Lunch Box Labs – Utilising Small and Portable Practicals

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Introduction

Engineering education comprises a significant number of hands on activities which are resource intensive.(Liggesmeyer and Trapp, 2009) This is especially true for units that involve a significant amount of hardware investment. For example, in a typical computer hardware unit, there needs to be a range of capital investments in analytical and prototyping equipment as well as prototype consumables such as electrical components. In a typical computer hardware unit, it has been a tradition to scaffold classes and lessons around singular and narrow topics which investigate the hardware associations using modern microcontrollers. It would, therefore, involve the use of custom-manufactured circuit boards with dedicated hardware for a typical practical session. Although, the collection of these practical sessions does cover the learning outcomes of the unit, it did not provide a gestalt understanding of the computer system as a whole.

It has been recognised that practice sessions are essential to reinforce learning. (Litzinger et. al., 2011) Furthermore, comprehensive comprehension and understanding in a designated disciplines has been reported to be more easily achieved if students were allowed to develop these understandings in their free time. (Rossiter, et al., 2019) This flexible use of free time is, however, limited with the current university arrangement of fixed timetabling and fixed laboratory equipment. An alternative solution, however, may be able to circumvent this limitation. This is with the use of small, affordable electronic components packaged in a portable, take home kit.(Badamasi, 2014; D'Ausilio, A. 2012) Therefore, the question of: *"What can be achieved when the equipment is so readily available?"* was raised.

We describe the implementation of a third year digital electronics unit at Macquarie University and the effectiveness of such a teaching implementation. We have effectively altered the conventional teaching of a computer hardware unit with the implementation of a Project Based Learning (PBL) pedagogy. The implementation involved converting traditional laboratory based sessions into a single, large-scaled project that can be completed using equipment that is contained in a small lunch-box container. The hardware choices however have been observed to have limited the scope of the delivery of the unit, but have enable a more agile ad-hoc, on-demand class delivery approach.

Approach and Outcomes

The teaching implementation was deployed in a 3rd year digital electronic unit, ELEC342, within the Electronic Engineering stream. The unit has been traditionally structured to include a lecture and a workshop tutorial component. The weekly lectures were a single two hour face to face lecture. This lecture followed the traditional format of a single narrow focused topic being presented in each lecture. Later in the week there would be a single three hour laboratory session. The laboratory session would practice and build expertise in that single topic. Additional teaching activities includes quizzes, assignments and self-study session, which occupy the recommended 150 hours of engagement. In a typical laboratory session, the students utilised purpose-built laboratories and hardware that enabled students to explore the single aspect of the Electrical Engineering curriculum introduced in the lecture. The combination of these learning and teaching activates cover the intended learning outcome of the unit.

To improve flexibility in the teaching implementation, the approach adopted was to abandon individualised, singular and disjointed laboratory activities. Instead, we replaced the hands-on workshops with a single project based learning activity. With this implementation, the students were assigned a single large project that encompassed all the learning outcomes for the unit. Successful completion of the project required demonstrating mastery of each of the learning outcomes.

To ensure that a failure to achieve a single learning outcome did not result in complete failure there were two milestone oral reviews. These reviews allowed progress to be tracked and students who were not making satisfactory progress to be reminded on what they had to achieve.

Also, day to day support was available for the students. This support was available from online 'briefing notes' that detailed each topical aspect of the project, as well as free access sessions where any student could request assistance. The students were encouraged to undertake peer assisted learning which allowed students to progress outside of normal hours.

The briefing notes were made available on an on-demand basis, where students had to identify a lack in their knowledge, attempt to capture their lack of understanding and request additional information. Briefing notes were created in anticipation of the expected requests, but ad-hoc notes could be created when unusual or unexpected requests are received. Each briefing note also included working examples of the topic as well as scaffolded exercises that the student could undertake to improve their proficiency in that topic.

The learning outcomes for the unit revolves around the details of computer hardware. This is a technical unit that is designed to explore and investigate how CPU and peripheral unit hardware operates in modern microcontrollers. The students acquire an understanding of the design and use of modern microcontrollers. Additionally, learning requires an understanding of common computer hardware: RAM, ROM, CPUs, registers, I2C, SPI, as well as some peripheral circuitry. This learning was previously facilitated by dedicated trainer boards, with the circuits already imprinted on the boards, and boiler plate laboratory instructions that the students followed.

However, in the new approach, each student is loaned a hardware kit, shown in Figure 1. The kit of parts must be returned at the end of the unit. This loaned kit contains a single Arduino UNO ("Arduino Uno Rev3," 2019) microcontroller board and a set of additional components: a breadboard, an I2C based 16x2 LCD display, a Microchip 23S17 SPI based 16 bit expansion port, a piezoelectric speaker, LEDs, push buttons as well as resistors, jumper wires and other passive components. These components form the base of the kit and are common for each year's project. Additionally, any year's project specific components can be provided as part of the kit for that year.

The student signs for their kit of components, packaged in a lunch box sized container during the first scheduled session of the unit. This session is the only compulsory session of the unit and is also used to set any ground rules on behaviour and to introduce the project. In 2017 and 2018 the project was to design and construct a four sector fire alarm, with push button switches taking place of the actual smoke or heat sensors. In 2019 the project was to design and construct a multi-zone multi-alarm digital clock.
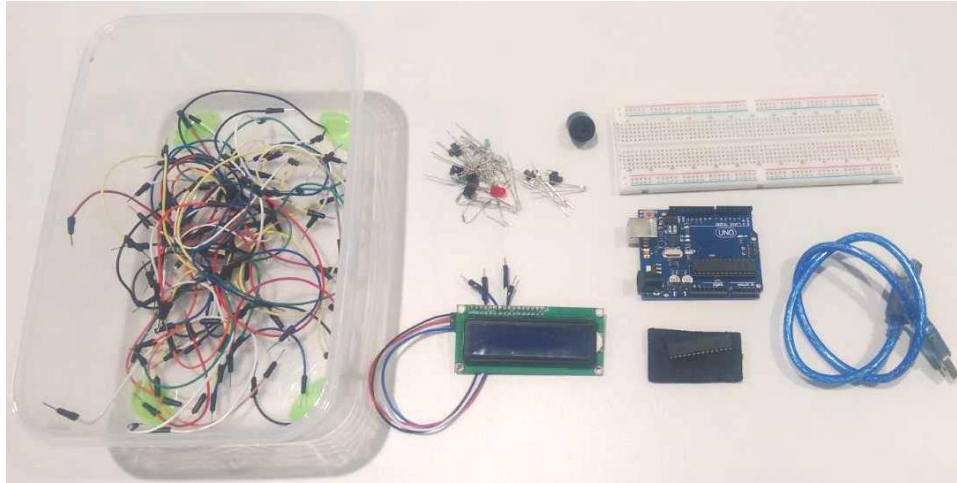
Figure 1: Component Kit with lunch box as distributed

The projects are designed to mimic real world products. This allows students to extrapolate tangible engineering examples into design criteria for their project. The use of familiar systems reduces the learning curve as students try to understand the requirements for the project.

As the goal of the unit is to understand the hardware, not just the project, the unit pitches the project as close as possible to the hardware. This need resulted in the requirement that student's program the hardware using assembly language. Programming in assembly language increases their exposure to the hardware specifications and increases the understanding of how the different sections of the hardware interoperate. Assembly language programming instruction is provided in the initial weeks along with guides and examples. All the briefing notes provide assembly language examples.

Impact and Evidence

The progress of the students was tracked through the two summative oral assessments, as well as a final exam. Each student is invited to complete an end of unit survey. The survey includes questions on how engaging the student found the unit, and how useful the student perceived the unit in their overall

The oral assessments are used to gauge the progress of each student, and to determine if the student understands the concepts required at each stage.

In the first running of the unit in 2018 the oral assessments were quite late and close together, in weeks 9 and 10. It was explained to the students that these were the latest dates that each oral could be attempted but that it was expected the attempt would be earlier. It was found that having the dates later in the session allowed students to delay engaging with the work early, and caused a rush to complete for the first assessment. The second assessment, scheduled just after the first did not allow a sufficient time for any meaningful progress to be made by late students.

In the second running of the unit the first oral assessment was to be completed by week 5, before the mid-session break, and the second by week 8, just after the break. This gap of five weeks allows significant progress to be made between the two assessments.

There is a formal unit survey conducted at the end of each unit. The quantitative results for the self-described level of engagement and usefulness are shown in Table 1. They are ranked on a 5 point Likert scale and improved substantially from the previous pedagogy to the new pedagogy, with improvements of over 10% for each category.

Table 1: End of unit survey results for Unit Engagement and Usefulness

	2017	**2018**	**2019**
	42 responses	18 responses	24 responses
Engaging	4.1 / 5.0 (sd 1.1)	4.6 / 5.0 (sd 0.6)	4.5 / 5.0 (sd 0.7)
Useful	3.9 / 5.0 (sd 1.1)	4.5 / 5.0 (sd 0.6)	4.6 / 5.0 (sd 0.7)

The students also provided qualitative feedback, and these were generally positive with the students influenced by the change in pedagogy. Examples of these comments are:

*"I thoroughly enjoyed the self driven approach as it allowed deeper understanding of the content."*

"Personal project gave a sense of responsibility."

"Able to work outside of class."

"Take home work was good."

"I think there should be more assessment dates, to force the workload to be spread."

The flexibility allowed in the unit did however, have its downsides. The students when questioned about their lack of progress admitted to neglecting their work to concentrate on immediate deadlines for other units.
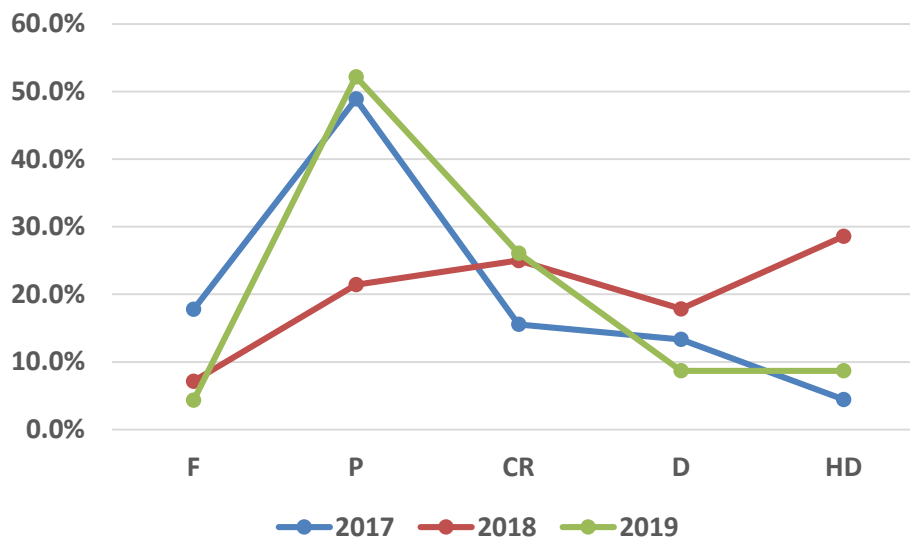
Figure 2: Final unit grades awarded between the different years of offering.

The final grades for the unit, as shown in Figure 2, indicate a substantial increase in the percentage of passing students in the 2018 running and a further increase in the 2019 running of the new project based learning delivery. It is not clear why there was a significant increase in HD results for the initial running of the new pedagogy. Possible reasons include additional resources provided through the *drop in any time* practical time slots, or the emphasis on the project rather than written exam results. Additionally, the self-directed learning approach of PBL may have been one of the reasons that facilitated the increase number of HD grades awarded. (Loyens, Magda and Rikers, 2008) However, this increase was not sustained in the second running of the pedagogy. It is believed that competition with two other simultaneous units which also adopted a project based pedagogy reduced the time dedicated by students to this unit. One student who achieved well below their expected result stated that once he had achieved the passing grade he concentrated on the other project based units instead. There

has been research to suggest that PBL can be overwhelming to students when there are multiple projects with competing learning concepts simultaneously. (Mora, et al., 2015).

Discussion and Future

The use of the project based learning approach allowed the students to focus on the project, and have the time to appreciate the complexities of a full product. The lecture series was still held, but because most of the information required to complete the project was available in the initial specification, and the briefing notes provided examples of concepts needed for the learning outcomes the lectures devolved into a Q and A session followed by a more generalist lecture of the topic, including historical reasonings behind choices that have been made.

It is expected that the lecture material will be changed to a flipped style of delivery, with more recorded material being provided at the start of the unit and the lectures moving even more to a Q and A and historical session. Feedback from the students indicated that the Q and A session was invaluable, and the historical perspective was fascinating. It provided context for *why* various devices or subsystems operated in the way they did.

Assembly language programming was justified because of the intimacy it brings with the hardware. However, some students struggle with adapting to assembly programming from typical higher level languages. There is discussion about whether using the C programming language instead would facilitate understanding the hardware without such a concentration on the language itself.

The initial running allowed the students significant self-actualisation of their time scheduling. Despite repeated warnings that they should work consistently there was a significant group of students that concentrated instead on immediate assessable tasks for other units. The late deadlines exacerbated this problem and required considerable effort on the student's part to recover. This concentrated effort at the same time facilitated the formation of peer based learning groups as the students worked on similar problems. The second running imposed a more spread set of milestone dates which forced regular work. This resulted in more students being ready for their oral defences on time. In a future offering additional formative milestones will be added to ensure students understand the progress that is expected.

We are in discussion with other units to consider combining projects, so that a student in multiple units may undertake a single project that can encompass the learning outcomes from each of the units. There is expected complexity in being able to offer a single project, as not all students study the units in the same order or at the same time.

Retention of the knowledge gained in a unit is impacted by the teaching pedagogy. PBL is believed to increase long term retention. (Strobel and van Barneveld, 2009) We are interested in ensuring that the retention of the knowledge learnt by students using the PBL approach is greater than under traditional pedagogies. The students from the 2018 cohort are now undertaking their Advanced Computer Engineering Unit. There is no hard data currently available, but colloquially the students appear to have a better retention of topics that were covered in the ELEC342 unit.

Conclusion

The ability of the students to work in ad-hoc situation produced a remarkable increase in retention the first year it was introduced. The students excelled in their results, producing much better work than in previous years. This can be seen in the sharp rise in HD results to 28% of students, as most students were engaged and able to complete the project. They were also more engaged with each other, partially due to necessity, with peer groups spontaneously developing to work on the project outside of scheduled times. The comments, both formal and

informal from the students indicated the greater sense of control gave them a greater sense of responsibility and agency for their learning.

The significance of the portability of the practical hardware, coupled with the single project based pedagogy is apparent in the increased summative performance and the qualitative feedback.

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