Engaging year 1 students through problem based learning

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Abstract—Some degree programmes can become disjointed due to the numerous paths that students are being offered. As a consequence, some students struggle to see the connections between different modules, become disenchanted and struggle to engage with the technical content. This paper describes a project to tackle this potential disengagement and/or poor learning by introducing a fun problem based learning assignment that draws on most of the year 1 curriculum.

I. INTRODUCTION

Certainly within the UK and perhaps a little more widely, there is currently a lack of interest in studying engineering at University level. Of perhaps greater immediate concern is that many students do not, at the outset, have an inherent interest in the more mathematical parts of the topic that traditionally formed a large basis of year 1 studies. Disenchantment with mathematics is well publicised (e.g. HELM, IMA Conference, [2], [3]) and is not the main topic of this paper. Instead we focus on some of the other engineering topics that nevertheless rely on high mathematical ability. In particular we consider that one major issue is the need to engage and enthuse the student body to a far greater extent than previously. Once engaged, they will be more willing to tackle the hard technical details required to progress.

Hence this paper makes a major assumption at the outset, that is that a sizable proportion of typical UK students struggle to come to terms with, engage with and understand the core technical content in year 1 [15]. As such, even if they pass (often after a few resits), they are poorly prepared for future years. A second assumption is that students do not, at the outset, have an inherent interest in the more mathematical parts of the topic that traditionally formed a large basis of year 1 studies. Disenchantment with mathematics is well publicised (e.g. HELM, IMA Conference, [2], [3]) and is not the main topic of this paper. Instead we focus on some of the other engineering topics that nevertheless rely on high mathematical ability. In particular we consider that one major issue is the need to engage and enthuse the student body to a far greater extent than previously. Once engaged, they will be more willing to tackle the hard technical details required to progress.

Hence this paper makes a major assumption at the outset, that is that a sizable proportion of typical UK students struggle to come to terms with, engage with and understand the core technical content in year 1 [15]. As such, even if they pass (often after a few resits), they are poorly prepared for future years. A second assumption is that departments have been too slow to change their degree delivery to accommodate the changing experiences and abilities of the intake. For instance [1] students are far more computer literate, perhaps better at some aspects of project work (due to the increase in coursework at A level), but less able to tackle technical problems independently. Moreover, at school level they are used to highly professional teachers using imaginative and varied teaching styles to help the learner. They need help with the transition to university level studies, perhaps more nurturing and most critically, they respond well to effective ‘advertising’ of a topic (e.g. learning through games [4], [7]) etc. We need to be more imaginative in how we teach if we are to enable the students to be better learners [11], [10].

One tool that is accepted as quite effective is the reduction in emphasis on a formal exam and more use of coursework assignments. These enable students [9] to test their progress quickly, to gain confidence and most importantly give them an incentive for engaging with the topic throughout the term, not just in the revision period. Of course a downside to this is the potential for plagiarism, however that also is not a major issue. For now we summarise our approach as using varied and interesting assignments so that students cannot easily plagiarise each other, or previous year’s work, and actually want to do it themselves. Moreover, in year 1 set the bar low so that students gain confidence by achieving the targets; there is time enough in later years to make the assessments more demanding once the students are better prepared.

The purpose of this paper is to describe a project for engaging and enthusing students with the topic while, as a secondary benefit, helping them learn some of the more technical details. In particular the philosophy is that we understand best when we use something; learning by doing. In fact the IFAC education committee makes a very similar recommendation on the importance and benefits of practical experience within control education. Hence, our aim is to get the students to use their first year learning on a real, non-trivial, case study system, and thus to reinforce the technical content by application. Moreover, a competition, or game, element is introduced to engage and enthuse them, while the context is linked to an obviously useful and everyday task.

The paper gives some further background to the departmental context in section 2 followed by conceptual details of the project in section 3. Section 4 then describes the problem based learning (PBL) assignments and equipment. The conclusion includes a critique and future work.

II. BACKGROUND

This section looks at two aspects of the curriculum, that is laboratory provision and the use of numerical software to support learning. This background summary is used as a base from which the proposals in the later sections originate.

A. Academic involvement with laboratories

Perhaps like much of the world, academics in the UK are employed primarily for research and while it is accepted that they will teach several courses, basic competence is all that is really asked for. Unfortunately, the downside is that many staff take a relatively minimalist view to their teaching duties [6] in that they are conscientious with their individual modules but are less keen to engage with issues that cross the whole programme1. Also, there is a preference for exam only modules due to the lower load, but this does not mesh with year 1 teaching where the use of coursework assignments is

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1This issue is discussed more fully in a separate paper in preparation [13]
generally considered to be good practise. Thus 2 problems can arise: the curriculum can gradually lose cohesiveness as individual module leaders make small changes each year without reference to the overall programme aims and students do not perceive the linkages between modules because module leaders, even if aware of them in theory, are not aware enough of the details to make effective use of these in their teaching. Hence, the tendency towards modularisation can lead to more student discontentment, worse engagement and hence poorer progression.

Within the author’s department a further development of this concerns laboratories. As a means of protecting the importance and cohesiveness of laboratory experience, all the laboratories are grouped into a single module and removed, along with any explicit linkage, from the technical modules. This was intended to overcome a general lack of interest by academics in maintaining and making links to laboratories within the technical modules as well as streamlining some administration. However, the downside was that the technical modules became even more distant from any laboratories with which they were originally intended to be linked. The department has substantial student evidence, both from applicants and current students, that the laboratory experience is really important to them so this disjointness is not desirable.

Nevertheless, it was felt that sustainability was best served by having a separate laboratory module and this issue raised an opportunity rather than an obstacle. Until now, first year labs had been rather narrow in their focus and in some instances, having functional learning outcomes, could be rather boring. The department needed to develop a vision for how a lab could actually excite the students and serve the original purpose of reinforcing or using key skills learnt elsewhere. The proposal for achieving this is discussed in the later sections of this paper.

B. Matlab and Simulink in the curriculum

Due to similar thinking [12] to that reflected in [1], the author’s department had taken a very definite decision to put more emphasis on software tools and their use in engineering. Specifically, it was decided to teach MATLAB in year 1 in the expectation that students would use this as a tool to reinforce and assist with the learning of topics throughout the remaining years. In fact, such a policy is rather simplistic in that students, just as with mathematics, may not easily see the potential of what they are being taught and could be quickly demotivated by the need to learn what appears to be ‘programming’.

1) Problem based learning: One difficulty with teaching and assessing MATLAB in year 1 is that the students know too little engineering to be set meaningful MATLAB based assignments. Consequently assessments could become rather boring software tasks demonstrating confidence in loops, conditionals, function and script files, arrays, etc. Most students have little interest in this for its own sake.

An alternative problem based learning (PBL) model of basing assessments on more interesting material that has not yet been covered in the programme, tends to frighten the students who may struggle to come to terms with what they are being asked to do, although it does enable us to place the problems in a relevant and interesting context. For instance, typical assignments in ACSE include: (i) code and illustrate a least squares line fit to some data (using polyfit.m), although strictly speaking this technique is not taught until year 3; (ii) simulate a time series model and compare with some raw data and (iii) develop a gui to investigate how a 2nd order ODE response varies with damping ratio.

After 3 years of gradual evolution typical student feedback for this module varied enormously. Most, probably the interested or motivated students, who really got to grips with the PBL approach adopted, were, eventually, quite enthusiastic about what MATLAB could do for them and pleased with the module. A few could not get to grips with PBL (or independent learning) at all and struggled to make much progress. Some typical quotes are:

1) This is a a very useful tool for control and system engineers. The module is good and interesting but slight complicated for first year students. Very complicated coursework....

2) It has helped me in my other modules as well. I like the fact that it help me in my other assignments.

3) Well to be honest, I really like the idea and that style of learning despite of all the difficulties that I faced at the beginning of the course.

4) I do not feel so. I feel that in the first year, the traditional methods are more suitable. This is because many things are new to us, and some of us take longer adapting to a whole new topic and level of thinking.

In fact, some of the positive quotes above reflect in part the very latest change to this module which was implemented this year as a precursor to the bigger project discussed later.

2) The future of MATLAB teaching: The first two years evaluation indicated that students were struggling to relate the MATLAB to their other learning and struggling with motivation. Part of this was due to timing and part because of the lack of proper communication between staff. It was thought important to make explicit links to other first year modules to drive home the relevance; this would have dual benefits of helping to reinforce students other learning as well as encouraging them to see MATLAB as a useful tool.

However, using MATLAB to solve typical year 1 problems is not challenging enough for assessment and so a more imaginative route was needed. Coincidentally, these module reflections occured simultaneously with a department project looking at the student experience and module cohesiveness [6] and it was decided to modify the MATLAB module to become more overtly a service module to the remainder of year 1, rather than an end in itself. Specifically, the plan was to use the MATLAB module as a glue to show how all the first year modules were connected and important for a systems engineer. The challenge was to design an assignment which acted as a glue while also encouraging the development of key skills and confidence in MATLAB.

The first stage in this process is described in more detail in the next section, but early student feedback is very positive:
1) Yes, this assignment helped me to link different aspects of first year modules and to understand more of model, control, design and simulate of the systems.

2) Yes it did help me to see the point of last semester and even gain a little more understanding of related modules.

3) It did help me to integrate my year one’s learnings.

4) I think that this task does put year 1 into perspective and also gives the student more freedom as they can design a system of whatever they want.

5) Yes I feel it has. It has definitely been one of the more interesting assignments this year.

C. The future for the whole curriculum

The background section has highlighted two substantive issues. The first a break down of the formal link between academic modules and laboratories and thus a tendency towards rather mundane experiments, the second was difficulties in engaging students with learning MATLAB (software tools for engineers). Along with these two issues is the underlying difficulties with delivering a programme that students perceive to be cohesive. The next section completes the picture of programme context and then describes how these issues can be tackled sensibly with a single and sustainable project.

III. INNOVATIONS PROJECT

The author’s department delivers degree programmes over six sub-themes [control, mechanical, electrical, medical, mechatronics, computing], but all of which have a large bias towards control and systems engineering. Thus, to bring cohesiveness to students on these 6 streams, any assignment would need to be focussed around control and systems rather than what are quite disparate sub-themes. Moreover, there was a desire to consider issues raised in the previous section and a few other items of increasing priority:

- better linkage of laboratories to modules.
- MATLAB acting as glue to bring all 1st year modules together while reinforcing key technical competencies for those modules.
- motivating students by transparent embedding of industrial relevance.
- opportunities for design and build.
- introducing transferable skills such as group work, presentation, report writing, etc.

However, the most critical enhancements in year 1 were to improve the links to industry and increase opportunities for design and build experiences. The reader would not be surprised to observe that one can tackle the entire list and priorities with a well designed group project in year 1; an idea that we believe is becoming prevalent elsewhere.

This section gives some more detail on the desired learning outcomes and how these can be combined into a single assignment.

A. Key technical learning outcomes in year 1

Central learning outcomes are the key generic skills that students should really be developing in year 1. Within ACSE, the most important keywords were agreed to be: Modelling, simulation, the integration of feedback, design and build. That is, a systems or control engineer would be aiming to achieve a given behaviour from some system. To achieve this they would need to model the system, simulate the model, add feedback loops and retest the design and iterate between designs until satisfied. Finally, once the design is satisfactory and fully tested using appropriate software, the engineer would consider building a prototype.

The above procedure maps quite well onto the typical module content of a year 1 engineering programme and thus, on the whole, students will learn these skills. However, often the skills are assessed in isolation, through exams. A practising engineer would need to use the skills simultaneously. Thus a logical goal for the department was to design an assignment which integrated all the learning outcomes from the academic modules thus helping students see how all the topics are needed and can be used together for a useful end product. It should be noted that conventional practice has relied on projects in later years to achieve this integration.

The difference here is that ACSE sees an increasing need for such assignments also being earlier in the programme.

B. MATLAB, the link to industry and transferable skills

Within academic degree programmes, the links to industry are often rather tenuous. Here the intent is not to consider that issue for the entire programme, but rather to focus on that issue in the context of MATLAB. In particular, it was felt one could reinforce the importance of MATLAB by using assignments that emphasised a matching in the use of this tool with common use in industry. For instance, it is known that several industries now perform a large part of design and build with software and only moves to building prototypes when any design has been thoroughly evaluated with simulations. This saves significant time in developing new products.

The department uses industrial speakers to give students an insight into life as a professional engineer and many of these have used illustrations that reinforce this model of design and build, thus emphasising the relevance of any similar assignment. More importantly, there is ample evidence [8] that many large companies use MATLAB/SIMULINK as one of the first tools in this procedure.

The reader will see immediately that the procedure outlined in section III-A for incorporating key learning outcomes has strong synergies with the proposed use of MATLAB above. Hence one can tackle both issues with a single assignment. Thus, in summary:

1) the main aim is to create a design and build project where MATLAB is used as the main simulation tool for assessing the design. The design and build is focussed around behaviours and thus must involve modelling, simulation, programming and feedback.

2) a secondary aim is to tailor such an assignment so that students can implement and test their design on real equipment.

Transferable skills such as group work and report writing can be embedded around this as required.
C. Stage 1

Due to the substantive expense and potentially large credit rating of the type of assessment described above, an action research approach was adopted. Thus the project was designed in stages with later stages following evaluation and reflection on the initial stage (typical student feedback was given in section II-B.2).

Thus a logical first stage in this project was to implement and evaluate a lower risk alternative and hence in 2005-06 the project was restricted to the software side only. That is students were asked to demonstrate how MATLAB could be used for design and build to a system of their choice, for instance reflecting the sub-theme within their programme. A key part of the assignment was a demonstration of iteration within the design, a point where the use of simulation software is of greatest benefit. For instance a simple example may be to develop an active suspension unit (by iterative simulation) for a quarter car model; such a project involves all the key aspects of modelling, simulation, inclusion and selection of a feedback gain and using MATLAB for the coding and to generate illustrations for report writing.

Despite the assignment being fairly loosely worded, to give students some freedom to reflect their specific interest and programme, the feedback was almost universally very positive (see section II-B.2). This has given the department confidence to take this project to the next step and include real equipment. This development is discussed in the following section.

IV. DESIGN AND BUILD FOR YEAR 1 WITH INTERESTING EQUIPMENT

This section describes the physical equipment around which the assignment is based and gives further discussion to some of the practical issues related to implementing the project

A. Credit weighting and organisation

As mentioned earlier, the reduction in the number of common core modules gives less flexibility for embedding integrating assignments as there are few modules taken by all the streams and, being core, these modules do not have the spare capacity for additional assignments. Nevertheless, for structural and sustainability reasons, it was decided to place the build and test part of the project within the laboratory module; thus creating some space in this module here was made a priority. It was not possible to create enough time for the entire assignment, however, the modelling and simulation part most logically fits within the MATLAB module and space was created there by reducing the emphasis on the formal coding aspects.

For those interested in detail, ACSE has made a notional allowance of of 30 hours per student for working with the equipment; this time to include any thinking, report writing and presentations in addition to the time in the laboratory. Similarly, the modelling and simulation part, with corresponding report, also has an allowance of 30 hours work. Students would have about 5 weeks to complete this task which would constitute about a third of their workload during that time.

Having an assignment which crosses over two modules may create some minor administrative and co-ordination issues, however it also has the double benefit of helping students realise the interdependence between modules and also allows with Business Skills students unable to do the laboratory module to benefit from the other half. Separate, but linked, reports would apply to each half.

B. The scenarios

One of the key difficulties in this project is the conflict between making an interesting project [14] and one that is realistic for year 1 students. The department would like any equipment to be multi-purpose, that is have a potential use for later years. Thus, a further underlying constraint, to add to the wish list of section III, was to come up with scenarios that could be embellished for higher level students while being simple enough for year 1.

In the first instance two alternative scenarios are being developed; with future scenarios being considered subject to evaluation of these first two. As stated earlier a main objective was to make the scenarios fun, relevant and futuristic while having relatively simple dynamics so that the modelling, coding and control is manageable for year one students. Hence the following topics were proposed:

1) Linking image capture to a feedback loop.
   This was inspired by tennis and the annual furore at Wimbledon as to whether a line call was correct or not. Students would capture some images of a ball in flight, predict the trajectory (e.g. assume a parabola) and then control a catching device with simple dynamics.

2) A mini self balancing robot (i.e. swegway).
   This has been used elsewhere in projects for higher years and clearly can be done with a full size rig [14] or even with simple parts such as lego mindstorms [5].

C. Designing assignment aims and objectives

Clearly, the need to do real implementation and limited time put severe restrictions on how much ‘design’ the students are able to do. So the projects were designed to have some parameters that can be changed easily and quickly. Students would be aware of this during the modelling stage and thus able to use simulation to propose best values. Also, the need to interact with real equipment suggested a preference for coding in C, thus students would need to be provided with templates so that they could focus their coding efforts on the key parts of relevance to the project, such as the control part. For higher level students, the intention is to remove some of the support material and extend the objectives the equipment should meet.

V. THE SCENARIOS

This section gives outline technical specifications for the two scenarios currently under trial.
A. Image capture, prediction and ball catching

Tennis players will be aware of the importance of making a correct line call. Control engineers will be familiar with the value of modelling for predicting behaviour and also the need for feedback to automate reliably. Information engineers will often need to automate decision making based on image capture. The project here makes use of all these skills.

In summary, a throwing mechanism throws a tennis ball across the room (about 4-5m). The initial elevation is fairly constant, but the speed of the throw can be varied. Depending on the initial velocity, the ball will impact the floor at a different distance from the wall. A catching mechanism (a small train on a track moved via a chain connected to a DC motor) is set up on the floor, students must control the catching mechanism to the correct position for catching the ball. In order to estimate the impact position, students can access images from a camera whose view is orthogonral to the trajectory. Thus in real time:

1) the ball throw triggers the camera to start taking pictures.
2) the images are processed to identify the ball position.
3) given ball positions at several sampling instants, the ball trajectory is computed [This could be updated recursively with new information].
4) The trajectory is used to estimate impact position which is is the target point for the control mechanism of the catcher. There is a maximum of about half a second between image capture and impact. Simple PI tuning would be adopted as the catching mechanism is a simple DC motor driving an inertia.

Some important aspects for this project are given next. It is noted that many of these issues could be designed in as decisions for the students to make, thus enhancing their awareness and development.

- The selection of the camera: The more data that is processed during capturing, the more precise the dropping position would be. We decided to buy a camera which supports the resolution 640 by 480 with a frame rate 86. For the current experiment, a Black & White camera is sufficient. An additional lens is also used to make the selection of the camera position more flexible.
- Experiment environment: The camera needs to be a reasonable distance from the target, thus requiring a large room with uniform illumination distribution [5m by 5m is really too small but one can just manage within that]. Illumination of the room and in particular the view direction of the camera is critical. When this is affected by sunlight, which varies, or is not uniform due to poor lighting positions, it is recommended that one provides additional high power lighting (we used two 500w lamps) for the relevant area. Strong lighting can introduce a shadow, but this is manageable and adds to the image processing challenge.
- Image catching procedure: The resolution 640 by 480 with the frame rate 30 or 60 is ideal. We extract the red component (there are red, green, blue components in an image) as this has the best data to distinguish the target with background. In brief, first get the background of the scene, second remove the background from the later frames using stored information and use a threshold to transfer the image to a binary image - the black denotes the target and the white denotes the background. Hence detect the position of the ball.
- Estimate the dropping position onto the floor from the model’s prediction. The model will be a simple parabola as air friction has a relatively small effect.

B. The ACSE swegway or balancing robot

A swegway is a relatively well known item used in everyday life, but sufficiently interesting to stimulate students. Moreover, if kept near the vertical position, the dynamic modelling is not over complicated and can be managed by year 1 students with just a little guidance. Students could be asked to do relatively simple tasks such as moving backwards and forwards in a straightline between two obstacles, without colliding. A PD controller should be sufficient to stabilise the swegway and this could be designed with some trial and error beginning from ‘strong’ guidance. More elaborate tasks could be given to higher level students.

The equipment is designed not for looks but to optimise access to the key components students need to engage with, e.g. motors, control board, and sensors.

- The robot is driven by two 12V dc geared motors. The motors are mounted side by side. Their speeds are varied using pulse width modulation (PWM) which is generated by the microcontroller.
- The microcontroller board contains an Atmel ATmega32 controller which is clocked at 16MHz. It has 32K bytes of program memory and 2K bytes of data memory. Amongst its on-chip peripherals are 4 PWM channels and an 8 channel 10 bit analogue to digital converter.
The microcontroller is programmed in C on a PC. The cross compiled code is then programmed into the microcontroller with the JTAG interface (and lead). The programming environment uses WinAVR.

It balances using 2 Sharp GP2D120 sensors that measure the distance between the top of the tower and ground. One sensor is at the front, the other at the rear of the robot. The output from the sensors is fed into 2 of the ADC channels on the microcontroller.

Each motor has a shaft encoder. These give direction and step information to the controller which uses these to generate speed and position.

VI. CONCLUSIONS

Student feedback demonstrated problems with the perceived cohesiveness of engineering programmes. This was exacerbated by the numerous entry routes and consequent reduction in core modules as well as modularisation itself encouraging an attitude of module isolation. This paper has described a proposal which seeks to overcome this issue by incorporating design and build projects within year 1 where the assignments are developed to integrate all the key components from the other year 1 modules as well as make clear links to industrial relevance. Preliminary trials were very encouraging and this paper describes the equipment prepared for stage 2 to be implemented in the Spring of 2007. An evaluation will be ready for dissemination at the conference.

There are major obstacles to the approach detailed in this paper. Specifically for ACSE and many similar departments, the wide spread of entry routes and consequent reduction in core material across all new entrants makes it increasingly difficult to embed activities of this nature. For instance a logical place for the PBL assignment is within the laboratory module, but students taking streams with Business Skills have to drop the laboratory module to make space for the Business skills modules. Likewise, some streams do not take the MATLAB module. As such lots of imagination will be needed to provide students with assignments bringing coherence to their programmes.

REFERENCES