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Technology-Enhanced and Personalised Laboratory Learning Experience for Undergraduate Electrical Engineering and Electronics Students

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Teaching large and multicultural cohorts in lecture theatres is often a challenging task, and it becomes more challenging when it comes to laboratory teaching where students carry out practical work is involved. Students often complain about the quality of delivery with regards to the support they get from teaching assistants and technicians, and the lack of meaningful and personalised feedback they receive afterwards. Taking into consideration the fact that cohort sizes are often caused to increase from year to year, a serious sustainability issue therefore arises. Students in such cohorts may eventually disengage from their studies as a result of their perception of a lack of personalised learning experience. This often combines with other compounding factors into a downward spiral of disillusionment and demotivation that further jeopardises their studies and makes subsequent re-engagement less likely. Furthermore, the physical capacity restrictions of the laboratories and resources impose a further limit on how work is organised, and with constant budget cuts and increasing expectations and workloads, some form of crisis may seem inevitable.

Keyword: Technology-enhanced learning; personalised lab experience; large cohorts; multicultural; student satisfaction; personalised feedback; motivation; engagement.

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Technology-Enhanced and Personalised Laboratory Learning Experience for Undergraduate Electrical Engineering and Electronics Students

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Abstract

Teaching large and multicultural cohorts in lecture theatres is often a challenging task, and it becomes more challenging when it comes to laboratory teaching where students carry out practical work is involved. Students often complain about the quality of delivery with regards to the support they get from teaching assistants and technicians, and the lack of meaningful and personalised feedback they receive afterwards. Taking into consideration the fact that cohort sizes are often caused to increase from year to year, a serious sustainability issue therefore arises. Students in such cohorts may eventually disengage from their studies as a result of their perception of a lack of personalised learning experience. This often combines with other compounding factors into a downward spiral of disillusionment and demotivation that further jeopardises their studies and makes subsequent re-engagement less likely. Furthermore, the physical capacity restrictions of the laboratories and resources impose a further limit on how work is organised, and with constant budget cuts and increasing expectations and workloads, some form of crisis may seem inevitable.

This paper portrays how such a crisis was averted by implementing a package of transformational change delivered in a planned, incremental fashion over a period of 5 years to bring a notable improvement in the overall laboratory and practical coursework provision to second year Electrical Engineering and Electronics students, by employing a number of innovative approaches to enhance student experience. Moreover, the incorporation of tools such as instructional videos, online pre-lab and post-lab questions, blogs for student projects, weekly FAQs and Twitter feeds were particularly innovative and effective in their deployment, and resulted in a win-win situation in which both students and staff were able to communicate instantly and asynchronously in a manner that was hitherto not possible. This is particularly timely as the continuous increase in student numbers means that such techniques will be used increasingly. As a result, student satisfaction has improved in a steady and quantifiable manner, with a 29% increase over three academic years.

Keywords: Technology-enhanced learning; personalised lab experience; large cohorts; multicultural; student satisfaction; personalised feedback; motivation; engagement.

1. Introduction

In the current educational environment, class sizes are often under pressure to increase, resulting in a unique set of learning and teaching issues related to large cohort teaching. Such large cohorts (in this context, 'large' refers to classes in excess of 150 students) are predominantly encountered in the first and second years of study in many universities. This often accompanies a further commitment from the academic staff to support students at these stages to help them in the process of transition to university while introducing them to their new discipline. Accordingly, academic staff require skills and expertise such as developing and delivering effective teaching sessions, engaging students, audience management and control, and experience with interactive learning tools (Al-Ataby, 2016). In line with this, many science and engineering faculties around the world are facing a common issue regarding student satisfaction with laboratory teaching (Nikolic et al, 2015). Since the early days of engineering education, laboratories have been a vital and integral part of undergraduate and post-graduate programmes, and addressing students' needs and requirements while carrying out practical work have been a major concern. Student satisfaction is paramount in many universities because of the competitive nature of the higher education market. In the UK, national student survey (NSS) (NSS, 2017) has added to that competition for national and overseas students. Moreover, accreditation bodies (such as the IET) consider laboratory/practical skills to be part of the learning and teaching programme outputs (NSS Academic Accreditation, 2015). To improve student experience and satisfaction for such large and multicultural cohorts in laboratories, and to deliver personalised and rich experience, technology may be adopted to address the related problems (Kukulska-Hulme, 2012).

Information technology (IT) tools are now embedded in many people's daily lives and they are greatly incorporated in higher education environment nowadays. The majority of today's students are highly digitally literate, mobile, always connected (on-line) and efficient at multitasking during classes (Oblinger, 2004). The National Union of Students (NUS) has requested universities and academic staff to review the adopted teaching methods and to evaluate whether they are adequately making use of new technologies or not. Furthermore, the Higher Education Funding Council for England (HEFCE) has commissioned the NUS to carry out research to gather student perspective about technology and to assess the need, awareness and training required for students in higher education. The results of this research have shown without a doubt that the students believe that the use of technology would definitely improve their learning experience (NUS, 2010). Furthermore, the students have requested that their academic staff should use more technological tools in teaching, and they think that lecturers need more training when it comes to the use of technology. The research also showed that that the students have asked for the use of the state-of-the-art tools in teaching, and requested this to be an integral part of their learning experience. The students also requested that the electronic Blackboard system (or more generally, the VLE: Virtual Learning Environment) should be integrated with the lectures, laboratories and entire learning and teaching process (NUS, 2010).

This paper presents a package of transformational change that is based on the use of a number of innovative tools to substantially improve student satisfaction and experience with teaching laboratories. Moreover, the incorporation of tools such as instructional videos, pre- lab and post-lab online questions, blogs for the student projects, weekly FAQs and the Twitter feed were particularly innovative and effective in their deployment, and resulted in a win-win situation in which both students and staff were able to communicate instantly and asynchronously in a manner that was hitherto not possible. This is particularly timely as the sharp increase in student numbers will mean that such techniques will be used increasingly. Student feedback has improved in a steady and quantifiable manner, and student satisfaction rate has gone up from 68% to 88% in three academic years.

This paper is organised as follows: next section is about laboratory teaching methods and process; Section 3 is about the case study used in this paper; Section 4 is showing performance results and Section 5 is conclusions.

2. Laboratory Teaching

Laboratory work is an integral part in engineering education to the level that no engineering programme can be respected, accredited or approved without laboratories and some level of practical work (Feisel and Rosa, 2005, Wolf, 2010, Nikolic et al, 2015). Laboratory teaching offers unique skills to students such as team work, time management, problem solving, ethics and research skills. It requires a high level of interaction with peers, academic and support staff, teaching assistants and laboratory technicians. Lab teaching staff must have the appropriate skill set in order to be able to deliver successful lab sessions. Examples of these skills are communication, facilitation and crowd management, in addition to the specialist technical skills and knowledge. On the other hand, laboratory teaching suffers from a number of serious issues, especially with large and multicultural cohorts. Students often complain about the quality of delivery with regards to the support they get from teaching assistants and technicians, and the lack of meaningful and personalised feedback they receive afterwards. Subsequently, this contributes to the disillusionment and demotivation of the students that further jeopardises their studies and makes subsequent re-engagement less likely.

3. Research Methodology and Case Study

In this paper, a laboratory module for second year students will be used as a case study. This is a 15-credit module consisting of assessed practical experiments, coursework, reports and a group project, and is delivered across two semesters (full academic year). The students that are enrolled in this laboratory module are the UK home and EU students, a few international students from the Middle East and Africa, and a majority direct intake students from a partner university in China (referred to here as XJTLU), with an overall of over 300 students. Accordingly, it is both a large and highly diverse student cohort. This module is essential and is a core module for Electrical Engineering and Electronics students because it fosters a range of skills (hands-on and transferable) required for any electrical/electronics engineer. It requires a solid foundation in electrical and electronic circuit theory and design, mathematics, besides other knowledge and skills such as software development and engineering ethics.

This lab module was known to have a high workload, and it is not very popular amongst students. Student satisfaction rating was consistently low (in the range of 50- 60% in the best of cases). Furthermore, the level of student engagement and enthusiasm in this module was a real concern. Students used to give negative comment about the amount and quality of feedback that they receive after carrying out an experiment or submit a report/coursework, besides the complicated process to run the labs/experiments and the vague instructions, not to mention components/equipment problems. Equally, this module was a burdensome on teachers, teaching assistants and administrative staff.

To address the aforementioned issues, and to improve student experience, a package of transformational change was suggested and implemented over three years by remodelling lab delivery by employing a set of innovative tools that have substantially improved student engagement. Subsequently, a number of tools and utilities have been chosen and tested to engage the students in the large cohort with the labs and provide better quality and timely feedback. The tools were mainly self-developed, along with other tools that were off-the-shelf. It is worth mentioning that these tools were used in the Electrical Engineering and Electronic Department for the first time. The main motive behind using these innovative tools was to engage the students in- and off-labs through the localised version of the VLE (referred to VITAL or Virtual Interactive Teaching At Liverpool). The used tools and utilities were integrated within this VLE for student convenience and to avoid the burdensome of accessing various systems, portals and websites (Cann, et al, 2002). In this case, the VLE is considered as a single point of access for the students to all the tools for better experience (O'Leary and Ramsden, 2013, Salmon, 2001). Figure 1 shows the list of tools in the Learning Resources page of the VLE.

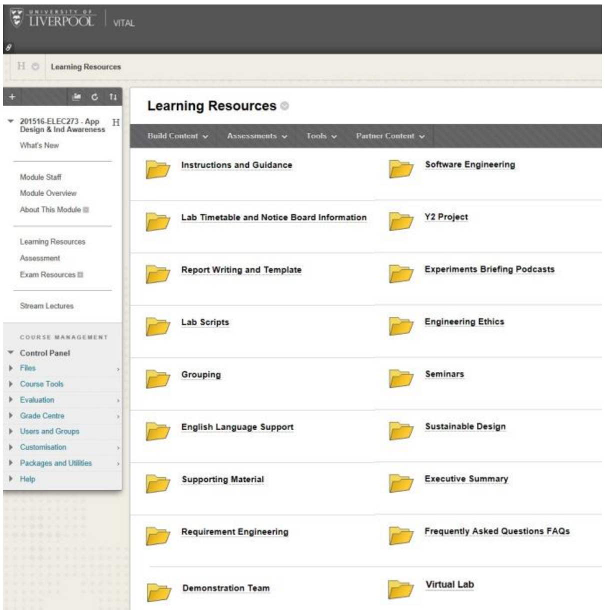

Figure 1. Folders accessible from Learning Resources page of the VLE.

The following sub-sections provide a brief description of some of the tools used in this research:

3.1. The Virtual lab tool

Student often complain about the lack of time to carry out practical work. Moreover, the labs are only accessible in certain times because technicians and safety staff must be present. Students would like to test various theoretical concepts practically, and the practical sessions cover a small range of these concepts only. Simulation tools and software packages can be used as a way to help students practice some of these theoretical concepts. As a result, a virtual lab tool was created and made available to the students through the VLE. The tool was built using GeoGebra, which is a Java-based free web tool. Experiments can be designed using this tool and students can run these and even collect data, measurements and test different component values. Since these experiments are available in the VLE, they are accessible anytime from any device (mobile or PC) with any operating system because the tool is cross-platform and the experiments are embedded in the VLE. Figure 2 and 3 show two examples of the virtual experiments.

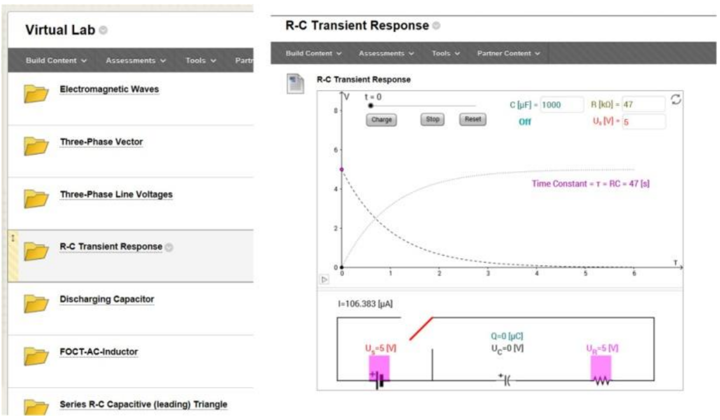

Figure 2. Virtual Lab Tool - Transient Circuit.

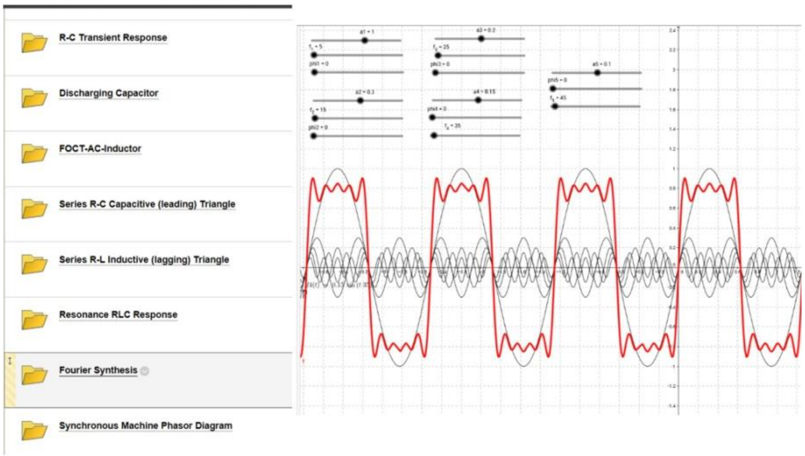

Figure 3. Virtual Lab Tool - Fourier Synthesis.

3.2. Smartphone and tablet applications

Smart phones and tablets (whether standard tablets or PC tablets) are now widely used devices and integrated in our daily life. Almost all the students nowadays have these gadgets on them while they are studying. It is noticed that when students lose interest during a lecture or lab session, they start directly using their gadgets for either gaming or accessing social media applications. It was realised early on that there would be enormous potential for such devices and gadgets to be harnessed for the purpose of students learning and teaching. Accordingly, a decision was made to utilise mobile applications for educational purposes by developing and customising applications for lab experiments. Moreover, lab manuals and experiment script can be made available as a mobile application for the students, by which students can follow the steps and record data/measurements and capture screenshots from an oscilloscope or take a photo for circuits and experimental kits. It was envisaged that this would certainly engage the students in, during and after lab sessions. It is evident that developing such mobile applications may take some time and require advanced programming skills, but it is obviously a one time effort exercise. Developing a new application can be avoided if a free version of the required application can be found in the application stores (which are now packed with loads of applications). This may require customisation of the lab scripts and experiments. An example of a mobile application that was developed in-house is the Fourier Synthesiser that is required to carry out an experiment for the second year students as part of the lab module. The application was developed using iOS (XCode) to work on Apple devices such as iPads. This application generates waveforms using harmonics. Figure 4 shows the main user interface of the application, Figure 5 shows the possible presets and Figure 6 shows the main settings options. With this application, standard time-domain waveforms such as square, sawtooth, triangle, half sinewave and modulated waveform can be generated. Actual signals can be generated from the iPads and viewed on an oscilloscope through audio output using special connection leads as shown in Figure 7.

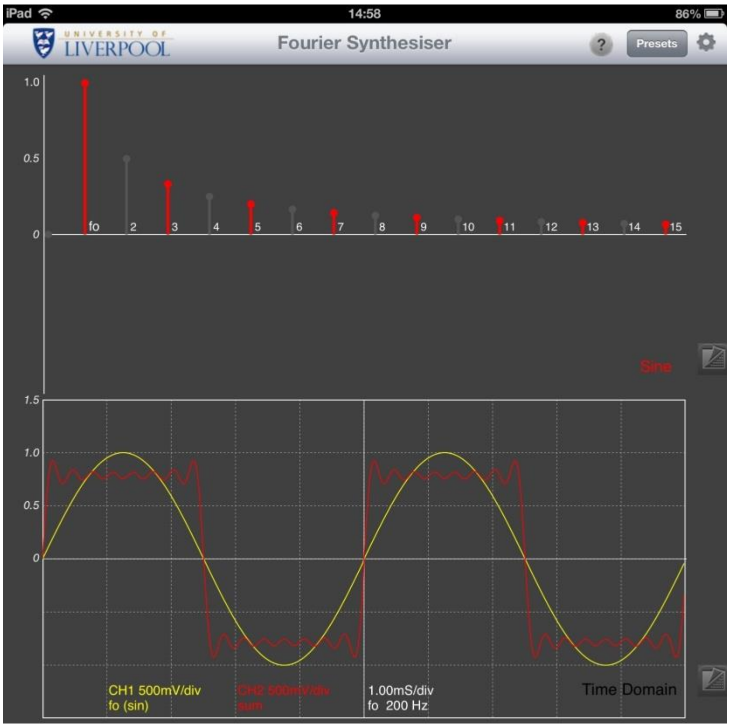

Figure 4. Fourier Synthesis Experiment iPad environment – 1.

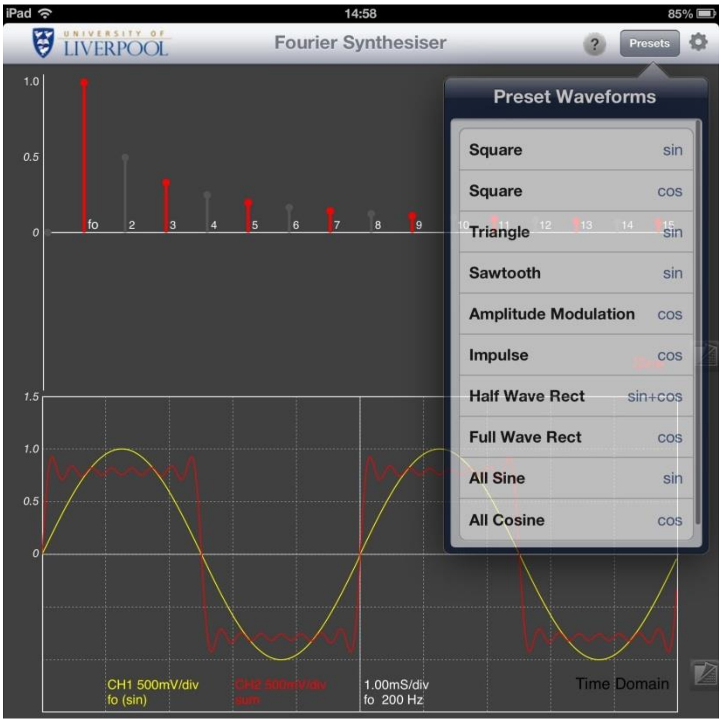

Figure 5. Fourier Synthesis Experiment iPad environment – 2.

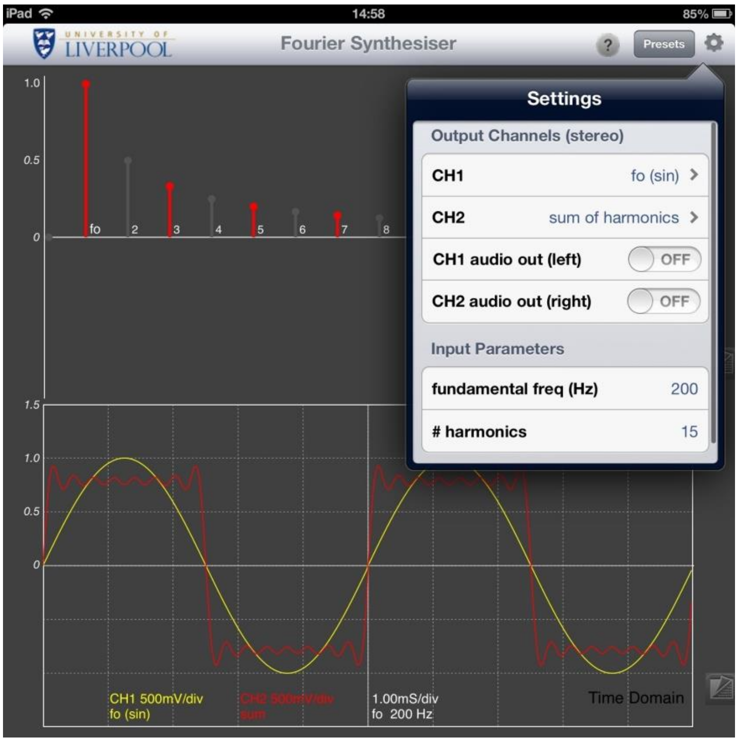

Figure 6. Fourier Synthesis Experiment iPad environment – 3.

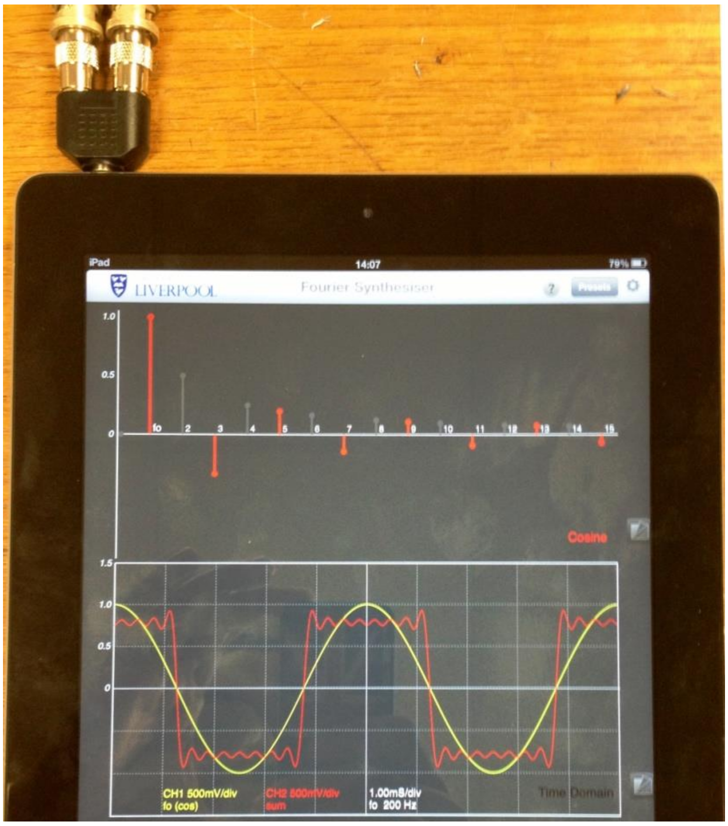

Figure 7. Fourier Synthesis Experiment iPad environment – 4.

3.3. Pre- and post-lab on-line tests and exercises

The employed VLE system has a built-in on-line test tool that can be used for many purposes such as pre-requisite assessment, pre-lab and post-lab tests, homework and exercises. In the context of laboratory assessment, the on-line test tool was used extensively. In particular, the pre-lab tests were used as a means to ensure that the students have read the lab script and prepare for the experiment before the lab day, which has proven to be more effective in terms of student performance in the practical session. These tests were usually assessed (summative tests), and are marked electronically because they are designed to be multiple choice, true/false, numerical answers matching and hot spot questions. Figure 8 shows an example of a question from a pre-lab test. This type of test is required to be submitted before the lab session. The on-line testing tool was also used for other purposes such as post-lab tests, lab procedures induction quiz and safety induction quiz. Moreover, in-lab on-line assessment and feedback were very useful in terms of cutting marking cost of the student teaching assistants (STAs) and providing a prompt feedback to the students (in contrast with marking hard copy or electronic reports which may take weeks for the feedback to be available).

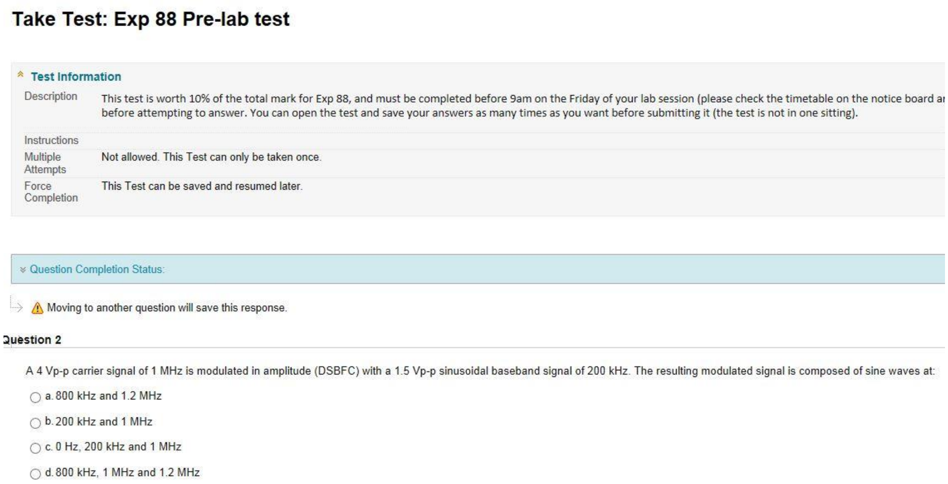

Figure 8. Sample of pre-lab on-line test.

3.4. On-line enquiry tool

When a cohort is large and multicultural, it is highly likely that students will have many questions about lab procedures, timetable, marks, feedback...etc (Burnett and Krause, 2006), and the most convenient way for the students to ask questions will be by sending emails to the lab organisers. Student questions are usually of the same nature and they are mostly repeated ones, and individual reply to such questions may take time from the organisers. It would be beneficial if the answers to such questions are communicated to all the students in the cohort. Accordingly, a decision was made by the lab organisers not to answer questions by emails but rather by using an on-line question tool. This tool was built using Google forms (which is free) and allows students to send anonymous questions to the lab organisers from the VLE. Using this tool, a student can send a question to the lab organisers, who will be notified by email and text message. Then, one of the organisers approves and answers the question and both will become visible in one page (referred to Student Questions - Q&A Page) in the VLE, which is accessible by the students. Furthermore, the questions and answers can be archived and made available for the student in the upcoming year's cohort. As a result of using this tool, less emails and questions were exchanged between the students and the lab organisers due to the fact that students will have common questions every year. Figure 9 provides a screenshot of the tool.

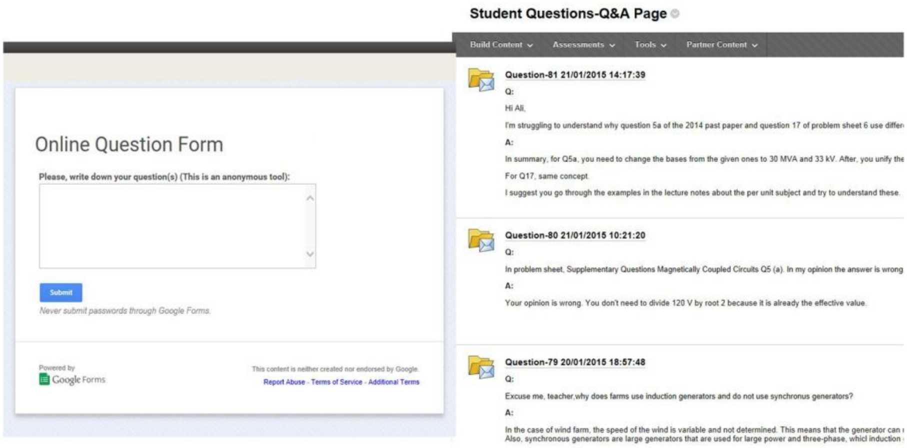

Figure 9. The On-line Question Tool.

3.5. Lab briefing, podcast, stream capture and instructional videos

Recorded media (video or voice) can be very useful in the context of laboratory teaching. They can be used to record experiment briefing in the form of podcast to brief the students before attending the lab session about the work they will be carrying out. Also, they can be used to provide generic feedback information and hints/tips about the lab in general. Students (in particular international) were found to be very interested about the idea of finding a recorded media about the lab that can be viewed many times conveniently before attending the lab session. For each lab experiment, a briefing video was created and made available via the VLE. These videos can also be embedded in other systems and can be reused frequently. Figure 10 shows experiment briefing podcast folder. There are many free tools that can be used for that purpose. Any software to capture the desktop of a PC besides a recording a voice will be suitable. For example, CamStudio can be used to generate the video files, and then these files can be uploaded and plugged in the VLE page of the lab module. The University of Liverpool now has an in-house developed software (called Stream Capture) to video-record lectures, practical sessions, tutorials, etc. All the lecture theatres in the University are equipped with the required hardware and software to record lectures. Stream capture software can also be installed on any PC in the campus and used to record the required media. The videos will be automatically saved in the University Stream Server and can be linked to a module so that they are all accessible from the module VLE page automatically. Figure 11 provides a screenshot of the stream capture system. Recorded media was found to be very useful for other purposes such as recording instructional videos for important lab events (e.g. procedures for the group project demonstration day). By checking the number of views, it was found that the students are viewing the recorded material extensively, and for lectures, it was verified that this is not affecting student attendance rate.

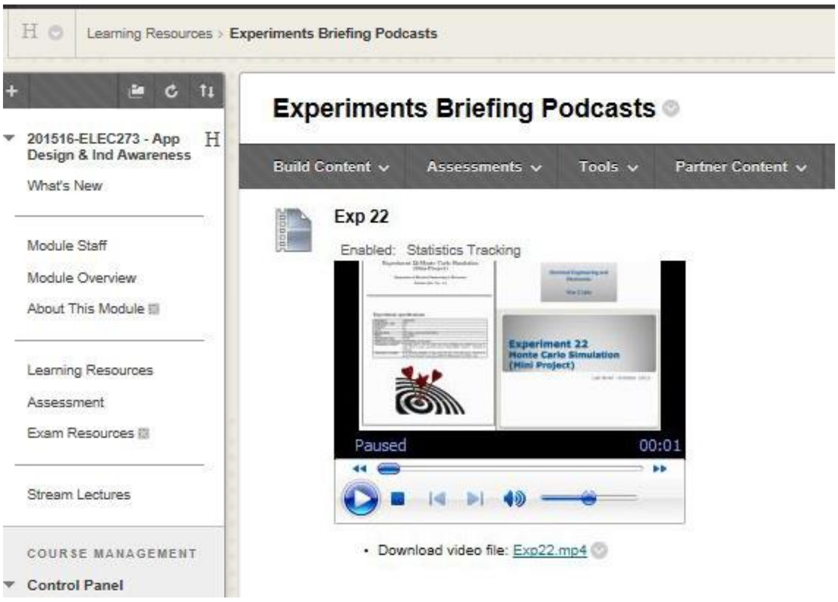

Figure 10. Experiment briefing podcasts.

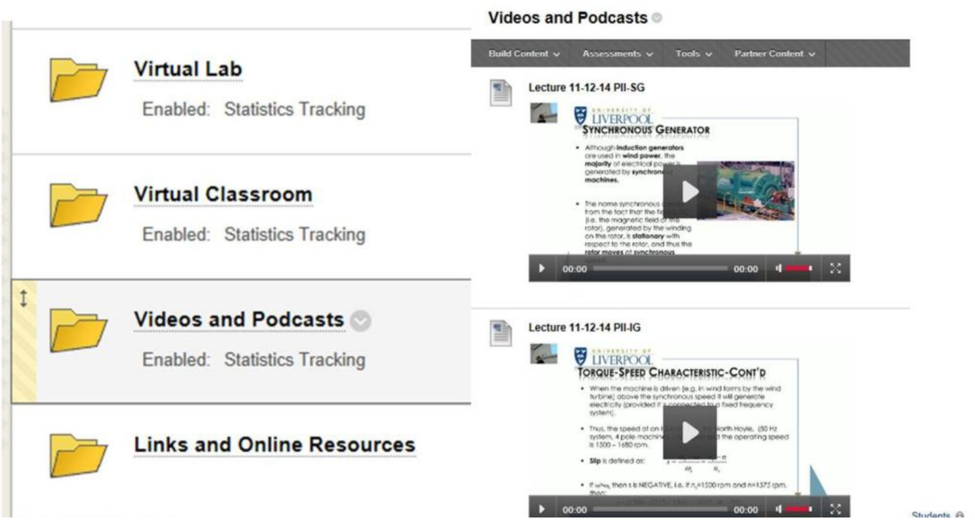

Figure 11. Stream Capture System.

3.6. On-line feedback tool and student polls/surveys

The students were provided with an on-line anonymous feedback tool (accessible from the VLE) that is available always so that they can express their lab experience after each lab day. Similar to the on-line question tool, the feedback tool was built using Google forms. The feedback form provides questions with a rating scale plus free text input, and a detailed feedback report can be obtained from the tool for the benefit of the lab organisers. The feedback was always monitored and responded to before the next lab session and remedial actions were taken immediately. It is worth mentioning that student feedback was collected independently from the Departmental feedback collection process, which collects student feedback at the end of each semester. Figure 12 provides a screenshot of the feedback tool.

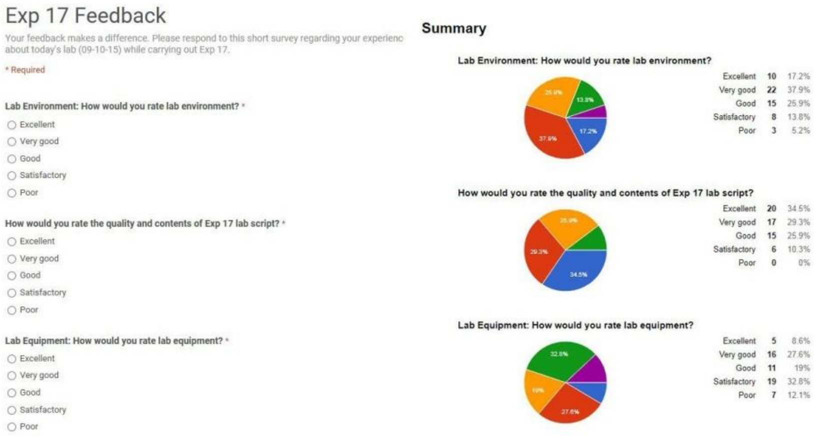

Figure 12. The on-line feedback tool.

3.7. Weekly FAQs page/email and Twitter feed

In order to communicate important notifications and by the way of feedback, responses to some common questions were sent to the students on weekly basis. This was done by an email and also a document that is stored in the VLE. It was evident that this has reduced tremendously the number of enquirers and questions of the students, reduced confusion and reminded the students about what is expected from them each week of the semester. After one year of using this method, there was a pool of FAQs emails and documents that were used in the following years by only updating (adding and modifying) some questions to make everything suitable for the current year. Figure 13 shows the VLE page were all the FAQs documents are stored and a sample of the contents is shown in Figure 14.

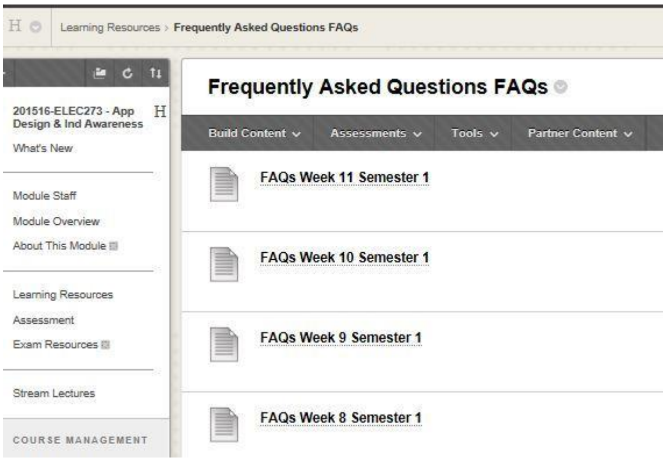

Figure 13. FAQs VLE Page.

FAQs Week 2 Semester 1, 2015-16

Q: When is the deadline for the Lab Induction Quiz and the Safety Induction Quiz?
A: It is going to be 9am Friday 9th Oct for both quizzes (before the first practical lab session). Both are formative tests.

Q: How do I know what experiment I'm doing this week?
A: Check the timetable. This week, you should have Exp 17 (Error Analysis)

Q: Where is the lab timetable?
A: The provisional timetable is on the notice board of the third floor labs and on VITAL.

Q: When is the deadline of Exp 17 pre-lab test?
A: it is 9am Friday 9th Oct. Its mark is counted (10%).

Q: How is Exp 17 going to be assessed?
A: By means of a formal report (check the instructions on the lab script). The deadline for submitting the report is Mon 19th Oct midnight (10 days after the lab day). The report is worth 90% of Exp 17's mark.

Q: If I need some information about the equipment used in the lab for Exp 17 this week (oscilloscopes in particular), where can I find such information?
A: There is a document called "Exp-Q The Oscilloscope" on VITAL learning resources under "Supporting Material" folder. You may have a look and obtain information.

Q: Where can I find a hardcopy of the lab script?
A: You should have a copy if you attended the lab tour.

Figure 14. Example of FAQs email/document.

The educational use of social networking applications (such as Twitter and Facebook) has been considered widely in the last five years. Although a number of researchers have shown that digital literacy may not be transferred to academic learning or professional practices, the educational advantages of using social networking can be seen as better learning experience and higher student engagement, compared to using other means such as emails or text messages. In particular, Twitter can be highly used as a way to quickly update and remind the students, ask short questions to open discussions, or to improve student teaching and learning by improving their engagement (Kim et al, 2015). In the lab module, Twitter was used and a plug in was employed to view the tweets from the Blackboard system. Figure 15 shows an illustration of this. According to student feedback, the use of Twitter feed was particularly innovative and effective. It has resulted in a win-win situation in which both students and staff were able to communicate instantly and asynchronously in a manner that was hitherto not possible.

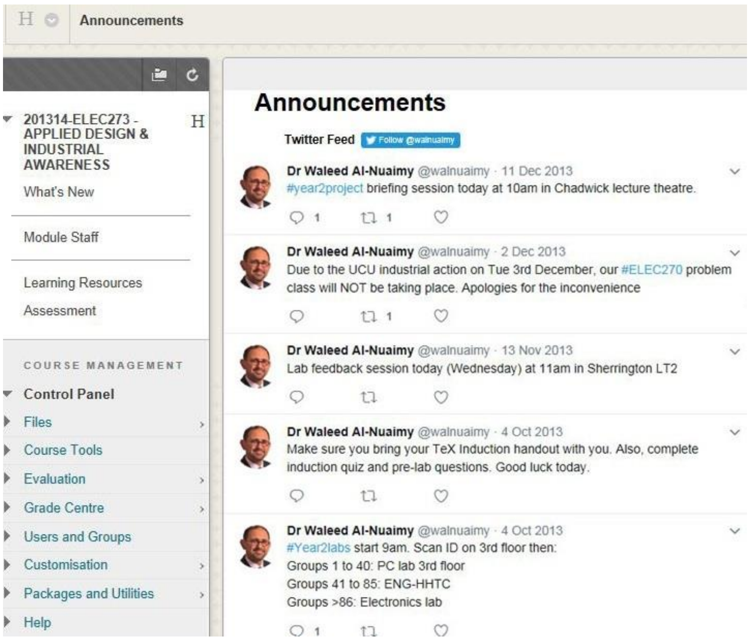

Figure 15. Twitter feed in the VLE.

3.8. Inclusion of (self-taught) LATEX

As a way to enhance report writing and technical documentation skills, the LaTeX typesetting system was included in the lab module. The students were asked to self-learn LaTeX, and an induction exercise was provided as an opportunity to start this process with supervision and support in the lab. As such, this was a formative task that is not directly assessed. A one lab session was timetabled in the PC room, and a number of STAs were made available to support the students during that session. There are several free LaTeX distributions and editors; the students can install and use MikTex on campus, but to get started, the suggestion was to sign up to use the free online LATEX editor and compiler at www.sharelatex.com. The students were advised to create a free account on this site, and create a new blank project named with the experiment name.

The students were provided with files that can be downloaded from the VLE, and asked to upload these to Sharelatex website to start creating the lab reports. Another template was provided for Y2 project report as well. The students were advised to contact the lab organisers and the STAs in case they have a problem with generating lab reports, who will be able to access Sharelatex and help the students with a specific report remotely.

3.9. Student project blogs and posters

Second year students are required to carry out a project. The project is a group project that is required to be carried out during the first 5 weeks of semester 2 and a project demonstration event (assessment day) is held on week 6. The deliverables of the project are a bench showing a functional system or software, a poster, a blog, a log book and a report. It can be a hardware-based, software-base or a mixture of both. Students are assigned a project during week 12 of the first semester and start immediately in the second semester. The projects are suitable for year 2 students and the main idea behind the project is to familiarise the students to group/team work and prepare them for the final year project in the final year, besides it is a requirement for IET accreditation. The project also contains an element of self and peer assessment (using WebPA peer assessment system). As a way to promote year 2 projects, and to give external visibility to students' work, it was suggested that all year 2 projects be posted on a public blog website, so that anyone can access. This will be a permanent way of showcasing of work to visitors as well as act as an aid to future students. The students are required to submit the blog to a designated website following a certain procedure, and the deadline is usually during the demonstration week. Figure 16 shows an example of a blog. The blog for the EEE students at Liverpool can be found at http://year2projects.blogspot.com. The blog website contains a permanent record of previous second year projects.

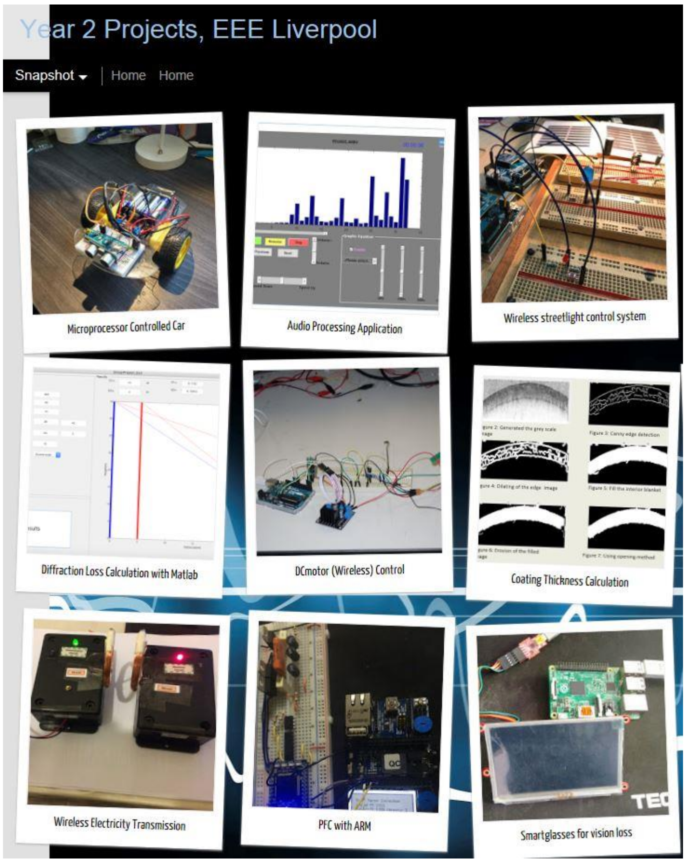

Figure 16. Year 2 Projects blog of EEE Students at Liverpool.

The students are also required to produce a poster of their project. The poster is meant to be used by the students to present their work in a visually appealing way, summarising their achievements so it should include what the aim of the project was, what they did, what the results were and their conclusions in a brief form. Samples of these posters can be found at http://year2projects.blogspot.com/p/posters-2012-13.html#!/p/posters-2014-15.html. The benefits of this exercise were very evident in the third year (final year), where the students are required to prepare a poster of their individual project.

3.10. Electronic coursework submission, marking and feedback

At very early stages, lab organisers have recognised the importance and benefits of the electronic submission, marking and feedback of all the coursework components related to the lab modules. The advantages of this are huge, including cutting the cost of paper submission for both the department and the students, printing hassle, ease of submission, automatic plagiarism check (through Turnitin system) and quick and better quality feedback. All the components of the lab module are submitted electronically since many years, an exercise which is ahead of many schools and department in the University.

3.11. Circulation of 'you said/we did' tables to promote feedback

Feedback should be an integrated element of any educational programme or module. Student feedback is collected online feedback/survey links that are available in the VLE and sent to the students after the lab day. Moreover, there is a questionnaire system that is used to collect student feedback in week 7 every semester. The students can also express their feedback and comments to the lab organisers directly (in person). As a result, there will be a good amount of comments that can be utilised. The lab organisers usually compile a list of feedback in the form of a table. This table is circulated to the students as 'you said/we did' email or VLE announcement, which incorporates lab organisers response and action plan to the given feedback. According to student feedback, the circulation of such tables was very effective and useful, and promotes the concept of feedback and significance of student voice in education.

3.12. Engineering Ethics, Requirements Engineering and Software Engineering

Much of the electrical engineers work involves developing and implementing solutions to problems where ethical considerations must be addressed by adopting a set of standards, and hence, ethical principles are required. The lab organisers have incorporated engineering ethics into the taught programme for the first time. Aspects of professional ethical conduct are key employment skills that will be further embedded into the curriculum. This was widely welcomed by the students (as evidenced by feedback on Twitter and verbal feedback in class). Other industrial sessions and concepts were also incorporated in the lab module. For example, requirements engineering, which defines a list of activities related to identifying and communicating the purpose of a system, covering all the activities involved in discovering, documenting and maintaining a list of requirements, was incorporated for the first time in the EEE programme. Moreover, software engineering concept was also introduced to the students because of its role in today's technological advancement.

4. Performance Results

The lab module has been transformed from being a demanding (high workload) and disengaging practical module into a module that the majority of students enjoy and appreciate. According to student feedback, the module has become one of the top rated EEE modules in year 2. Figure 17 shows student satisfaction rate for five consecutive years collected by departmental student surveys. As it can be seen, the satisfaction has increased year after year, with 2014-15 academic year being the highest in terms of satisfaction (88%). Historically, in the EEE department, lab modules usually do not score high in student satisfaction because of many reasons and the fact that many elements are involved (e.g. equipment, technicians, teaching assistant...etc), but getting this high percentage indicates that the students are quite happy with the experience overall.

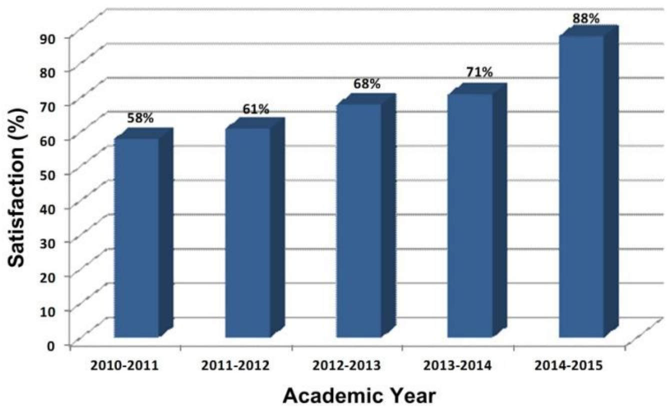

Figure 17. Lab module student satisfaction rate in five years.

As another way to express students' satisfaction, Table 1 shows the number of student enquiries/complains for three consecutive years. It can be seen that although the number of students has increased considerably, the number of student enquiries has reduced dramatically, with a reduction from > 20% to < 2% in the ratio of enquiries to the number of students, an indication of satisfaction and clarity of the lab management process and procedures, signposting and pro-active addressing of student needs. It is worth to mention that student enquires used to be collected in paper form only, but now they are completed electronically (on-line), which reduced hardcopy wastage significantly and helped in tracking enquires efficiently.

Table 1. Number of student enquires per year.

Year	No. of students	Enquiries	Ratio of Enq./No. of students
2012-13	168	36	21.43%
2013-14	260	15	5.77%
2014-15	320	5	1.56%

Finally, it was noticed during the course of this research that student performance has also improved from year to year for the three consecutive years. The highest increase was in 2012-13 session, where module average has gone up by 9.2% compared to the previous year. The subsequent years have also seen an increase in performance with respect to the previous year. Consequently, an overall improvement of about 15% in student performance was therefore resulted over three academic years. Table 2 shows lab module average improvement for the last three years of this research.

Table 2. Lab module average improvement per year.

Year	Module Average Improvement
2012-13	9.2%
2013-14	2.5%
2014-15	2.9%

As an ultimate result of this research, the lab module average was above the expected range with a very low failure rate. It has become one of the most popular modules in the second year.

5. Conclusions

Laboratory teaching of a large multicultural cohort is often a challenging task. This paper has proposed a number of innovative approaches to enhance laboratory experience, improve satisfaction levels and reduce complaints while catering for a more than 80% increase in student numbers yet constrained with a reduced budget. This was achieved by the implementation of a package of transformational change that has brought about a notable improvement in the overall laboratory provision in the second year, and was delivered in a planned, incremental fashion over a period of 5 years, each year focussing on a particular aspect. Emphasis was on aspects such as academic report writing, professionalism and improved feedback, and this has been notably successful in bringing about a step change in the quality of the written work produced by year 2, by means of a number of specific, targeted and co-ordinated steps, and reflected on the quality of their final year work and beyond as well. The incorporation of the blogs (for the student projects, posters and weekly FAQ) and the Twitter feed were particularly innovative and effective in their deployment, and resulted in a win-win situation in which both students and staff were able to communicate instantly and asynchronously in a manner that was hitherto not possible. This is particularly timely as the sharp increase in student numbers locally mean that such techniques will be used increasingly. Student feedback has improved in a steady and quantifiable manner. As a result of employing the aforementioned approaches in this paper, student satisfaction rate has increased remarkably to 88%, an indication that the students are quite happy with the experience overall. Moreover, an overall improvement of about 15% in student performance was resulted over three academic years, with module average being above the expected range besides a very low failure rate, and it has become one of the most popular modules in the second year. This has highly added value to the Departments reputation and the good performance in the NSS. It is worth mentioning that the approaches proposed in this paper are now well established in the laboratory module and are being used successfully in other modules in the Department.

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