SIGNALS AND SYSTEMS:
CASTING IT AS AN ACTION-ADVENTURE RATHER THAN A HORROR GENRE

Roberto Togneri, Sally Male

The University of Western Australia
{roberto.togneri, sally.male}@uwa.edu.au

ABSTRACT

Simple but effective strategies for an undergraduate introductory course in signals and systems are described in this paper. These include peer facilitated tutorials, optional class tests, in-class only lab assessment and use of interactive animations. Peer facilitated tutorials were designed to support students to help other students. The optional class tests removed the stress and anxiety students face. With in-class only lab assessment the time students spent writing lab reports was replaced with time devoted to preparing and doing the lab together as a group. The use of interactive animations enabled students to visualise key concepts. Survey results and feedback confirm the positive response and improved student satisfaction.

Index Terms— signals and systems, peer-assisted learning, engineering education.

1. INTRODUCTION

All undergraduate electrical engineering courses will have at least one unit which introduces students to the basic tenets of both systems analysis (via the Laplace and z transforms) and signal processing (the Fourier family of transforms). Furthermore, all undergraduate courses will have key units which students find challenging, and the unit on signals and systems is one of these. The main challenges arises from the mathematical underpinnings of the transforms (especially the Fourier transform) and the threshold concept students have to hurdle over of mapping from the mathematical abstraction (where negative frequencies, complex exponentials and non-causal systems reside) to the physical reality (where systems have to be causal, frequencies are positive and signals are real) [1].

Although at the undergraduate level students only need to know enough to work as practicing engineers, the responsibility of a University education is to empower students to understand the tools they are using and be able to design and innovate. They can only do that by understanding the unifying mathematical fundamentals both in the context of exercises and quizzes [2] (to evaluate students' ability to articulate important concepts and carry out basic calculations and derivations) and laboratory or assignment work [3,4] (to evaluate students' analytical and design skills in the context of real systems and signals to verify and apply the theory they learned). In recent years student cohorts have changed. To enhance learning, teaching methods have been designed to support active engagement by students. Examples of strategies to improve interaction and motivation include flipped classes [5], problem-based learning [6] and gamification [7]. Traditional lectures have been replaced by online recordings or personalised video lecture delivery. These make use of technology to visualise and animate lecture concepts and present worked exercises [8]. Together these can create interactive group interactions for deeper problem solving [9,10]; a sort of semi-flipped classroom.

Given the potential arsenal of learning tools and pedagogies at the disposal of educators, the problem becomes that of selecting the approach. Most signals and systems unit run for only one semester (typically 12 weeks) and need to cover a range of learning outcomes. How does one design the whole of the unit? The implementation of any one approach requires an investment in the development of resources, ensuring students are available and engaged, and appropriate assessment tasks have been set. And it is critical to ensure the learning outcomes have been clearly and fully expressed (what learning are we wanting to take place?) to decide the approach to use. Only where learning outcomes are matched by learning activities and assessment will verifiable learning take place [11].

This paper describes some simple but effective methods used to improve the student learning and engagement of the ENSC3015 signals and systems unit offered to electrical engineering undergraduate students at The University of Western Australia. Prior to the adoption of these methods the signals and systems unit had one of the lowest student satisfaction ratings, and there was an immediate turnaround in 2016 when these strategies were introduced. The key drivers were to balance student workload, ensure fair assessment and provide an inclusive and welcoming learning environment both in class and online to facilitate student learning. The simple strategies that we have deployed include:

- student peer facilitators in practice classes who have first-hand knowledge of student concerns from their own experiences,
- optional class tests to allay student anxieties and build confidence leading to the final exam,
- demonstrations and animations during lectures in mixed mode fashion, and

- MATLAB [12] based labs where pre-lab and in-class assessment provide more effective learning and reduce the student (and teaching staff) workload.

In Section 2 we present our strategies. The implementation is detailed in Section 3, followed by our evaluation based on surveys and feedback in Section 4. A discussion of our findings is given in Section 5 and conclusions in Section 6.

2. METHODOLOGY

The ENSC3015 Signals and Systems unit is offered in the undergraduate engineering science as a core unit for the EE major. The broad learning outcomes emphasise the analysis, manipulation, calculation and conceptual understanding of systems and signals across all transform methods.

2.1 Student Peer Facilitators

Students learn best when they do so actively and collaboratively [9]. However students also learn when they invest their own time to access the online resources: recordings, video lectures, tutorial exercises and worked solutions, etc. Nevertheless even the best students find they need to ask an expert for help to dispel misconceptions or clear up something they failed to understand. The standard solution is to run scheduled consultation times for individual student or group tutoring from the lecturer. However very few students avail themselves of this service. One reason is that the lecturer, with many years of teaching the unit, may not appreciate or fully understand issues that students face. Obvious or even tacit knowledge to the lecturer, may be a difficult concept for students. The best tutors for students are the students themselves, the expert study buddy who knows exactly the difficulty the student is facing from their own experience.

We recognised the principle of learning from peers by replacing the standard small-class tutorials with full class practice sessions where the tutor working through examples on the tablet was assisted by three student peer facilitators who had completed the unit in the previous year. To reinforce both self-learning and group learning, students could choose to work by themselves, but were encouraged to work collaboratively in a group or seek the assistance of one of the student facilitators. The student facilitators roamed around the class and actively approached students.

2.2 Formative Class Test Assessment

Most units in the engineering sciences follow the standard assessment format of individual final examination, group laboratories and group assignments. For ENSC3015 the individual final examination was supplemented by class tests held throughout the semester. Being a mainly conceptual, mathematical introductory unit in signals and systems the main form of assessment was by written examination (up to 70% of unit assessment). The University's student body has supported having class tests to avoid all the assessment being left to the final exam. By running four class tests during semester of 5% each, the final examination then was only 50% of final unit assessment. However the reality is that students are under many pressures during semester and there is an element of stress and anxiety in sitting for a class test held when another unit assessment activity may also be due in that week.

Since class tests are really formative assessment (where the final examination is summative) the solution was to simply make the class test conditionally optional. That is, students were still required to sit the class test, but if they did better in the final exam than the class test, the class test mark was replaced by the final exam mark. A win-win solution, students sat the class test in the knowledge that if they did badly and they did better in the final exam the class test mark would be ignored. And they also sat the class test so that they could gauge how well they had learned and used that to improve their learning and be prepared for the final examination.

2.3 Summative In-class Lab Assessment

For engineering science students the concept and mathematics heavy signals and systems unit needs to be balanced with practical and hands-on laboratory or project based activities. At the undergraduate level, laboratory sessions which enable students to use either software or hardware tools and platforms to analyse the concepts and verify the theory by measurement are critical. All signals and systems units have such a component, and our unit was no different. We developed laboratories, using Simulink and MATLAB, that cover analysis and verification of both systems and signals concepts such as: zero-state response, transfer function, frequency response, Fourier series analysis, and aliasing.

However from 2018 we replaced the group lab reports with wholly in-class assessment. This approach was based on enhancing the active and collaborative nature of the activity for students, and also enhancing the diversity of the assessments. Students were required to individually complete pre-lab assignment exercises prior to the lab session and then work in groups to complete the assigned tasks. The in-class assessment involved the lab demonstrators interviewing students for each task and providing a group mark on how complete the answer is, be it an oral explanation, a written note or a demonstration by running MATLAB. This eliminated the rote and artificiality of lab report writing after the lab was completed (which is really a record reporting exercise) and allowed the demonstrator to ensure students could explain what they had done (rather than hide behind a written report which may have been wholly prepared by another member of the group). To ensure timely completion there were two lab demonstrators per session of 21 students.

2.4 GUI Demos

Signals and systems is very concept heavy, especially in the ability to visualise signal operations, in particular convolution, and understand the effects of aliasing and the significance of negative frequencies in Fourier analysis. These are all concepts which can be explained both from the mathematics and also via animation and visualisation. It is surprising that good animations of these concepts are hard to find. The best example to date are the Education MATLAB GUIs[1] from Georgia Institute of Technology which provide a toolbox of engaging MATLAB interactive animations; especially useful demos are: Fourier Series, Continuous LTI, Discrete LTI, Continuous-Time Sampling, Discrete Convolution and Continuous Convolution. Also highly recommended is the Magnitude Response Learning Tool[2] [7]. Links to these demos were provided to students on the unit learning management system.

3. IMPLEMENTATION

The format of the ENSC3015 Signals and Systems unit is detailed in Table 1. The delivery adopts the basic format consisting of lectures, practice classes (tutorials) and laboratory classes where students implement, analyse and explore the basic signals and systems concepts using MATLAB and Simulink.

Activity	Comment
2 hour lecture / week	recorded lectures emphasising key concepts demonstrated on tablet PC and **GUI demos**
2 hour practice class / week	tutorial practice class with **student peer facilitators**, followed by **formative class test assessment** (worked exercises)
3 x 3 hour laboratories	**pre-lab and in-class assessment** of three labs (Introduction MATLAB/Simulink, Using Simulink for CLTI and DLTI, Using MATLAB for Fourier Analysis)
2 hour final exam	summative assessment (worked exercise)

Table 1. ENSC3015 Assessment and Activities

The unit is delivered over 12 weeks of lectures and practice classes. Assessment consists of 4 formative class tests, 3 labs (each lab runs over 2 weeks, students attend one session) and the final exam.

4. EVALUATION

4.1 Online Student Survey (2016)

In 2016 (the first year when we first introduced these innovative strategies) an anonymous online survey administered through the learning management system was conducted. 125 students took the unit and 40 students (32%) evaluated the unit. The results for selected questions are presented in Table 2.

From Table 2 it is evident that students were very positive regarding the strategies we adopted, with 79% preferring the student peer facilitators (Q1), and 82% the formative (optional) class test assessment (Q2).

Question	Response
Q1: Did you find the peer assisted tutorials more accessible to you than the traditional tutorial (with only the one tutor/lecturer)?	79% (Yes); 21% (No)
Q2: Do you prefer the optionally assessed class tests (only included if better than the exam) to having class tests as compulsory assessment?	82% (Yes) 18% (No)
Q3: If you attended the test study preparation tutorial immediately before the test did you find this helpful	59% (Yes) 41% (No)
Q4: Regarding the unit resources please indicate which you made the most use of and would like to see improved upon (select all that apply):	LEC (77%) GUI (5%) VID (15%) TUT (44%)

Table 2. 2016 Student Survey Responses (N = 40), LEC: Lecture Notes, GUI: Self-study GUI Demos, VID: Online Video Lectures, TUT: Tutorial Animated Worked Examples on Tablet

Class tests were conducted immediately after a practice class preparation session (also attended by the student facilitators). Around 60% of the students found this helpful in preparing for the class test (Q3). The final question (Q4) asks students to rate which resources they used. Surprisingly the lecture notes were the most important resource (77%) followed by working through examples on the tablet (projected to a screen and also recorded) (44%). Disappointedly the GUI demos provided to students were rarely used. Selected students' comments included:

- "I am a particular fan of how the class tests are structured (i.e. if you do better in the exam that will be the mark which you receive) as it gives me a better opportunity to consolidate my knowledge as well as get regular exposure to exam like questions."
- "Other than that, having the peers, "panic" tutorials (cramming before the test) and the optional tests was great! I hope more units introduce them." "The content is certainly difficult, however, with the tutorials being done in class with demonstrations really helped with understanding the material during the lectures, and not having to rewatch and struggle to understand the unit"
- "Maybe provide more of a reason to use the demos, or a way to include them throughout the course so as to help with understanding the theoretical sections."

4.2 Lab Demonstrator Interview (2018)

Prior to 2018 the labs required a lab report to be handed in by the lab group after the lab session. In 2018 this was replaced by wholly in-class assessment to be completed during the lab session. The same lab demonstrator in charge in 2017 (when we had lab reports) and 2018 (lab reports replaced by in-

[1] http://dspfirst.gatech.edu/matlab/SPFirstMATLAB.html

[2] http://www2.spsc.tugraz.at/people/bgeiger/MRLT/

class) was interviewed and the following comments were expressed:

- Strategies had to be developed to assess the pre-lab of each student during the lab session. A quick check is first carried out, and students who have not completed the pre-lab are noted.
- It was discovered that improved group dynamics were the result of the strategy to randomly pick a member from each group to explain the task; groups took the time to discuss and prepare each team member before flagging the lab demonstrator.

4.3 Students' Unit Reflection Feedback (2013 – 2017)

Students are required to complete an anonymous institutionally administered student satisfaction survey for all units across the university. There are 6 general questions asked, for the engineering sciences the two key questions are: "The learning resources were adequate for my study in the unit" (LRAS) and "Overall, this unit was a good educational experience" (OGEE). Results over a 5-year span are provided in Table 3. It should be noted that the innovative strategies were only introduced from 2106. Also in 2015 there were problems with the delivery of the unit and the results for 2015 are not included in Table 3.

Year	**Response** *N* **(%)**	**LRAS** μ (σ)	**OGEE** μ (σ)
2013	28 (36%)	2.68 (0.89)	2.82 (0.66)
2014	44 (44%)	2.84 (0.95)	2.84 (0.88)
2016	53 (42%)	3.53 (0.77)	3.47 (0.74)
2017	42 (33%)	3.29 (0.85)	3.29 (0.91)

Table 3. Students' Unit Reflection Feedback Response from 2013 to 2017 (1: *Strongly Disagree* to 4: *Strongly Agree*). LRAS: Learning Resources were Adequate for Study in the unit; OGEE: Overall, Unit was a Good Educational Experience.

From the surveys it is quite evident that there was an increase in student satisfaction and improvement in the student experience and engagement. The overall student experience increased from 2.68 and 2.84 in 2013 and 2014 to 3.53 and 3.29 in 2016 and 2017, an improvement of between 0.45 and 0.85.

5. DISCUSSION

From the student evaluations, interviews and student feedback the following are additional observations that we can make.

For the lab reports in 2017 there were a few but significant instances of dysfunctional groups where one member did not contribute, other members complained, and this soured the student experience. This motivated the introduction of in-class assessment where the demonstrators confirmed that the learning experience and assessment was improved by being able to directly interview students and get them to explain and show what they have done. As a surprise bonus this improved the team dynamics as groups took more responsibility for their learning and that of their team when preparing to be interviewed.

The use of the GUI demos was found to be disappointing. One explanation is that the demos were not a complete interactive experience which would enhance the learning of key concepts. A convolution demo animation was developed which would allow custom waveforms to be used but was discontinued due to the poor interface. The Educational MATLAB GUI *dconvdemo* does allow this (for discrete-time signals) but the more important *cconvdemo* (for continuous-time signals) does not, students need to see how convolution works with a wider range of waveforms. Another reason is that students need to be motivated to use the demos, either as part of a lab or assignment assessment or, as we are now doing, running the demos during lectures (which are also recorded).

The formative (optional) class tests were found to be very popular as they helped to both reduce stress and anxiety and prepare students for the final exam. However some students do take advantage of this and do not attend the class tests. We have modified the class test in 2018 and now require a fair attempt (at least 20%) and students are contacted otherwise, as potentially at risk. This has had the added benefit of providing a mechanism to follow up on poor performing or non attending students to identify learning difficulties or time management issues.

6. CONCLUSIONS

In a standard signals and systems consisting of lectures, tutorials and MATLAB-based laboratories simple but effective strategies were implemented to improve the student engagement, learning and overall experience. With a combination of student peer facilitated tutorials, optional class tests, and in-class assessment of labs, the student satisfaction improved from 56.7% to 67.6%. The student and demonstrator feedback has been positive and we discovered additional benefits that were not anticipated (e.g. improved lab group dynamics when adopting in-class only assessment, mechanism to target students at risk when they do poorly in class tests).

We will continue to improve the student learning in the unit by identify and addressing key issues students face as they come to light. Insufficient mastery of pre-requisite knowledge (esp. complex number algebra), more support for basic drill exercises and practice, and better motivation through presentation of application examples are some of the issues we will be investigating.

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