds to bear on a problem. These can cancel errors, an "assembly bonus effect" (Driskell, Hogan, & Salas, 1987). However, this cannot explain the improved flow and breadth of ideas in more "creative" team tasks. Hackman (1983) used the term *synergy*, defined as phenomena emerging from interaction and affecting performance; it may be positive or negative. When a team first forms, time has to be spent on developing relationships and identifying the common aim. This can lead to conflict so that less energy is spent on the task itself. In industry, a team may tackle tasks over extended periods and so is able to develop into a cohesive and productive unit. In education pupil teams are usually short lived because the majority of work (in UK schools) is done individually. Tuckman (1965) wrote that teams go through stages of forming, storming, norming, and performing. Only in the last stage is productive work done. The earlier stages are, however, important in establishing team identity and preparing for further work. Austin, Steele, MacMillan, Kirby, and Spence (2001) estimated that with newly formed teams of engineering designers in an experimental setting 21% of project time was spent on social interaction and team maintainance.

Idea generation: Team working can improve the range of ideas generated in any context as indicated above. In addition, the process means that individual students see the perspectives of others, helping them to examine their own values.

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. Garner (2001) and Minneman and Leifer (1993) saw ambiguity as a positive aspect of the designer's work in the early stages.

Multidisciplinary tasks: Team working enables individuals with a range of knowledge and skills to work together and solve problems that an individual specialist could not.

Realistic scale projects: More substantial tasks may be set. These can simulate whole product design more effectively and give the student a better idea of product development in industry. The scale of such projects can also inspire and motivate.

Team-Based Design at Loughborough University

The program in Industrial Design and Technology with Education is a three-year industrial design degree with a minor element studying design and technology in schools. This leads into a one-year postgraduate teacher-training course. Experience of team-based work is seen as important for students both as potential designers and teachers. For example, an important part of the department philosophy in teacher training is that teachers should learn to collaborate in both planning and teaching (Denton, 1998; Denton & Zanker, 2000). This can lead to:

- improved cohesion of approach to the subject within a school department,
- teachers learning from each other in terms of both pedagogy and subject knowledge, and
- more efficient in use of staff time and resources.

Within the program there is a spine of formalized team-based design and planning exercises. These progressively extend student experience. In addition, when working on individual work, students are encouraged to form informal groups to extend each other.

Year One

Day one is a team-based exercise known as the Nomadic Brief (Denton, 1998). A "fantasy" context is used: small nomadic groups living off the countryside each of a particular type which the students decide (e.g., warriors, priests, healers). The new students (120 in two groups of 60) are put into random teams of five and walked into some outstandingly beautiful local countryside (inspiration). Each team must design a sculptural shelter made from bamboo, polythene sheet, and string as in the example in Figure 1. The form of the shelter must also reflect their team type. Team working is used both as a design strategy and to help the year group gel in that by the end of the day students will know four others well and, due to presentations given by each team, they will know something of all those in their group of 60.

Each team completes the design and construction by a deadline. They then give a presentation on their design to the whole group of 60. The group then brainstorms possible assessment criteria. Teams peer assess each shelter on these criteria. Debriefing focuses on team working, design methods, design detail, giving presentations, and assessment.

In subsequent design exercises in year one students produce individual outputs but informal cooperation is encouraged for brainstorming and critical analysis at various stages. Students complete a design analysis exercise in teams and a design exercise where some sections are cooperative and other parts are individual.

Year Two

The major team-based exercise in year two involves the design and production of an injection molded device (see Figure 2). Self-selecting teams of four design a small injection molded "useful" product for use as a corporate gift. The teams design the products, make the molding tool, and produce moldings and promotional graphics. This project runs over five weeks at five hours per week involving lectures on injection molding, mold tool design, project management, and costing. Individuals are delegated by the team to attend specific taught sessions and complete specific aspects of the work. The team coordinates these activities and ensures necessary information is pooled to enable the team to progress.

Year Three

During year three students pursue major design projects and gain the majority of their degree classification marks. Experience has shown that some students feel they may be disadvantaged if placed in a team with a weaker student or one who may not work as hard (Denton, 1997a). This is an accepted difficulty of team-based work, and so such work is not imposed in year three. However, if students wish to propose a team-based major project, staff consider it. Examples have included a fluid flywheel assisted scooter and a remotely controlled underwater reconnaissance vehicle (see Figure 3). Readers may wish to refer to student portfolios at the department's web pages: http://www.lboro.ac.uk/departments/cd/docs_dandt/prospectus/undergrad_home.htm

Figure 1. An example of a nomadic structure produced by a team of first-year students.

Figure 2. An injection molded product produced by a team of second-year students.

Figure 3. An underwater remotely controlled reconnaissance vehicle designed and made by a team of year-three students.

Year Four (Postgraduate Certificate in Education)

The aim for this year is to develop the graduates' ability to teach design and technology in UK schools. During the year students complete two long-term planning exercises in the university and others on teaching practice. One of these university-based planning exercises is team based because we believe that team-based planning can have significant benefits.

The team-based exercise uses self-selected teams of four postgraduates to plan a teaching and learning experience lasting between 7 to 12 weeks in a school. Teams have four weeks to produce a scheme of work, lesson plans, visual aids, and exemplar outcomes. In addition to this exercise a session examines approaches to using team-based design work in schools. This is done by working through a team-based simulation called the "NASA brief" based on Ginifer's (1978) work to provide a shared experience as a basis for discussion. The session draws together a number of key factors and approaches that students can apply in their teaching practices during the year.

During the postgraduate year staff also use team-based work to explore the teaching of aspects of design and technology such as mechanisms and structures. Team-based work enables a greater amount of hands-on work to be covered in the time available, it boosts motivation, and it has a significant impact on students. An example is a team-based challenge to design and construct the longest cantilever beam from a one meter square section of wall at chest height using rolled newspaper and thread as structural members (typically teams manage four to six meters). Another example is the use of paper to design a shell structure/mechanism in the form of a human arm that is articulated by thread and can grip a cup (see Figure 4). University-based work on team-based design is then reinforced by students employing these principles in their teaching practices.

Issues and Principles

This section examines issues involved in developing team-based design experiences for pupils. The principles also apply to students training to teach. Within the UK the only guidance given by the National Curriculum is that pupils should be given experience of team-based design work at each Key Stage.[1] This article focuses on Key Stages 3 and 4, but teachers in secondary schools must liaise with primary schools (Key Stages 1 and 2) to establish a logical progression. A long-term plan for building team-based design experiences and competence must acknowledge **basic skills** underpinning such activity. In reviewing a number of authorities on group and teamwork, the author identified the following very basic framework:

- Interpersonal skills: Communications (including drawings)—explaining, clarifying, values; interpersonal sensitivity; general—reliability, reasonableness, cooperation
- Team process skills: Forming teams, establishing norms; procedural and task-oriented behaviors; membership–constructive interaction, encouraging others
- Team and task management: Task decomposition into subtasks; delegation; time management
- Design skills: Group "brainstorming" (mindmapping) for analysis, idea generation, and evaluation

Some authorities emphasize the issue of leadership. However, a focus on cooperative task management can be more useful. Within a cooperative

Figure 4. An example of an articulated arm/shell structure made of paper by a team of postgraduate teacher trainees.

approach the team may find that individuals are able to offer leadership at different points, depending on expertise as well as personality. Recent work by Austin et al. (2001, section 3.1.4) with designers in civil engineering supports this notion of flexible leadership.

Basic interpersonal skills can be developed in most design and technology learning contexts and do not require specific team-based work. For example, pupils may be encouraged to act in informal groups when brainstorming and discussing and evaluating individual work. Garner (2001) emphasised the importance of sketching as a communication tool for designers and not simply as a recording/design tool. Stumpf and McDonnell (2002) provided a discussion on the role of "argumentation" in the early phases of design episodes. While they were referring to professional designers, there are some interesting points for educators to consider. Developing pupils' basic interpersonal skills underpins subsequent team-based design skills.

Team process and team and task management require pupils to experience team-based work rather than only cooperative work. Pupils must gain experience of forming teams, establishing norms, coordination, encouraging others, and ensuring delegated work comes together as a whole. Experience can assist pupils in managing the stages of "forming, storming, and norming" prior to "performing" suggested by Tuckman (1985) above. Similarly, student teachers need to experience team-based design work and analyze the process in order to be able to manage the process with pupils. It is important that staff manage the team-based learning process so that pupils gain success. Failure in a team task (i.e., the task is not completed by the deadline) can be difficult for pupils and lower their self-esteem.

A survey of team-based work in undergraduate engineering design at a number of UK universities (Denton, 1997b) showed that, when briefing teams, staff focused on task-related objectives only and failed to promote team skills as learning objectives. This is an important point: staff, whether at a university or a school, need to make team process objectives as clear in planning and briefing/debriefing as the subject-based learning involved. To develop team-based design skills staff need to establish a long-term strategy based on a number of learning experiences. Experiences can be structured around task, time scale, team selection and size, support, and assessment. Each element must be considered in relation to incremental progression over time.

Task: The task must be suitable for team-based design at the age range being considered. Around a shared core, subtasks can be delegated to individuals or subgroups. Different subgroups may form, act, and feed back at various times. Increased scale and complexity can improve motivation as the final outcome has greater impact. An example, at age 11, might be a puppet show, possibly planned in coordination with the English department. The team designs the overall show/theme. Individuals or subgroups are delegated to produce various puppets, the stage, equipment, or effects: together the impact can be impressive.

Team-based design work may be based on tasks supplied by industry. There are indications that pupil motivation improves when working with industry (Denton, 1992). Success in such pupil-valued work can promote self-confidence. Such tasks tend to be high profile and can promote the subject in a school. Design and technology teachers in many countries complain of low subject status: a well-planned team-based design project based on an industry-led topic can be powerful in developing positive status.

Team-based design can also be developed by simple "micro-tasks," for example, the development of team-based brainstorming skills in year 7 pupils via sharp five-minute sessions over a series of lessons. For the first five minutes of the lesson the concept of team-based brainstorming is introduced with the classic exercise "how many uses for a brick?" (DeBono, 1982). The exercise is debriefed, the class is "warmed-up," and then the normal lesson continues. In subsequent lessons the class is put back in the same or different teams and asked to quickly brainstorm other contexts, for example, uses for a clothes peg or ways of fitting a lid to a wooden box. The class is debriefed each time, showing techniques such as noncritical acceptance of ideas in a brainstorm and branching a brainstorm diagram. Similarly, staff can focus on interpersonal aspects. These exercises can be repeated with other year groups using brainstorming tasks pitched at appropriate levels.

Another commonly used approach to team-based design is the "egg race." These are more abstract tasks, typically involving teams designing a vehicle to carry a raw egg over a specific course using materials such as balsa wood, wire, and rubber bands.

Time scale: Team-based design skills can be, partly, developed in tasks lasting minutes, as above. Increasing the scale to one lesson, staff may consider team-based production line simulations. Examples include designing the most efficient way of assembling identical vehicles made from Lego kits or producing a series of identical paper airplanes (recycle used paper). These simulations usually involve a period of team discussion and experimentation followed by a five-minute production run. This is analyzed and improved for a second iteration and possibly a third. The class must be debriefed in relation to both the production line design and the team work aspects.

For longer term team-based projects staff should be particularly aware of Tuckman's (1985) stages of forming, storming, and norming before teams start to perform. Because longer time scale projects are usually more complex and, typically, require a stage of clarification, this important stage typically happens when a new team is in the storming stage and far from productive. This problem can be minimized by some form of warm-up before the main task begins. As indicated above, experience of forming teams and team-based design can assist in progressing through the storming and norming phases more quickly.

Team selection and size: In terms of progression the simplest strategy is self-selection by pupils; the most sophisticated is to "socially engineer" teams; that is, staff select membership on the basis of factors such as balancing abilities, gender, or culture. Between these we may have teams selected on a random basis, typically position in a class list. Random methods may have hidden effects: pupils with surnames beginning with A frequently work together and this can also lead to pupils with common cultural surnames finding themselves placed in teams together.

Self-selected teams, once through the possibly traumatic process of selection (e.g., individuals not wanted by any team), tend to be more harmonious (Perry & Euler, 1988). Such teams are usually of similar backgrounds, for example, gender, ability, or interests. However, such teams may lack a range of perspectives that would assist in idea generation (Hackman,1983). Bradshaw (1989) observed that teams composed of high intellect members do not always perform as well as heterogeneous teams because members tended not to accept alternative views and argued strongly for their own ideas.

Staff-selected teams may be less harmonious but offer a better range of perspectives. Harmony does not equate to good performance. Experience shows that if pupils are briefed carefully on the value of learning to work with people outside their friendship group they tend to accept the position. There are indications (Bennett & Cass, 1988) that when making up teams staff should avoid creating an unsupported minority. An example would be one boy with three girls; better, two boys and two girls.

Small teams are easier for younger pupils; handling interpersonal aspects and design decision making is easier. Once pupils have gained experience in smaller numbers staff should work towards pupils being able to work productively in larger teams selected specifically to mix ability, etc. The size of a team should match the task: enough work to delegate and ensure all members can contribute. Large teams working on simple tasks risk individuals drifting off-task. Experience shows that teams larger than seven, in a school, can lead to coordination problems. This is probably a sensible limit even for experienced pupils. It is, however, possible to have a whole class as a team if staff act as leader and coordinate the activity.

Support: Team-based work can be very threatening for some pupils. Staff need to exercise their knowledge of individuals in setting teams and supporting them. One advantage of team-based design is that staff will find that they spend less time responding to requests and have more time available to observe individuals and teams in action and intervene selectively.

On longer projects, particularly when teams are "socially engineered," staff need to plan warm-up exercises to support the teams in the initial phases. Warm-up exercises may take a number of forms: introductions by individuals who describe their interests and expertise or short team-based exercises lasting a few minutes enabling analysis and iterative improvement.

The biggest issue for the teacher is ensuring success for each team, that is, a suitable outcome is achieved by the given deadline. This requires considerable skill in handling team-based project work. Those with little experience of such work would be advised to start with simple exercises and team selection techniques and build experience iteratively.

Assessment: Assessment is probably the biggest difficulty for staff in managing team-based design work. In the UK examination boards often state that team-based projects are acceptable providing staff can identify who did what. This demonstrates ignorance of the nature of team-based design work. For example, when designing one member will often act as "scribe" while others make verbal suggestions. There may be no hard evidence of design thinking other than by the scribe who, in fact, was primarily noting points made by others.

Assessment of team-based design work requires a pragmatic approach: mark the team outcome as a whole and award identical marks to each individual. Simplistic, but consider:

a. Team-based design is an approach that is not used all the time. Staff have many other assessments on which to base an individual's overall grading.

b. When setting up teams it is important that pupils know how work will be assessed at the start and it is made clear that they must manage the team to ensure all contribute. A series of progress meetings in which delegated tasks are minuted can be very valuable training.

c. Staff may mark the outcome as a whole and then apply an individual weighting according to their observations of workload or achievement.

d. In evaluating the project it is possible to use a profile form to focus the members of the team on their performance and then ask the team what weighting they would give to each member. In most cases this will be equal, but not always. Staff will have to monitor this carefully. Hodskinson and Patel (1995), working with engineering undergraduates, considered such peer assessment compares well with that of academic staff. This may not be as close with pupils in schools, but it can be valuable evidence for staff in making decisions.

Summary

Team-based design approaches are becoming prevalent in industry for good reason. If managed correctly, they appear to bring better results in terms of the speed and quality of the product and the quality of the working relationships. It is hardly surprising that industry is pressuring universities and schools to develop team-based work skills and experience. In addition, there is a good deal of evidence that team-based work can promote learning as well as offer prevocational experience of teamwork.

This article presented some of the ways in which the Department of Design and Technology at Loughborough University approaches training teachers to manage team-based design and to plan for the development of team-based design skills and experience in a secondary school. The issue is complex, but the potential rewards in terms of learning are worth the effort. The major issue preventing some school staff from adopting such approaches is that of assessment. There are no easy answers, but to fail to develop team-based experiences because of this would be a serious abdication of responsibility. Rather than focusing on assessing only the easily assessable, we must look more broadly at a pupil's ability to design. One important feature of that is how that pupil is able to integrate and cooperate with others in team-based design work.

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Notes

[1] Key Stages: 1 =ages 5-7, 2 +ages 7-11, 3= ages 11-14 and 4= ages 14-16. Ages 16-18 are noncompulsory in the UK and are not covered by the National Curriculum.