ENGAGEMENT AND LEARNING IN MICROCONTROLLER SYSTEMS PROJECTS AMONG MIXED ENGINEERING AND PRODUCT DESIGN COHORTS

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ABSTRACT

Microcontroller based systems are important in many current and emerging products and engineering systems. It is therefore arguable that inclusion of this type of technology should be an important aspect of the education of contemporary product design and engineering undergraduates. This paper reports on the experience gained in running an introductory module into the use of microcontrol systems for a mixed cohort class of product design and mechanical engineering students. The use of the two cohorts was driven by economies of scale and offered both challenges and opportunities. The product designers typically had a lower scientific and mathematical background than the engineering students, but had a greater experience of design, build and test type projects. The aspirations of the students also differed in terms of the applications to which they might expect to deploy the technology. The module was set up with both lectures coupled to formal practical sessions and more open project classes. The nature of this type of work with a high level of iteration lent itself to cyclical learning. The classes ultimately worked well though issues related to effective assessment, learning methods, group dynamics and project planning had to be resolved.

KEYWORDS

Mircrontrol, Systems Design, Product Design, Mechanical Engineering

INTRODUCTION

Microcontroller based systems are an important aspect of many modern industrial systems and consumer products, finding applications in areas as diverse as specialist medical devices, automotive control applications and domestic kitchen equipment [1-5]. It could be argued that an awareness of microcontroller system development and a confidence to include this in their own designs should be part of the education of both product design and engineering students.

Product design and engineering students have a need to learn about topics such as microcontrol systems but their educational background, expectations and practical applications can often be quite different. Microcontrol systems are unusual in that it is impossible to entirely divorce the physical design, control coding and electronics in the development of a single system. Ensuring all students have the opportunity to learn effectively is an issue which educators must address.

Bringing together the creativity associated with product design with the more methodical approach associated with systems development, while challenging has been shown to offer significant benefits to both groups of students [6,7].

STUDENT COHORTS

The work reported represents the experience gained from running a series of level 2 undergraduate microcontroller systems modules over a period of 4 years. The class sizes were made up of between 40 & 60 students per annum split approximately evenly between students on Mechanical Engineering and Product Design degrees.

The Mechanical Engineering degree was a fairly standard broad-based UK Institution of Mechanical Engineers accredited degree. The Product Design degree sat roughly centrally between the aesthetic and technical aspects of this discipline and was run in conjunction with the University's College of Art & Design. The degrees shared around 1/3 common content. Figure 1 shows a schematic of the syllabus and degree of commonality of the first two years of the two programmes. While both degrees featured many aspects of the CDIO framework neither programme was formally following these guidelines.

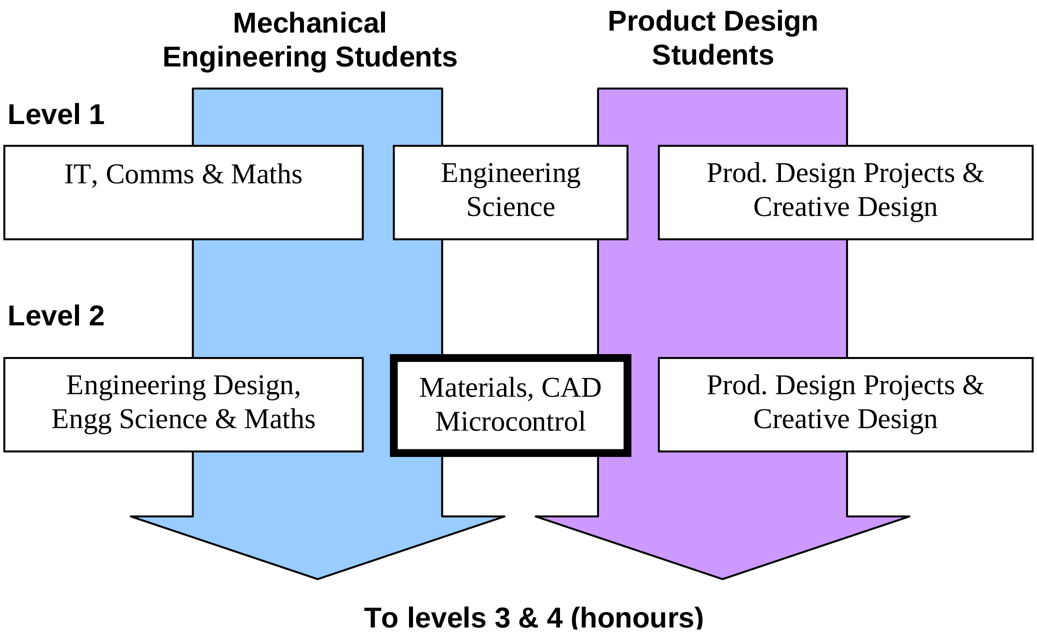

Figure 1. Overall syllabus for years 1 and 2, Product Design and Mechanical Engineering Degrees at Dundee University UK. The microcontrol elements features in the common portion of year 2.

The student cohorts were also culturally and educationally somewhat different. Both entered University with similar overall performance but the product design students did not necessarily have the same level of mathematics or science as the engineers. Entry to the engineering courses required both mathematics and physics at a senior high school level, whereas the product design students need only to have qualified in one of these areas. Both programmes featured a common engineering science element at level 1 of the degrees, with the engineers backing this with mathematics and generic skills training while the product designers were engaged in creative work which was often project based.

The students' expectations with regard to the relevance of systems design to their own discipline were also different. The product designers' ambitions were typically biased toward high end consumer products and the engineers generally interested in applications in areas such as the automotive sector.

LEARNING OUTCOMES & MODULE STRUCTURE

By completing the module, both groups of students were expected to gain an appreciation for the use of microcontrollers in modern engineering system and consumer products. As this was an introductory module the emphasis was on fundamental skills, knowledge and understanding rather than systems development to a professional level. The students needed to demonstrate the ability to produce a simple microcontroller based system including basic sensing and actuation electronics, control code development and creation of basic physical representation of the product.

An abridged summary of the learning outcomes are given in Table 1.

Table 1
Abridged summary of the learning outcomes for the microcontroller systems module

Knowledge	Define what a microcontroller is Identify various commonly associated ancillary components State key software commands
Understanding	Give examples of applications of microcontroller based systems Differentiate between a microcontrol based system and one based on fixed electronic or mechanical control Discuss the strengths and weaknesses of microcontrol based systems Explain the role of algorithms and coding structure in effective systems Understand the role of cross disciplinary groups in achieving successful outcomes
Application	Apply software techniques to solve simple control problems Determine suitable support circuitry to allow controller to interact effectively Integrate software, sensors and actuators in simple systems
Analysis	Analyse system to evaluate weaknesses and bugs
Evaluation	Assess the success of a prototype system Critique this against target and establish future targets Evaluate the contribution of team members
Creation	Devise a workplan to create an effective prototype Synthesize a target specification Create a simple but functional microcontroller based system.

It was assumed that students entering this module had no coding experience and limited experience of electronics and systems building. With this in mind the course structure was split in half. In the first half of the module, each week students had a classroom lecture on a particular topic, eg. digital input, and this was then supported by a corresponding practical session allowing students to gradually explore different aspects of the topic. In the second half of the module a project phase was instigated where students in mixed product design and engineering groups would spend the remainder of the module working on a project, the brief of which was kept very open to encourage students to explore the subject area without being intimidated. Assessment took the form of a short written class test mid-session primarily assessing knowledge and understanding, and presentations outlining the proposed design, a mini viva and product demonstration following completion of the project which focussed in on application, analysis, evaluation and creation elements.

The students were grouped in pairs for the first half of the module (weeks 1-6), with an engineering and design student in each group, where numbers allowed. Each pair were supplied with a PC for programming purposes, microcontroller board, bread board, power supply and assorted sensors, actuators, components and wiring. For the project phase (weeks 7-11) the pairs were grouped into four individuals in a cross-disciplinary team. See Table 2 for more details.

Table 2
Module Structure

	1 hr Lecture	**3 hr Practical**
Wk 1	Introduction	Equipment & circuits
Wk 2	Basic coding intro : variables, loops & output	Circuits intro : simple code and output
Wk 3	Digital input, conditional code	Bicycle light exercise
Wk 4	Analogue to digital	Pot and sensors
Wk 5	Powered output	Powered output exercise
Wk 6	Class Test	Temperature Control Practical Test
Wk 7	Project Proposal	Project
Wk 8-10	Project	Project
Wk 11	Project	Reflect & Review

Assessment of the generic skills related to understanding and evaluating the roles of individuals within the team was achieved via a peer review element. Students were asked to provide a quantitative mark for fellow team members based on contribution to the project's success. In the first two years of running the programme this was all that was demanded of the students however in subsequent years students were asked to qualitatively justify the marks by critically providing an appraisal of the participation and role of each individual.

Relationship To CDIO Standards

While the module was not developed for implementation within degrees formally following CDIO standards, the module itself does address many of the key issues identified by the CDIO initiative particularly those in sections 4.3. Conceiving and engineering systems, 4.4. Designing and 4.5. Implementing of the syllabus.

Hardware And Software Used

The choice of controller and programming language changed over the years in which the module ran. There is generally accepted to be a trade off between the conceptual difficulty but greater fidelity associated with developing systems using full commercial practice and the desire for the students to be readily able to create sufficiently functional systems, so gaining an appreciation for the application of the techniques to their own work [8,9]. Assembler language was discounted as being too steep a learning curve given the time available and the desire for the students to go beyond the controller and develop a system. C and specialist forms of Basic were both used in practice depending on the controller chosen. C programmable PIC16F876 & 16F877 controllers (Microchip Technology Inc., Arizona USA) mounted on specialist development boards and Basic programmable Basic Stamps (Parallax Inc., California, USA) were both used. The Microchip devices offered greater capability and a more industrially applicable programming system but were slightly more complex to use than the educational based Basic Stamp. The system used in any given year was largely left to the senior academic tutor and did not directly impact the general teaching approach or learning outcomes.

REVIEW & IMPACT ON STUDENT DEVELOPMENT

The module went through a number of changes to reflect lessons learned and improve its effectiveness. Project groups were initially self-selected however it was found that mixed groups of engineers and designers worked more effectively. Product designers passed on skills related to working on open project briefs while the engineers were better able to lead the group in terms of analysing technical systems.

A practical test was carried out mid-module in the initial years of the module. Students, under exam conditions and with a time limit of two hours, had to develop the electronics and coding for a simple but unseen system. This was a strict test but was felt perhaps to be unfair on those students who were still coming to terms with the technology.

The project concepts chosen by the students tended to be more driven by product design consumer type products (eg. Automatic baby sun shade, musical garden products), however the engineering students felt comfortable and could relate to these while still addressing all the necessary learning outcomes.

Overall performance of the two cohorts was similar, with the engineering students showing a slightly stronger performance overall, though the difference was largely as a result of slightly better performance in the class test rather than the project. See Figure 2.

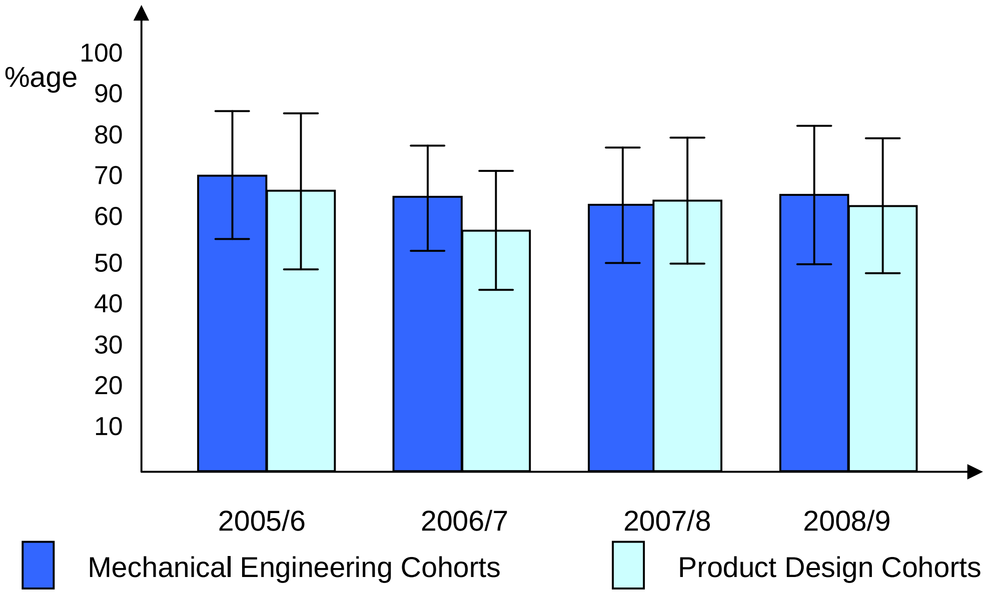

Figure 2 : Mean performance & standard deviation for Mechanical Engineering & Product Design cohorts

The product design students reported satisfaction in the completion of a functional rather than purely cosmetic prototype and that they were able to develop both technical and methodological engineering design skills back to their own discipline. The importance of this type of cross disciplinary approach in product design has been discussed by de Vere et al. recently [10].

Within the practical sessions students were given a series of short focussed exercises in the first half of the module with more open sessions once they began working on their projects.

The nature of systems development of this type is one of incremental progress which lends itself well to a series of mini learning cycles. The most effective development process is one where the sophistication of a system is gradually built up until the target product specification is achieved. This can be seen in Figures 3 & 4. Lessons learnt in individual development phases can be passed to both the next cycle but also in later cycles more closely matched technically to the original cycle (eg. sensor incorporation).

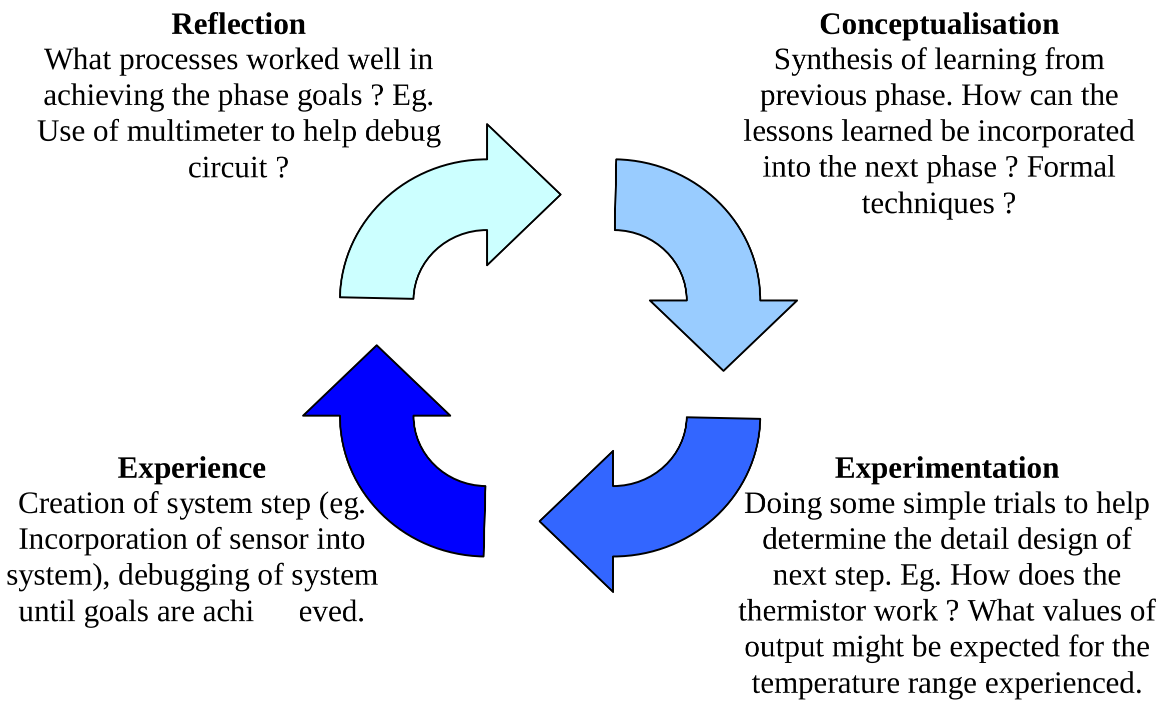

Figure 3 : Typical practical single phase learning cycle

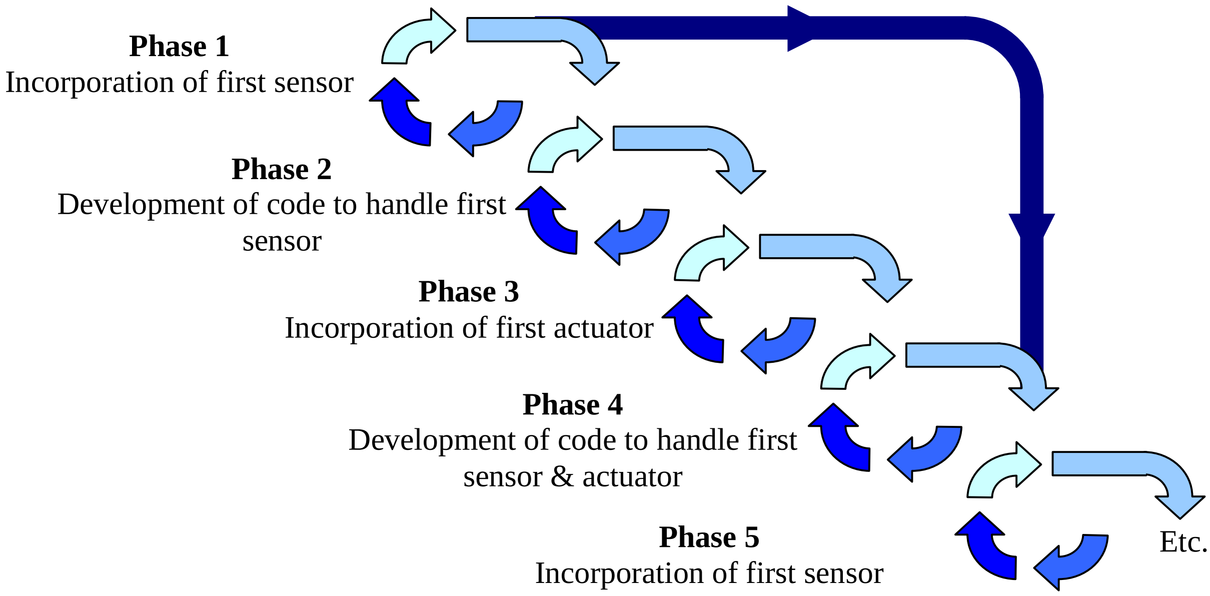

Figure 4 : Learning cycles related to system development

It was felt that to be truly effective a much more broad based approach to system design was required. The physical elements by necessity of time were often quite cursory and there was no opportunity to develop more subtle issues such as packaging, usability or product reliability. This omission became more marked as the two cohorts progressed through the remainder of their education.

In the following semester the product designers worked on a more general product with the expectation that microcontrol was involved. This helped reinforce and build on the students' confidence and competence in this area, with the result that around half the students, given an entirely free choice, opted to have microcontrol in their major final year project. By contrast, this figure was lower than around 10-20% for mechanical engineering students without this level of reinforcement.

Examples of the enthusiasm and confidence of the product design students could be seen in their final year projects. These included a device to encourage wandering and exploration, Figure 4. This was a fully functional device consisting of a GPS sensor chip coupled to a microcontroller the output of which was a galvanometer with a needle pointing the way home. Another device was an active shelf with an embedded MP3 audio device, Figure 5. The control of track selection and volume of the player was determined by sensors in the shelf picking up the weight and location of objects on the shelf and feeding these to the controller which in turn sent appropriate data to the player.

Figure 4 : Wandering GPS device

Figure 5 : Musical Shelving

CONCLUSIONS AND DEVELOPMENT

Using a highly practical approach proved effective and giving students a degree of freedom in choosing their own projects broke down the fear factor associated with a relatively complex topic. Both cohorts brought different skills and expectations into the module but these were generally dealt with by working together in cross-discipline groups.

The technological platform in terms of hardware and software is an issue which should be considered carefully in terms of trading the opportunity for students to personally realise systems of their own conception, with the fidelity of the approach to commercial norms. In practice it was found that the decision as to which platform to adopt would need to be made on a case by case basis. For an introductory course however there was relatively little which limited the students' opportunities in system development so long as a high level language was used and that the emphasis was on application in a project concept.

The nature of systems development of this type is one based on a step approach in which the degree of sophistication in terms of sensors/inputs, software, and actuators/outputs are in turn increased until the desired result is achieved is one which must be learned. This incremental approach lends itself well to reflected learning and personal development and it is an area which will be exploited further in future versions of this module.

The overall mechanical engineering syllabus at that time offered little opportunity for further systems development of this type and the students skill stagnated, By contrast reinforcement and further opportunity for free development gave the product design students significantly enhanced skills in this area.

For students to make most use of the technology then it must be embodied and continually reinforced within broad based design, build and test modules. To this end a new much larger module is currently being developed to allow students to explore and learn microcontrol systems in the context of a more general commercial product development module aimed at both engineers and designers and built around CDIO principles.

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Biographical Information

Gareth Thomson is the course director for the Mechanical Engineering family of degrees at Aston University, Birmingham, UK. He is currently leading the introduction of CDIO to these programmes and assisting in the incorporation of these principles into the related product design degrees. His teaching and research interests include mechatronics and human factors in design and engineering.

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