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Improving the Learning Experience for the First Year Engineering Students using Technology Enabled Activity Led Learning

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***Abstract**: Activity Led Learning (ALL) strategies were adopted to improve the students' engagement, pass rate and most importantly learning experience for a first year Electrical and Electronic Engineering module which caters for a large mixed student cohort. To implement ALL, a new method of delivery, enabled using three key learning technologies, was adopted. The number of formal lectures was reduced and replaced with interactive tutorials as well as additional computer based laboratory sessions.*

Tutorial sessions were implemented using Interwrite® Personal Response System (PRS), a commercial Audience Response System (ARS). The Multisim® simulation software was introduced in the laboratory sessions to help students visualise the behaviour of electrical and electronic components and apply circuit laws. The adopted assessment strategy combined problem based laboratory together with on-line assessment, created using RESPONDUS®, and an in-class test.

Students' satisfaction survey, coursework submission rate, focus group as well as informal feedback were used to evaluate the relative benefits of the introduced technology enabled ALL strategies . Laboratory sessions improved students' engagement resulting in increased coursework submission rate. ARS promoted group work and interaction, resulting in greater students' learning experience. The variety and division of the assessment into small components promoted regular work and was well received by the students.

Overall, the adopted strategy had a positive impact on students' learning experience, increased students participation in terms of coursework submission which resulted in improved students' achievement. The pass rate of the module increased from 70% to 87% and the student satisfaction improved from adequate to satisfactory.

Introduction

The challenge of education is to provide the best possible learning experience with the highest outcome. Undergraduate education should encourage contact between students and faculty, develop reciprocity and cooperation among students, encourage active learning, give prompt feedback, emphasis time on task, communicate high expectations, and respect diverse talents and ways of learning (Chickering and Gamson, 1987). The students' teaching environment such as facility, class room size as well as the number of student in the classroom has also a significant effect on both performance and instructor effectiveness rating by students (Bedard and Kuhn, 2008).

The first year Electrical and Electronic Engineering module considered in this paper is a core module which attracts a large student population. The total number of students in the module is normally between 120 and 240 and was 140 in the 2008-09 academic year considered in this paper. It is mandatory for all programmes in the area of Systems Engineering including Aerospace Technology, Aerospace Systems Engineering, Electrical Systems Engineering, Electronic Engineering, Communication Engineering, Computer Networking and Communication Technology and Avionics

Technology, as well as the Music Technology programme from the Faculty of Arts and Media. The student population on the module is referred to as ‘large mixed student cohort’ due to its wide range of technical ability as well as academic and ethnical background. Effective teaching requires the module team to address such diversity.

Cantillon (2003) argues that whilst lecturing to a large group is an efficient knowledge transfer exercise it is not an effective way to teach skills. The engineering module considered in this paper had traditionally been delivered using a content driven approach where concepts were explained with worked examples, but without the use of laboratory sessions, leaving little time for students to consolidate their knowledge and apply it (Bligh, 2000).

Student feedback taken the previous years reported difficulty in relating the taught material to the ‘real world’. The student engagement was low with an 82% coursework submission rate and a pass rate around 70%. To improve the students’ learning experience, engagement and participation, activities that encourage active learning were introduced within an Activity Led Learning (ALL) framework. ALL focuses the learning experience on activities facilitated by tutor(s) (Wilson-Midhurst *et al*, 2008). In this work the activities considered are laboratories and tutorials using audience response system (ARS) (Kay and LeSage, 2009). Both laboratory sessions and ARS offers the means to implement contingent teaching which is defined as “*making teaching dependent upon the actions of the students, rather than being a fixed sequence predetermined by the teacher …, this requires not just the students to interact, but the teacher to be interactive too… This is important because it makes the teaching relevant to actual needs*” (Draper & Brown 2004, p91)”. Exploiting ARS as a means to achieving contingent teaching for large class sizes, where the needs of a few can otherwise remain unnoticed, is particularly important.

Computer laboratories have been shown to be beneficial to the learning process by, for example, providing transferable skills in problem solving, computing as well as communicating technical concepts and most importantly, according to the authors, bridging the gap between theory and practice (Newby and Marcoulides, 2008, Boud et al 1986). The large class size and the limited staff resources meant that it was not practical to instigate hands-on laboratory sessions involving electrical hardware components. However, computer laboratory sessions exploiting electronic circuit simulation software was believed to provide an appropriate substitute to enable the students to apply theory to simulated experiments and learn how to use software to design electrical circuits. The introduction of laboratory sessions was aimed to address the diverse talents and ways of learning, e.g. learning by doing (Chickering and Gamson, 1987).

Audience Response System (ARS)

ARS is one of 26 acronyms to describe a system comprising a set of small computerised devices, often referred to as ‘Clickers’, to enable students to interactively answer questions displayed using multimedia projection facilities (Kay and LeSage, 2009). ARS software can provide immediate feedback by displaying the correct solutions, as well as the responses from the students.

ARS increases students’ interests, discussion, interactivity and engagement (Caldwell, 2007). ARS can also raise standards and reduce the retention problem Nicol and Boyle (2003). ARS can help instructors by actively engaging students during the entire class period, gauging the students’ level of understanding of material being presented and providing prompt feedback to student questions (Martyn, 2007). ARS used intermittently during a lecture can overcome the reduction in attention span that typically occurs after 20 min (d’Inverno et al, 2003). It is possible to grade students’ answers using ARS and thus promote attendance to the classroom. Such an approach has, however, been reported to have the potential to undermine the process of creating a positive learning environment (Kay and LeSage, 2009). Maintaining anonymity can help students make the effort to formulate and provide an answer without the risk of being ridiculed by their peers. This commitment to an answer is believed to be particularly important and formative (Abrahamson, 2006). ARS can promote the active learning process and give prompt feedback (Martyn, 2007). ARS can help develop cooperation among students when the students are working in groups and emphasize the time on task as each question is given a limited time. Class discussions and explanation from their peers has been shown to help students’ understanding (Nicol and Boyle, 2003). However, the use of peer-to-peer discussion is time consuming and could lead some students to become distracted (Drapper and Brown, 2004). One of the main advantages of ARS is to enable the module team to adopt a dynamic and interactive delivery guided by the students’ real time feedback (Kennedy and Kutts, 2005). A drawback of such an approach is that answering queries or adjusting the delivery will take significantly more time than presenting the material in a lecture format. There is therefore a balanced to be achieved between covering the curriculum and promoting better understanding. Readers interested in a comprehensive review of ARS should refer to (Kay and LeSage, 2009).

The remainder of this paper describes the new teaching and learning strategies used and the evaluation of the changes, in terms of formal (as well as informal) student feedback, combined with students' performance.

ALL Strategies

The new method of delivery involves three types of sessions: formal lecture, tutorial with ARS and laboratory sessions, see Table 1. The same pattern was repeated for each component of the module over the whole academic year. Due to the large number of students and restriction in lecture theatre and laboratory space available, the cohort was divided into two groups of about 70 students. Whilst this duplicated each session from the module team perspective, it facilitated the deployment of ALL.

Table 1: New Method of Delivery

Session	Teaching Methods
First session	Formal Lecture to present key definitions, concepts and applications, together with small worked examples (2 Hours)
Second Session	Tutorials to develop analytical and numeracy skills associated with circuit theory and electronic circuit analysis (1 Hour without ARS and the second Hour with ARS)
Third Session	Laboratory sessions (2 Hours) using Multisim software, based on the topics that students learned in the previous two sessions

Tutorial sessions using ARS

Interwrite® Personal Response System (PRS), a type of ARS, provides the means to generate different question types such as multiple choice, numerical input, and TRUE or FALSE. Multiple choice were found to be the most appropriate to assess electrical circuit theory and electronic. Numerical questions were used to encourage students to apply and develop their mathematical skills in solving electrical circuit questions.

To promote focused subject related discussions among students it was decided to divide the students into small groups of three and allocate one clicker per group. When a concept question was asked, a time was allocated to enable the students to determine or calculate the answer, discuss it with other members in the group before agreeing on a common submission. The time allocated for each question could be increased or reduced in real time. Once all the groups had submitted their answers or when the allocated time elapsed, the software displayed a histogram highlighting the range of answers provided by the students.

In addition to the expected groups' discussion, ARS encouraged animated 'arguing' and 'debating' to reach a consensus solution. This would not have been seen had one clicker been allocated per person. On occasion the module team did hear '*I told you it was not the right answer*' or '*it's your fault*' but always in a lively 'game' atmosphere. It was also interesting to note the communication between groups, which the module team encouraged, 'just to check the answers'. Such behaviour helps the students by learning from their mistakes, as well as their peers, thereby developing reciprocity and cooperation whilst encouraging diverse ways of learning (Chickering and Gamson, 1987).

Figure 1 illustrates the use of PRS to address a typical misconception made by students who erroneously consider the top right corner of the electric circuit as a node, when the circuit is drawn using solely vertical and horizontal branches. Multisim® is used to represent the components and draw the circuits to familiarise students with its use before being exposed to it in the laboratory. The histogram displays the correct answer and indicates that 13 groups answered correctly and 3 groups incorrectly.

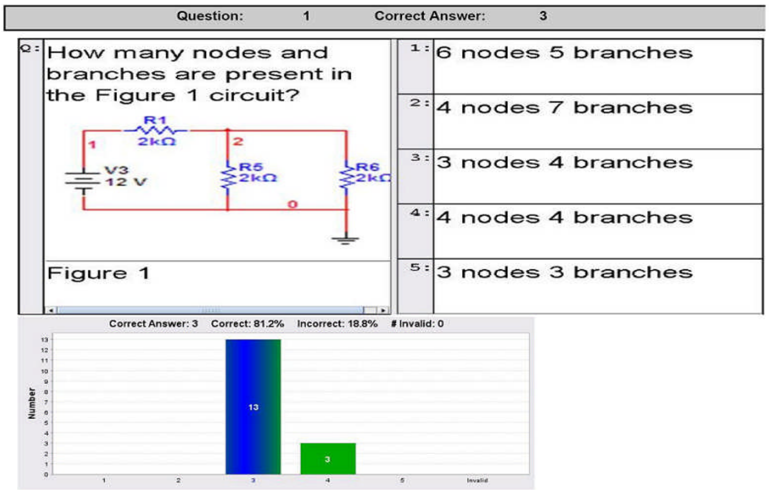


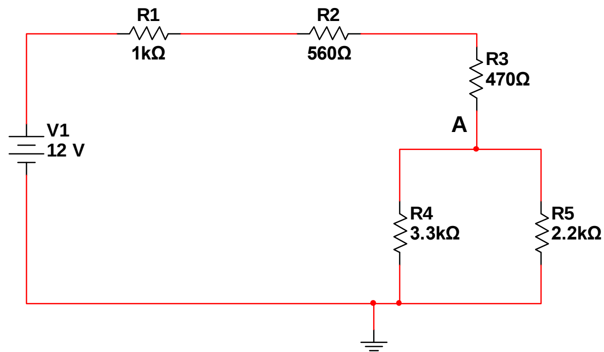
Figure 1: Example histogram from tutorial session using PRS

Laboratory Sessions

Laboratory sessions took place every three weeks. These laboratory sessions were based on simulating Electrical and Electronic circuits using the National Instruments Multisim software. Multisim was used to simulate and analyse circuits, or investigate the behaviour of electrical and electronic components. The laboratory exercises were designed to help students relate the theoretical and analytical material that had been covered in the lecture and tutorials to ‘real life’. The laboratory session lasted two hours which enabled students to carry out both simulation work and theoretical calculation. They offered a good opportunity for students to identify and locate within their lecture notes the information they required. An example laboratory question is given in

Figure 2, where the students are required to analyse the behaviour of electrical circuit during open and short-circuit fault conditions. The use of simulated measurement devices such as voltmeter, ammeter and oscilloscope has also helped address issues linked with the connection of instruments in parallel or series.

For the circuit shown in Figure below:



a. Simulate the circuit using Multisim and measure the voltage across the resistor R3. Verify your answer by calculation.

b. Measure the voltage across the resistor R3 for the following fault conditions:

   i. Resistor R4 is open circuited.

   ii. The point A is shorted to the ground.

Calculate the voltage across the resistor R3 for the fault conditions given in part (b) and verify with the measured values.

Figure 2: An Example Laboratory Activity

Assessment Strategy

Most of the laboratory sessions were designed to be part of the coursework assessment. Such assessment helped students develop transferable skills such as computing and numeracy, as well as subject specific skills. The ability to do most of the coursework during the laboratory sessions minimised the risk for overloading the students with assessments. In the first term, the work carried out from laboratory studies was written up as a report, which gave explanations for their answers, including a number of numerical calculations supported by Multisim simulation studies. In the second term, some of the assessments were associated with online tests (formative or marked). The introduction of an online assessment was to provide feedback to students before the next laboratory session. Hence making students aware of the area where they need to improve. O'Reilly et al (2005) reported that providing sufficient and timely feedback, together with a facilitative degree of structure, are two key qualities of online assessment method. The on-line assessment was created with RESPONDUS® (2010). RESPONDUS® is a software tool for creating assessment questions offline using a Windows interface and publishing them directly to online learning environments such as Blackboard or Moodle. Random sets of questions can be created to provide each student with a unique coursework.

Students were allowed to do their simulation work and calculations in the laboratory session and then were asked to provide their results online using a web based interface, see Figure 3. Once they had submitted their answers, the software provided immediate feedback to students, indicating the results and the correct answers for each question.

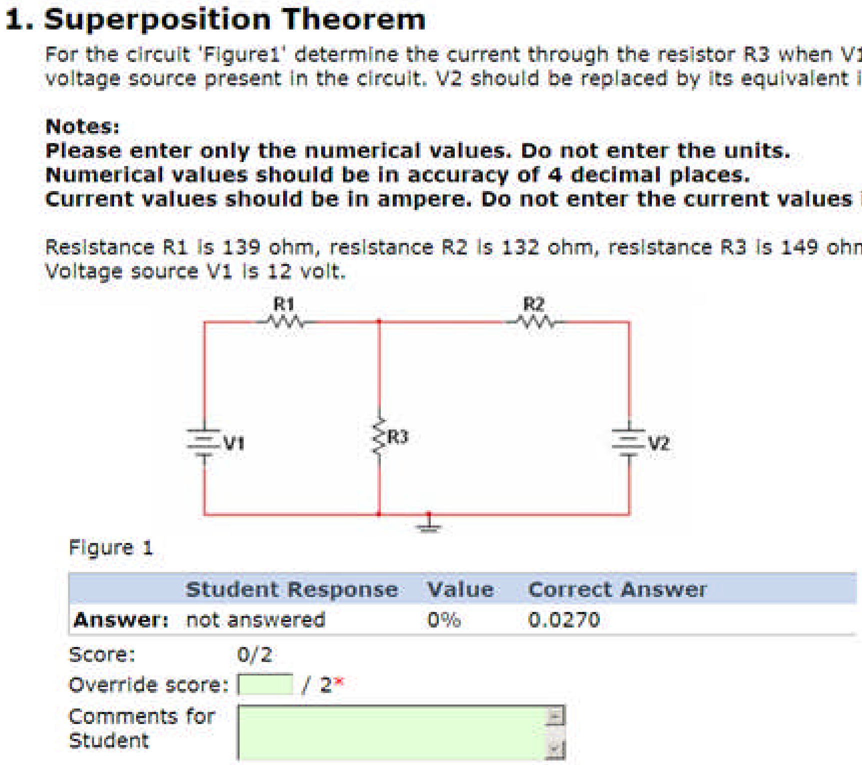


Figure 3: Online Assessment using RESPONDUS®

Some students who do well in the coursework can still fail the examination. While examinations generate high degrees of anxiety (Atherton 2007), it is our perception that failure at the exam highlights the lack of appropriately directed and timely work done prior the examination. An in-class test was introduced to help students prepare for the final examination. One outcome of the test was that it helped the student focus their efforts for the examination and provided an opportunity for the course team to address the most relevant issues during these revision sessions. The assessment components and their contribution to the module mark are given Table 2.

Table 2: Assessment Components

Components	Percentage of Module Mark
Laboratory based coursework	35%
In-Class Test	15%
Examination	50%

Feedback Methods and Analysis

Feedback Methods

To evaluate the relative benefits of the new teaching strategy which combined lecture, ARS and laboratory sessions, together with the use of a wide range of assessment strategies, the following four methods were used.

Informal feedback from students was gathered throughout the year to identify the issues and adapt the module delivery to the students' perceived needs.

Students' coursework submissions were monitored and exploited to analyse the students' participation and engagement.

Open-ended feedback questions were given to the students at the end of the first term, to identify the helpfulness of newly introduced laboratory sessions and ARS.

An end of the year, the Student Satisfaction Survey (for the module) adopted from (MacDonald *et al*, 2007) was re-designed to evaluate the students' satisfaction with respect to the usage of online facilities for teaching and assessment, the teaching and learning experience from laboratory sessions, ARS and online assessment. The feedback questions were framed to rate students' satisfaction with the following aspects relating to their experience in the module:

- Module organisation and communication
- Workload and assessment
- Usage of online facilities for teaching and assessment
- Teaching methods using laboratory sessions and ARS sessions
- Learning experience from laboratory work, ARS sessions and online assessment
- Overall module Satisfaction

In addition, students were asked to evaluate the importance they attach to each of these aspects.

A focus group at the end of the year aimed to identify the benefits and issues associated with ALL.

Students' pass rate and average score were used to evaluate the improvement in students' achievement.

Feedback Analysis

93 students handed in the open-ended feedback questionnaire. 91% mentioned that laboratory sessions helped their understanding of the subject, thereby corroborating the increased engagement observed by the course team, see Figure 4. 72% mentioned that ARS had helped their learning process. Table Three indicates the students' view on the positive aspects of the ARS sessions, and this confirms that ARS encourages active participation in the classroom, makes a class more interesting (Jane 2007, Martyn 2007) and develops cooperation among students, encourages active learning and gives prompt feedback to students (Chickering and Gamson, 1987).

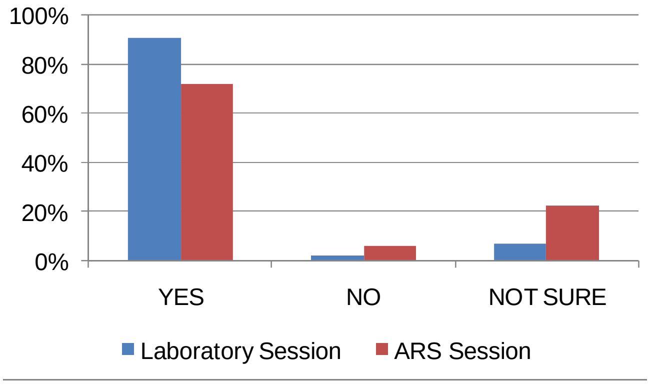


Figure 4: Students Response on the Helpfulness of Laboratory and ARS Sessions

Table 3: Students' Feedback on ARS Session

- It encourages the team work
- Students know what they want to revise on
- If the answer is wrong tutor explains the correct answer of if the answer is correct tutor affirms that the answer is correct
- It keeps the class interesting
- It encourages the group discussion

The main concern raised by students was the short amount of time allocated for them to determine an answer. Note that on many occasions the initial time was increased whilst the exercise was taking place. As a result, the number of questions within an ARS session was reduced whilst the time allocated to answer each question increased for the second term. This provided more time for students to discuss and answer the questions. The module team and independent observers' noted that the ARS session improved students' participation, making the sessions more active. The main drawback of ARS is the significant time required both for preparation and delivery (Kay and LeSage, 2009).

69 students handed in their Student Satisfaction Survey, which gave a feedback response of 46%. Students were asked to rate their satisfaction on scales from 1 to 5, in ascending order, from "very dissatisfied" to "very satisfied". Similarly students were asked to rate the importance of each aspect on scales from 1 to 5, in ascending order, from "not at all important" to "very important". The results are assessed against the grid values and action implications taken from MacDonald (2007), see Table 4.

Table 4: Grid Values and Action Implication

	Very Unsatisfactory (1 to 2.25)	**Unsatisfactory (2.25 to 2.75)**	**Adequate (2.75 to 3.25)**	**Satisfactory (3.25 to 3.75)**	**Very Satisfactory (above 3.75)**
Very Important (above 4)	Urgent need for immediate action	Action in these areas has high priority	This area to be targeted for future improvement	Ensure no slippage, improve where possible	Maintain excellent standards
Important (from 3 to 4)	Action to substantially improve this area	Target this area for improvement	Ensure no slippage	Maintain standards	Avoid overkill
Not so important (below 3)	Improve where resources permit	Ensure no further slippage	Restrict attention	Maintain standards where possible	No need for action here

The average student satisfaction score and the importance they attach for each aspect was evaluated, see Table 5. Most of the aspects scored "satisfactory" and "very satisfactory" except the online assessment that scored "adequate". The introduction of the online assessment method initially raised a number of issues, such as software crashes, material availability and the formatting of answers e.g.

number of decimal points and units for electrical quantities. The first online test highlighted issues that the students had with identifying the correct number of decimal places and how to use SI units. The students did, however, find it confusing and unsettling, as numerical answers provided without the appropriate formatting and units were considered erroneous. These issues were subsequently addressed by introducing strict and consistent formatting, see Figure 3. The software and hardware problems were addressed by allowing several attempts. Whilst the issues raised had been addressed in the subsequent online tests, they did have a persistent negative impact on the students' satisfaction.

Table 5: Student Satisfaction Survey Result

	Very Unsatisfactory (1 to 2.25)	**Unsatisfactory (2.25 to 2.75)**	**Adequate (2.75 to 3.25)**	**Satisfactory (3.25 to 3.75)**	**Very Satisfactory (above 3.75)**
Very Important (above 4)				Learning Experience Usefulness of laboratory sessions	Workload and Assessment
Important (from 3 to 4)			Usefulness of Online assessment	Usefulness of ARS sessions	
Not so important (below 3)					

The students considered the following aspects as "very important":

- Workload and assessment
- Learning experience
- Usefulness of laboratory sessions

It was observed that students were "very satisfied" with the amount of assessment and the balance of workload between the coursework for the module. This is a very positive feedback and slightly surprising for the module team, as the number of assessment had been significantly increased compared to the previous year. This justified the approach adopted where large coursework was broken down into smaller components and associated with a laboratory session. The ability to do most of the coursework during the laboratory session minimised the risk of overloading the students with assessment and promoted regular work. The learning experience and usefulness of laboratory session were rated as "satisfied". These aspects can be further improved by overcoming issues with online assessments that had been associated with the laboratory sessions in the second term. It is worth noting that 90% of responded students mentioned that they would like to see more laboratory-based learning. Overall the finding confirms that laboratory sessions encouraged active learning and promoted contact between student and staff (Chickering and Gamson 1987).

Students rated the usefulness and importance of the ARS sessions as "satisfied" and "important" respectively. This indicates that they do not feel the presence of a strong correlation between ARS sessions and their resulting grade and performance, recalling that ARS sessions were not assessed (Kay and LeSage, 2009).

In the Student Satisfaction Survey, students were also asked to rate the overall module satisfaction with scores from 1 to 5, in ascending order, from "very dissatisfied" to "very satisfied". The average score for overall module satisfaction was 3.53 and can be classified as "satisfied" which is an increase of 35% compared to the previous year module survey.

Students' engagement was also measured by their coursework submission, see Table 6. The increase in students' participation in coursework submission resulted in an increased pass rate and mark for the coursework component and the final examination. The increase in examination pass rate and average mark can be due to different elements, such as increase in engagement and participation in the coursework and increase in engagement in tutorial sessions with ARS. It may also be due to a relatively good cohort of students in the particular year. Several variables were introduced at the same time, making it difficult to identify the cause of the improvement reported in this work. It is however the belief of the authors that if methods have been demonstrated in the literature to be beneficial, it is not ethical to prevent some of the students to access them by creating carefully controlled groups. The aim of this work was indeed to improve the students' experience and performance based on existing educational research.

Table 6: Students' Achievement Comparison Results

	Academic Year 2007-08	Academic Year 2008-09
Number of students submitted all parts of coursework	82%	94%
Number of students failed in the coursework	31	7
Average coursework mark	50.5%	64.3%
Average examination mark	50.5%	54.7%
Overall pass rate	70%	87%

Throughout the year informal discussions with students were used as feedback to identify the issues in the module delivery. Through this informal feedback, the module team was made aware of students' concerns regarding the online assessment method. This was partially due to the relatively low score achieved during the first online test. This was despite having had two unmarked trials to enable the students to become familiar with the online assessment. Following the changes made to the online tests, the students agreed that the module team had addressed their concerns. The mark for the second test was significantly higher than the first. This was partly due to the increased awareness of the importance of formatting and units, as well as the increased number of submissions allowed.

The focus group highlighted that the student felt that the in-class test towards the end of the module helped them to prepare well for the final examination. From the focus group, the module team learned that students felt laboratory sessions and ARS sessions were interesting.

Conclusions

The proposed method that combined formal lectures, tutorials, ARS and laboratory sessions, integrated with different assessment strategies had a positive impact on the students' engagement and the learning experience. The compartmentalisation of assessment into small elements together with the range of assessment strategies, including problem based written assessment, online test, in class test, as well as end of year examination, were well received by the students. Laboratory sessions improved the students' attendance, engagement and hence improved the students' participation in the coursework submission. Whilst the ARS sessions did not have a significant impact on the attendance pattern for tutorial sessions, they had a positive impact on students' learning experience, as it provided the opportunity to work in a group and promoted discussion amongst students as well as between students and staff. The immediate feedback provided in the class was very helpful to students as well as staff. ARS provided an ideal platform to adopt contingent teaching. Online assessment provided a few concerns at the start, however many of these issues were resolved satisfactorily. We believe that the increased engagement and training provided by the laboratory sessions, ARS and the various coursework components, helped to increase the overall module pass rate and positively contributed to the students' experience and their achievement in this first year electronic module.

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