Microcontroller engineering themed teaching

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Subject Area: Electrical and Electronic Engineering; Microcontroller Engineering.

This case study has been developed from data gathered through observations of the teaching component, interviews with the tutor and a student focus group

Background

The approach to teaching microcontroller engineering described here is distinctive because it has been conceived as a coherent theme spanning four modules over two years rather than a series of linked but essentially independent modules. The lecturer in charge set some aims for where he wanted students to be at the end of year two and designed the theme to lead up to these. The aims were that the students should be able to design a small embedded system with control, actuation and communication functions; they should be able to program it using relevant tools; and this system should stand up to scrutiny from the School's Industrial Advisory Group as being something of relevance to industry. These aims are achieved through four component modules, each worth ten credits. The first component is a first year, first semester project to build and test a microcontroller board. This is very structured, with step-by-step instructions, designed to give the students an early success in building an electronic circuit which can be used, for example, as the controller for a (very basic) hand-held games console. The students keep this board and use it in future parts of their course. Also in the first year, and the first semester of the second year, there are two taught courses on Microcomputer Engineering. These cover the low-level programming of the controller with assembler language, moving on to more abstract programming with C; both courses include a weekly two-hour long practical lab class that is related to the topic covered in that week's lecture and in which students use the board they built in the initial project. Finally, in year two, there is an embedded systems group project which addresses a deliberately under-specified problem, with some contradictory requirements, on a theme relevant to the students' chosen degree course. There was also an aim that this final project should reinforce many of the softer skills, such as group working, report writing, group presentations and practical demonstrations.

The theme is common to Bachelor and Master level courses in Electrical and Electronic Engineering, Computer Systems Engineering, Communication Systems Engineering and Mechatronic Engineering. It is taken by about 180 students in the first year and 200 in the second, there being a number of overseas students who are admitted into the second year through a direct-entry partnership scheme with their home institution. In order to bring these students up to speed, the curriculum in their home institution covers the same content as the first-year microcomputer course and during their induction in the UK they build the controller board that the other students built during their first year project. Including the lecturers for the taught courses, post graduate lab assistants, technical support staff and project supervisors, about 20–22 people are involved in the delivery of this theme; there is also a Peer Assisted Support Scheme so there are student mentors involved as well.

Reasons

The main driver the lecturer had for taking this approach was that he wanted to give some industrial relevance to the microcontroller/microelectronics elements of all the undergraduate courses. He says "*feedback from our graduating students had highlighted the fact that our previous curriculum was not adequately preparing them for a career in electronics, a view supported by the School's Industrial Advisory Panel. The feedback identified a number of areas of weakness in the provision, including core knowledge, transferable skills, appreciation of practical engineering constraints and design creativity and exploration*." Aside from the obvious employability rationale behind industrial relevance he believed it would motivate students if what they learnt in the early part of their course wasn't just a pre-requisite for a subsequent module but had a direct practical application in its own right. Furthermore, he was aware that "*a very large proportion of students who enter this School now have never built a circuit of any form*" and he "*wanted them to have an early success in having built something*". More generally, the lecturer wanted to achieve a transition in his students' learning styles. On entry they were often not comfortable with any kind of open problem solving, being used to questions structured as small individual steps that lead the learner on, and they were lacking the confidence to persist if what they tried first did not work.

Lecturer's perspective

The multi-module nature of the microcontroller theme is, in the lecturer's view, essential. He says "*I had the freedom of 40 credits; if I'd only had 20 credits I don't think we could have done a credible job.*" There is also something in the nature of microcontrollers that is important. Firstly they are omnipresent and relevant to all the range of electronic and electrical engineering programmes the students are taking; secondly the software and hardware combination is "*a delight in which to let people make small mistakes which are recoverable*", compared for example to high voltage electrical engineering. This is key to promoting problem solving through experimentation and also important as it is in the nature of engineering that students should build something. Thus the theme starts by giving the students an early success which helps them realise they can be creative. This is intended as a source of motivation: "*I don't have to use this trick of suspending disbelief and saying "stay with me to the end of the unit and then you will see" [...] the first lab they do with me, they're able to turn on LEDs on a board from software [...] if you've never done it, it's a phenomenal step, that you've written a programme and in response to something you've done an LED has come on.*" At the end of the theme, the embedded systems project is deliberately less well specified and requires the students to make engineering decisions and to balance contradictory requirements. The two taught courses are intended to give the students the skill set and tools to cope with this. Throughout, there is also an element of self-directed learning as students are able to see the benefits that their peers gain from, for example, reading component data sheets. Illustrative of this is that on one occasion a student managed to get a ring-tone out of the piezo device on their input/output board; the lecturer "*thought someone's leg had dropped off or something because there were about 20 students all crowded round this guy*" and instantly they all went to look up the information about how to do it.

There are some issues with this approach. Dealing with students who enter directly into the second year is one, as described above. Similarly, the taught courses with their tightly integrated lectures and labs, building each week on what was learnt in the previous lecture, mean that if a student is absent for a couple of weeks it can be difficult for them to catch up. The lecturer is aware also that there can be some "project envy", with some students believing that others have more interesting projects or more helpful supervisors. Finally, there is an issue with the number of staff involved in delivering the material who need to buy into the philosophy of the approach: technical support staff and academic staff need to learn to allow students to learn from doing something the wrong way rather than to show them the right way to do it; academic staff with no expertise in microcontrollers are involved supervising some of the projects.

Students' perspective

About one hundred student questionnaires were returned by second year students and two groups of students were interviewed, one a group of second year students and the other a group of students from later years. A large majority (over 60%) of the student questionnaires indicated that the approach taken helped the student develop problem-solving skills more than other courses do; similarly a majority of the students felt it gave them more industrially-relevant experience, though in this case many felt they could not know this until they had worked in industry. Both direct knowledge of microcontrollers and softer skills such as team work and project management were cited by students as improved through this course and potentially of relevance to employers. In the interviews the students who had been on industrial placements confirmed this; one said "*without the project work my CV would be quite useless*." From the questionnaire we see that students also believed that the project work especially helped them learn about microcontrollers (over 85% believed it increased their depth of understanding). They were motivated by building and using their own microcontroller board: one of the interviewees said "*that's what's fantastic, for me, it all leads on. That board that I built in first semester, first term, four years later I was prototyping my masters project on that same board*." There were some students who felt that there was too much open-ended exploration, though one gets the impression that they would rather be told the "right" answer, and some other students reported that they found the material too hard; however, overall the students reported that they felt more confident in their problem-solving experience. The only other major issue reported by students was that some of them felt they needed more time in the lab. Finally, the students believed that the theme is coherent and well organised and repeatedly they stressed that they appreciated the continuity offered by this approach.

Issues

- There is a perception among some students that some of the embedded systems projects are more interesting than others. Essentially they all want to build a robot buggy. In response the lecturer plans to adapt the course so that in future all students work on different aspects of the same project while keeping the relevance to their chosen degree programme.
- It is difficult to cope with some students' expectations. The approach here involves some deliberate ambiguity and open-endedness which some students perceive as being a lack of "teaching". This may be exacerbated by variations in teaching style among those involved in course delivery. The result could be demotivating for these students.

Benefits

- Students are motivated and gain confidence by building something of use and using it throughout their course.
- Staff have observed that team project work in the subsequent years has been improved after students have had experience of group dynamics and project work in the second year.
- Students wanting industrial sponsorship or placement benefit hugely at interviews since they can take a working piece of electronics that they have built and about which they can talk.

Reflections

The "theme" approach to teaching microcontrollers has allowed the lecturer to create a coherent learning experience over four modules building up to achieving aims over the course of two years that would be difficult to achieve through independent uncoordinated modules. This is successful in motivating students and in furnishing the students with engineering knowledge and soft transferable skills that are key to employability. As one student said, "*it's not just learning for the sake of getting that certificate*."