Motivational projects for 1st year common engineering courses

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Abstract
Over the past few years many universities worldwide have introduced a common 1st year for all engineering disciplines. This is despite the opinion of many academics that large classes have negative effects on 1st year student learning outcomes. At the University of South Australia we also face low motivation of our engineering students studying non-major courses. In 2007 we successfully introduced a project based laboratory for 1st year students enrolled in electrical disciplines which increased student satisfaction, reduced attrition rate and improved student success rate. In project based laboratory independent laboratory experiments are replaced with a sequence of laboratory sessions in which students progressively build a functional electronic device. In each session students build, test and learn the functionality of one of the modules of the electronic device which will eventually become their personal property, useful in subsequent courses and for home experimentation. In this paper we present our experiences with implementation of the project based laboratory with three different projects in the common 1st year course, Electrical and Energy Systems, where each project aims to increase the motivation of students in one of three disciplines: electrical, mechanical or civil engineering.

Keywords: engineering education, project based laboratory, common first year

1. INTRODUCTION

Internationally, accrediting organisations require that graduates from engineering programs should be able to demonstrate that they have acquired generic skills necessary for practice in a complex environment [1]. One of the most effective ways to accommodate acquisition of these skills is to introduce experiential, project-style learning in the program as early as possible. This is also in line with the Teaching and Learning Quality Framework of the University of South Australia (UniSA) that emphasises [2]:

- Student engagement through experiential learning (including practice-based learning, service learning and the teaching-research nexus),
- Graduate qualities (discipline knowledge, skills and personal attributes)
- Flexible learning environments (formal and informal; face-to-face, online and print) and a
- Quality improvement cycle (ADRI: Approach, Deployment, Results and Improvement).

Within the School of Electrical & Information Engineering (EIE) at UniSA we have attempted to introduce experiential, project-style learning in early years of engineering programs in various ways over time. In 2006 we introduced a novel approach to the practical component of the introductory electrical engineering course in which students progressively build a small functional system during the semester, and perform their experimental verification of theory on the modules of that system as they are assembled. In this way they are performing project activity, which satisfies the student desire to be “doing engineering work”, and at the same time equips them with valuable practical skills, like soldering, the ability to wire circuits and use measuring instruments appropriately and successfully, to read schematic diagram and map it into the actual electronic system. Not less important are communication skills students develop through the interaction between group members while working in the laboratory as well as working on the joint practical report. Within their working group of 2 to 3 members, students practice their skills and knowledge by helping the members of the group and by teaching each other new skills. The collaborative work on the project report provides students with the space to exercise soft engineering skills gained in a co-requisite course including design of the structure of the report,
management of roles, time management, development of information literacy and communication skills. The project component of the course is assessed in two phases. First, students need to demonstrate the working device to the laboratory supervisor. This includes demonstrating the tests performed and measurement data obtained from these tests. Second phase is assessment of the report which is a product of the group effort. The project mark accounts for 25% of the total assessment in the course.

Previously we presented the students positive reaction to the introduction of a project based laboratory in replacement of a number of stand-alone laboratory experiments for a 1st year course, which had an average of 70 students only from the electrical engineering disciplines. In this project students would create an electronic power supply which they would keep and use in later courses [3]. After engineering programs had been restructured this course became a common 1st year course for all engineering disciplines at UniSA. In 2008 we had about 200 students in this course from three different disciplines. Due to our previous success we decided to keep running the project based laboratory, however, we realized power supply project would not be very attractive for mechanical and civil engineering students. Consequently we introduced two more projects: a racing car project for mechanical students and a moisture probe project for civil engineering students.

2. PROJECTS

Kolmos differentiates between three types of project work based on different level of freedom that students have[4]:

1. **Assignment project** where the problem, the tools (methods) and outcomes are all well known in advance and the supervisor can fully control these.

2. **Subject project** where the subject is well known and students have freedom to choose either a problem within the subject or methods for a pre-defined problem.

3. **Problem project** where even the problem itself may not be well defined. Thus, students need to first fully specify their own interpretation of the problem and the outcomes of the project, and then select or develop suitable methods for its implementation.

All three projects are well defined and can be classified as assignment projects. We selected the assignment project as the most suitable type of project for first year students enrolled in the course Introduction to Electrical Engineering because of their very limited technical background in the subject matter. In this course students have six 2-hour designated practical sessions in the electrical engineering laboratory over the 13-week study period. In this short period it is unrealistic to expect students to do more than become familiar with some common components and their functions, learn to operate some measuring instruments and follow a given testing procedure through to the drawing of appropriate inferences, and to develop practical skills in assembly and where necessary fault-finding and rectification, and of course the functionality of the device and its modules. The same students also undertake the co-requisite course Engineering Design and Innovation, which provides tools for systematic innovation – once there is a sufficient basis in technical knowledge and routine synthetic and analytical techniques.

Although there are three different projects, first session is the same for all students. In this session students learn to use NI Multisim software tool for circuit simulation so they can later use it to investigate performance of different parts of their projects.

2.1 Power supply project

This project requires students to build and test a simple, commonly used electrical/electronic power supply. As previously stated, the project is well defined and the students are supplied with all necessary electronic components and detailed instructions on how to assemble and test the device. The project is composed of several modules. The schematic diagram of the first module that students complete is shown in Figure 1. It represents an adjustable positive voltage source with the nominal voltage that can vary from 1.2V to 12V. Although the schematic diagram shown in Figure 1 looks simple even to inexperienced engineers, it certainly looks very complex to 1st year students. They usually do not have any knowledge about electronic components included on the diagram, but they also cannot read this diagram when they first see it. To complete the project students not only gain knowledge about components and diagrams, but they also have to make a cognitive connection between the diagram and the actual product they eventually build. For everyone novice to the
electrical engineering there is certainly a big difference between the physical appearance of the module shown in Figure 2 and its schematic diagram shown in Figure 1.

Figure 1. Schematic diagram of the first module: adjustable positive DC voltage source

Students solder the module in steps. After each soldering step they perform a set of measurements on the completed part of the circuit. This way, students learn in detail functionality of the components and how they operate when interfaced with other components. This approach not only enhances student learning but also provides sequential troubleshooting procedure which maximises the successful outcome of the project as each fault is immediately detected before more complex circuit is completed.

Students also have opportunity to clarify with the supervisor and members of their team if they have any doubts about measured results. A typical confusion is when they are asked to measure equivalent capacitance between H2 and H3 test points. For many 1st year students it is not obvious that capacitors C4 and C5 are connected in series between these two test points. On the other hand, some students skip this measurement when scheduled and try to perform it when they already solder resistors R1 and R2 and find out they are not able to measure the equivalent capacitance. Naturally, they want to know why, which leads to a very interesting and an advanced question about how an instrument (digital multimeter) measures a capacitance; answer not known by many experienced engineers. This is just one of the examples presented here to demonstrate that even an assignment project if used properly can be a reach platform for students learning and not just “soldering exercise”.

Figure 2. The printed circuit board (PCB) with only the first module completed.
The other modules included in the power supply project are:

- A negative adjustable regulated voltage source with nominal voltage range -1.2V to -12V; schematic diagram shown in Figure 3(a)
- Regulated fixed +5V voltage source; schematic diagram shown in Figure 4(a)
- TTL logic ON-OFF signal, square wave generator with an adjustable clock; schematic diagram shown in Figure 5(a).

Figures 3(b), 4(b) and 5(b) show progressive completion of the project.

Figure 3. (a) Schematic diagram of the 2nd module. (b) Board with two adjustable voltage sources completed.

Figure 4. (a) Schematic diagram of the 3rd module. (b) Board with three voltage sources completed.

Figure 5(b) Schematic diagram of the 4th module (b) Board with completed all modules.
In the last session students perform final tests of the product including load tests on all three sources at different voltages. Figure 6 shows sample of a graph of a load test of the +12V voltage source.

For safety reasons the project does not include the mains transformer which is normally part of a standard power supply [5, 6]. Instead, an external 230V/10V AC/AC adapter is used to connect the circuit to the 230V power supply. On the other hand the project includes some additional electronic circuitry to make it immediately useful in practical work in the subsequent course Principles of Computer Systems to power their digital circuit design project. Students have a choice of building one or more devices, giving each student an opportunity to own his or her own device. Students are strongly motivated by ownership of the finished product and the opportunity to demonstrate in some tangible way the nature of their studies.

2.2 Additional projects

In 2008 two additional projects, a moisture probe and a racing car are introduced for civil and mechanical engineering students respectively as we felt power supply project would not be very motivational for these students. Figure 7 shows the moisture probe and the racing car as completed projects.
These two projects are developed by Mr Derek Fuller as part of the Australian School Innovation in Science, Technology and Mathematics (ASISTM) project supported by Australian Government (http://asistm.godnss.org/~asistm/) aiming to improve the ways in which science, technology and mathematics are taught in schools. Both projects are based on the same microcontroller board, which includes PIC12F675 microcontroller of Microchip Technology Inc., and a regulated power supply. Work on these projects also has a modular structure. Figure 8 shows the microcontroller board and its schematic diagram which students complete as the first module. The projects differ significantly in sensor and actuator parts and the moisture probe is relatively simpler project that the racing car, although students working on the probe have to spend time on calibrating the probe. Block diagrams of both projects are shown in Figure 9 for comparison.

![Microcontroller board and its schematic diagram](image)

Students are supplied with both electronic and mechanical components together with printed circuit boards (PCB). As microcontroller programming is beyond the scope of this first year course, students are provided with a ready-made program which they download to the microcontroller using Microchip PICkit™ 2 Development Programmer/Debugger and MPLAB IDE software. However, students get to keep the car and the probe that they build and may wish to learn programming later in their program. The car has two motors that can be controlled and a number of sensors like light dependent resistor (LDR) that can be used to program the car to perform different functions such as line following, object avoidance, etc. The moisture probe is an electronic device with the purpose of indicating by a sound alarm when the soil moisture level falls below a certain threshold.

The work on these projects is also modular. During each session students complete one of the assigned modules including soldering components and testing the completed module. This way, students have a better control over the progress of the projects than if the testing was done after the completion of the whole product. It also helps laboratory supervisors to teach first year students troubleshooting rather than having to do it for the students.

3. EVALUATION

The project based laboratory was implemented in the second half of the first year engineering programs in 2008 with 200 students enrolled in the course. We sought student feedback on their experience. A ten question survey was used; nine Likert scale questions (with answers: strongly agree (SA), Agree (A), neutral (N), disagree (D) and strongly disagree (SD)) and one question for text comments shown in Table 1.

Of the 200 students, 75 (37.5%) responded to survey. Of these 75 students, 20 did power supply project, 25 did racing car, 15 did moisture probe with 15 did not declare which project they did.
The survey results presented in Figure 10 show that a large majority (95%) of electrical engineering students (doing the power supply project) agreed or strongly agreed the project motivated them to learn more and 80% of them were highly satisfied with the project-based laboratory.

Figure 9. (a) Block diagram of the racing car[8] (b) Block diagram of the moisture probe[7]
The chart also shows that mechanical engineering students and particularly civil engineering students are significantly less satisfied than the electrical engineering students. To improve the satisfaction, it has been decided to introduce more projects so students can choose projects they may perceive more relevant to their profession.

All comments supported the concept of the project based laboratory. Students liked the hands-on work, while suggesting improvements such as more tools, more time to complete the project, more detailed instructions etc. None of the students stated that they did not like the project based laboratory; most testified that they enjoyed it, stating that it was the best part of the course. Although many students were not very motivated to study electrical engineering as their non-major, the majority of students liked the project component of the course: only 38.5% were satisfied or strongly satisfied with the course (52 students responded to the survey), 63% were satisfied or strongly satisfied with the project (72 students responded to the survey).

<table>
<thead>
<tr>
<th>Question</th>
<th>(SA) + (A) [%]</th>
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<tbody>
<tr>
<td>1  The laboratory project has motivated me to learn more about electrical</td>
<td>95  73</td>
</tr>
<tr>
<td>2  The laboratory project enabled me to develop and/or strengthen a</td>
<td>70  64</td>
</tr>
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<td>number of the qualities of a University of South Australia graduate</td>
<td></td>
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<tr>
<td>3  The laboratory developed my understanding of concepts and principles</td>
<td>85  80</td>
</tr>
<tr>
<td>in electrical engineering</td>
<td></td>
</tr>
<tr>
<td>4  Laboratory supervisors motivated me to do my best</td>
<td>80  57</td>
</tr>
<tr>
<td>5  Staff involved were genuinely interested in my progress</td>
<td>75  57</td>
</tr>
<tr>
<td>6  I am satisfied that I acquired useful knowledge and skills in electrical</td>
<td>85  67</td>
</tr>
<tr>
<td>engineering</td>
<td></td>
</tr>
<tr>
<td>7  I have received feedback that was constructive and helpful</td>
<td>65  55</td>
</tr>
<tr>
<td>8  The staff teaching in this course showed a genuine interest in my</td>
<td>65  52</td>
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<tr>
<td>learning</td>
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<tr>
<td>9  Overall I was satisfied with the quality of the project-based laboratory</td>
<td>80  63</td>
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<tr>
<td>10 What did you like most about the project-based laboratory, and what</td>
<td>-</td>
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<td>can be improved?</td>
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Table 1: Student Feedback; (SA) = Strongly Agree, (A) = Agree.
Some typical comments were:

“It was good that it was carried out in a logical progression. I cannot think of any ways it could be improved on.”

“[I like] getting to build something while putting into practice what we have learnt.”

“It allowed general practical skills to be improved. It didn't however give me a good idea of why certain components were included and their purpose in the power supply.”

“[I liked] the practical side of electrical engineering. What would make it better would be handing out papers explaining or showing how each component works, this would cause us to have a better understanding of how each component worked and interacted with one another.”

4. CONCLUSIONS

The projects described in this paper are learning driven [9] rather than result driven [10] in the sense that the project results are known and the objectives are to focus on the learning process and acquiring knowledge and skills rather than developing an optimal design. In each session, knowledge and skills acquired in all previous sessions are consciously used to reinforce them. Although the final session is designated as being for the overall testing of the device, during each session students perform a number of small tests. These aim not only to teach students troubleshooting of the electronic device, but also to reinforce the theory covered in the course. These tests include: measurement of equivalent resistance or equivalent capacitance between two points in the circuit, monitoring how the resistance and voltage vary with adjustment of a potentiometer, etc. By testing each module as it is completed, students are learning the modular approach to building systems.

Although the projects are relatively simple, for the 1st year students they are a fertile ground for learning basic practical skills, essential for engineering profession, because students are strongly motivated to build an artefact with a clearly defined useful purpose, and because they want to build it well they want to learn how it works and the reasons why the task is carried out in the sequence and manner prescribed. Consequently, they ask numerous questions. These are not always answered directly. Academic staff of the School strives to embody approaches which encourage student reflection and deeper understanding of new knowledge and skills, and this is still done within the constraints of the time available and the limited knowledge retrieval abilities of the students.

The paper has demonstrated that having students build a simple, modular, testable artifact with a definite useful purpose, which they own at the end of the process is an effective motivator compared to the conventional run of stand-alone first year experiments. Although an assignment project lacks the potential educational richness, and indeed the relevance for fully-formed professionals of true problem-based projects, it has proven to be an adequate vehicle for stimulating student curiosity, thinking and problem solving skills within a fixed context, as well as the development of practical, social and literacy skills.

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References
