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PRODUCT DESIGN AND MANUFACTURING SYSTEMS (PAMS) IN MANUFACTURING ENGINEERING - a lesson in Team Working

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Synopsis

PAMS was first introduced into the manufacturing engineering undergraduate degree programmes offered by the School in 1988/9. It is a project-based activity where the students are organised into teams, spanning all three years of the students' undergraduate studies. The project acts as an integrating theme through a course module entitled "Total Design", and requires the students to acquire a number of transferable skills. These include information gathering, report writing, presentation skills, time management, project planning, teamwork, and managing meetings. This paper describes the year on year structure of the PAMS project, and the acquisition of the mentioned transferable skills, with particular reference to team working, and the subsequent implications for the students as they enter industry on graduation.

I. Introduction

The School of Manufacturing and Mechanical Engineering at the University of Birmingham is a large engineering school which operates six undergraduate degree programmes and seven postgraduate taught courses. The innovation described in this paper concerns only the three undergraduate programmes operated by the Manufacturing Division of the School. These are a BEng and BCom 4-year double honours programme in Manufacturing Engineering and Commerce, a 4-year BEng & Com joint honours programme in Manufacturing Engineering and Business Studies and a single honours Manufacturing Engineering programme, which leads to a BEng in 3 years or an MEng in 4 years. The double honours and joint honours programmes are run in conjunction with the Commerce Faculty, which makes a considerable input to the teaching and assessment of these programmes. All undergraduate programmes operate under a modular structure.

II. The PAMS Design Project

The **P**roduct **a**nd **M**anufacturing **S**ystem design project, known as PAMS [1], was started in the 1988/89 session as a means of integrating the diverse material covered on the Manufacturing Engineering programmes, and to provide an opportunity for students to learn and practise transferable skills. The PAMS project is integral to one course module, Total Design; this module continues over the first three years of each degree programme, and in total constitutes one ninth of the students' final degree. It is most heavily weighted in the second year.

A. Project Structure

PAMS is undertaken as a team project, where the students are organised into teams of 6-10 students mixed together from the three programmes. In the first year the team has to establish the need for a product, in the second year a product has to be designed to meet this perceived need, and in the third year the manufacturing system to make the product has to be formulated.

B. The Task and its Assessment

The students are presented with a scenario in which they are the engineering team within a small company. This scenario includes details such as: the geographical location of the fictitious company, whether the company will occupy an existing factory or a greenfield site, what resources can be assumed to be available, and the arrangements for financing the project.

The team is given the task of designing a new product, and the means to manufacture that product. The team has complete freedom in the choice of product. For the purposes of the project, this overall objective is split into three phases, corresponding to the 3 years over which the project is spread.

The end of each of these phases is assessed in three ways: by a formal verbal presentation, the submission of a written report, and by peer assessment, outlined in [2], whereby the students in a team assess each other's contribution against six criteria. These criteria were chosen in consultation with the students prior to the introduction of the system and include: teamwork, initiative, effort, achievement, participation in meetings and contribution to the written report.

At the end of the first phase, following a period of ideas generation and selection, each team has to present a short-list of up to three well-researched, alternative product ideas. This is usually done by showing how current products fail to perform adequately, or by demonstrating that demand exists, or could be created, for a product which is not currently available.

At the beginning of year two a choice has to be made between the alternative product ideas so that one can be developed further. There is an interim presentation at the end of the first semester when each team presents the Product Design Specification (PDS) for its chosen product, and at the end of the year, a detailed design has to be presented. The design work involves consideration of how the product will work, its appearance and how it will be manufactured. Detailed engineering drawings are passed to the technical staff within the school to enable a prototype to be made.

At the end of year three, teams have to present a comprehensive plan of how the product designed in year two will be made. This covers a very wide range of technical disciplines including the choice and layout of machine tools, the assurance of quality, marketing of the product, the financial justification for capital expenditure and predictions of profitability for the new enterprise.

C. The Objectives of the Project

1) A Vehicle for Integration: The project provides a vehicle for the integration of the disparate subject material taught in the manufacturing engineering degree programmes. Manufacturing engineering is by nature a broad discipline and the relationships between different aspects of it are important. The project aims to provide an opportunity to practise the theory learnt in the separate subject courses in an integrated, holistic way.

2) Total Design: The second objective is to provide experience of the complete activity of generating a new product to meet a perceived customer need, in what is known as 'Total Design' [3]. This is an activity which is central to manufacturing businesses and one of the key activities in which manufacturing engineers can expect to be engaged during their professional careers. The project aims to be a realistic simulation of real-life.

3) Transferable Skills: Thirdly, the project provides an environment in which a number of transferable or personal skills can be learnt. These include information gathering, report writing, presentation skills, time management, project planning, teamwork, and managing meetings. These skills could be characterised by what [4] calls 'operacy', the skill of getting things done. The PAMS project is far from unique in having the learning of transferable skills amongst its objectives (see for example [5]), but to date no other project has been found which provides such extensive experience, especially within the context of a small team. Transferable skills were always seen as an important element of the project, but in actual fact the amount of such learning has been much greater than expected.

III. Teams and Team Working

The formation of the students into teams for PAMS was, as indicated, a conscious decision, intended to provide a relevant metaphor to their likely industrial role on graduation. Over the 3 years duration of the project, inevitably students transfer both in and out of the programme for various reasons. This in and out flow of students has not proved a significant problem in the running of the project for two reasons: (i) experience has shown that for a team to function effectively, it is not necessary to maintain exactly the same number of team members year on year, and (ii) provided that a core membership of the team remains in tact, teams are sufficiently flexible and robust to accommodate the departure of one or two members, or to assimilate new members.

The primary learning outcome of PAMS is the understanding of the inter-relationships between manufacturing related functions. The secondary learning outcomes are to impart team skills and to provide an environment where students would work as part of a team. In addition, other management skills, such as negotiation, motivation, leadership, and delegation were all recognised as significant, although it was accepted that these were **not** intended to be part of the learning outcomes of the activity.

In order to impart to the students the foundations for working as a team on their PAMS project, the student groups each undertake a residential weekend course at the

University's own Outdoor Pursuit Centre, which is set in rugged countryside in the North of England. Each course involves up to 4 teams, and is run over several successive weekends in order to accommodate all the student groups. The course is facilitated by permanent University staff at the Centre who are skilled in outdoor activities, and supported/mentored by staff from the School in various aspects of team-building/team management skills. The course takes place within a few weeks of the students arriving at University in the first semester, and is an excellent ice-breaker both for the students and for the staff with the students, that is expected to bear dividend throughout their programme of study.

IV. The Course at Coniston

A. The Priestley Centre

The Priestley Centre, at Coniston, Cumbria in the Lake District region of Northern England was chosen as the best venue to run the Team-Building course for Freshers in Manufacturing Engineering on the basis of several sound arguments. Firstly, the School, and associated staff from the School, had built up significant experience over several years in running courses at the Centre for its postgraduate Masters degree students. The Centre offered the opportunity for the course to integrate outdoor pursuit type activities (sailing/canoeing, climbing/abseiling, hill walking/biking etc.), with more cerebral type activities that involved the development of management skills. All of these could be offered in the "team-working" context. The Centre was chosen because being 200 miles distant from "home", i.e. the University, and located in remote and wild countryside, there would be no distractions from the course. To assist this, the courses have always been arranged with "compulsory" transport from the University, which is organised by the School.

B. The Course Structure

Prior to arriving at the Centre, the students have been allocated into their PAMS team, with whom they remain for the duration of the project. A member of staff from the School is assigned to each team, and it is usual for this person to act as mentor to the team.

Before the students begin the "ice breaker" exercises at Coniston, each team spends a few moments with their mentor, establishing what they perceive at that point as their team's "ground rules". The principal strands in the ice-breaker exercises are the development of communication, mutual trust, and getting to know one another in a non-intimidating environment. If some role adoption and task-focused strategic planning takes place, then so much the better. These activities all take place in the expansive grounds of the Centre.

The course is intended to fully occupy the students, and therefore continues into the evening. The first evening session is given over to some formalised coaching in team skills, facilitated by interactive tutoring, discussion groups and commercially available video material that demonstrates good and bad practice. The students are also given a self-assessment questionnaire, which they may wish to share with their team members.

Time is provided throughout the course for the students to meet, either between themselves or with their mentor, to review and reflect on their performance and achievement to date, both as an individual, and as a team member. In particular, emphasis is given to the definition and follow-through of the process to achieve the task, rather than the task alone.

On the second day, the teams rotate through three outdoor activities that fully utilise the facilities of the Centre. The activities serve as "training " sessions for subsequent exercises, and involve watercrafts, ropework, and navigation skills. As each activity progresses, it becomes more intellectually challenging, culminating with a final, task to be achieved that calls upon the skills hopefully learnt. A relevant metaphor is usually associated with the task, for example, the throughput on a production line being replicated by a team river-crossing that uses only suspended rope equipment.

In the evening, the teams undertake two specific activities in rotation which emphasise construction and communication, again using relevant metaphors. These are each scheduled to last half an hour, although time has now become a team-owned resource to be managed. In addition, the teams are given a comprehensive portfolio of information, which forms the basis of their activities for the next day. They are given just one hour during the evening in which to assimilate the information, and to prepare their plan of action. This can involve them in some cross-negotiation with other teams if they are to optimise the resources which are made available to them.

On the final day, the teams are given the challenge of building a mountain bike, to a quality specification, with parts gained as a reward for successfully completing a selected number of available activities. They have a nominally specified financial allocation, in fictitious currency, which they can use in trading between teams and with the bank. It is also currency for purchasing resources, and given as reward for the successful completion of certain targets. The ultimate objective of the day is for the team to maximise its profit by achieving the task, with due regard to the process by which the task has been achieved.

The course concludes with a final debrief, when each team is asked to reflect on its performance over the course, using their initial ground rules from the first day as a starting point. Each team is asked to identify i) what was successful, ii) what was not so successful, and iii) issues to be re-addressed in the future. These are shared with all other course participants in a 10-15 minute presentation. Their contributions become an integral part of the team's portfolio of work when submitted for assessment at the end of the academic session. The students then return to Birmingham late on the Sunday evening by coach.

C. In Review

The course as described has evolved over a number of years. It is never assumed by the authors that the definitive course has been designed; it is almost as much a learning experience for the staff from the School as it is for the students.

V. The Industrial Context

Manufacturing in the United Kingdom reached its nadir in the early 1980's. A combination of high domestic inflation, economic recession through fiscal policies, and industrial unrest by organised labour, resulted in business closures across the whole manufacturing spectrum. As a consequence, market share was lost both at home and overseas, which was quickly filled by external suppliers.

A combination of new industries and new manufacturing philosophies, plus the understanding that change was inevitable, became the catalyst for new attitudes and work practices in the United Kingdom. Kaizen[1] (pronounced Ky'zen) is a term which is well understood in the UK, both by the manufacturing population and by manufacturing management alike. This modern workforce, which builds change on continuous improvement, the empowerment of individuals, and the ability to communicate in a team context is the key to manufacturing success.

A. Current Status In Recruitment

Manufacturing companies now recognise that recruitment of young graduate engineers must be focused on these new skills. All companies, from multinationals like Procter and Gamble, and Kimberly Clark, through to small manufacturing enterprises, make aspects of Kaizen a parameter of their recruitment profile.

B. PAMS and Industry

The trend in manufacturing industry was observed by the teaching staff in Manufacturing and Mechanical Engineering at the University of Birmingham, who had also noted that the key elements of team working and interpersonal skills could precisely meet the needs of industry. Anecdotal evidence from students is that at interview for graduate positions, a large proportion of time is spent discussing PAMS. It is evident that PAMS offers students an exposure to the types of challenge they are likely to encounter in industry, and which industry expects them to have experienced, prior to graduation.

The reputation and quality of the School's education is such that its graduates are targeted by industry and commerce; this is evidenced by the fact that 96% of all our undergraduates are offered positions on graduation. Employers have stated that they find Birmingham graduates are quicker to assimilate, are able to understand the issues, are better communicators and natural teamworkers, rather than their peers from other universities.

C. Future Developments - Sponsorship from Industry

Prior to the commencement of PAMS, Freshers need to be introduced to the fundamentals of teamwork. The dedicated weekend training course at Coniston, Cumbria was seen as the most appropriate method to impart this information.

[1] Kaizen is from the Japanese for the relentless quest for a better way. In manufacturing, it is known as a philosophy that indicates continuous improvement, where all employees contribute toward incremental gains, as part of their normal duties.

A major UK company, Britvic Soft Drinks Limited, (with an annual turnover in excess of $1 billion and with the Pepsi franchise in the United Kingdom), were approached by the School, and they agreed to sponsor the event.

The aims and objectives of the weekends coincided with the company's own training aims for its workforce. A feature of each weekend was the full participation of a team from the company. These teams comprised all levels, from the Managing Director and main board Directors, to the recently recruited graduate engineer. The company teams were given no dispensations over the undergraduates, and participated fully.

Feedback from the company and undergraduates is that it was a formative experience. For the company, they learnt that "reverting to type" was not an option, and the development of teamworkers was not just about grouping people together. As part of their continuing development, the company are to continue to sponsor the weekends, and to participate with their own teams. A closer relationship between the School and the company is that managers are to be visiting lecturers on courses where their experience supports the teaching programme. Students are being invited to visit the manufacturing operations and for some, the opportunity of internships will be available.

VI. In Summary

In today's competitive world, students require many skills other than their academic qualification in order to succeed. The PAMS activity has now run for eight years, enabling the School to observe several cohorts of students completing this element as part of their degree programme. The high regard in which these students are held is apparent by the targeted recruitment by industry and commerce. The interpersonal and transferable skills acquired during the PAMS programme form part of their experiential portfolio, which provides a basis for their continued professional development following graduation.

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