Introducing Scenario Based Learning

Experiences from an Undergraduate Electronic and Electrical Engineering course.

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Abstract— **The aim of this work is to introduce scenarios into the first and second year of our undergraduate electronic and electrical engineering curriculum to improve the educational and learning experience of our students and in doing so improve the quality of our graduates. This paper introduces the curriculum development involved in the implementation of scenarios. We reflect upon and analyze the successful aspects of this trial and identify those areas that are in need of improvement.**

Keywords – Student centred learning, scenario-based-learning

I. INTRODUCTION

The UCL Electronic and Electrical Engineering (EEE) Department, in which this study is based, runs two undergraduate programmes: a three year BEng and a four year MEng. We aim to produce graduates who have a strong theoretical grounding in the fundamentals of the discipline, are capable of independent thought, able to approach new problems, can communicate results to others in a logical way and work in a collaborative environment.

Both students and academic staff have expressed a number of concerns with the undergraduate program which is largely delivered by lectures, tutorials and expository laboratory classes. Students find that the course is not as hands-on as they expect and don't appreciate the depth of theoretical background required to fully engage with the discipline. Academic staff are concerned that student motivation and performance has decreased by the time they get to the second year.

In an attempt to address some of these problems, we introduced a series of, week long, engineering design projects called scenarios, where students work in small groups in a realistic situation on a fairly open problem where the outcomes are undetermined. The scenarios are designed to draw on and consolidate the lecture material that the students will have received in the preceding weeks. As such, planning of the course and design of the scenario needs to be carried out in an integrated fashion with emphasis on horizontal integration across lecture courses and application of knowledge through engineering design projects (scenarios). The use of a series of short focused scenarios in the first and second year, rather than the more often used design project running over an entire academic term in parallel with lectures, was designed to: enable a greater range of areas within the curriculum to be covered, simplify time management for the students, and provide increased opportunity to provide formative feedback that the students can apply in upcoming scenarios.

Here we present the pedagogical rational for such an approach and describe the implementation of scenarios. The observations of the staff involved and the student evaluations for a selection of the scenarios obtained after the first year of this trial are presented and analyzed. The successful and unsuccessful aspects of the first year of this trial are identified and improvements are proposed.

II. BACKGROUND AND PEDAGOGICAL CONTEXT

This work was initiated by the pilot study of Mitchell et al. who used problem based learning (PBL) to teach an entire 3rd year electrical engineering module that was traditionally taught using conventional lectures [1]. The student feedback from this trial was overwhelming positive, however, one of the issues with this trial was getting the students to adapt and acclimatize to this new learning style, especially after two years of conventional lectures. As such this optional course now has a relatively low take-up rate. Here we wanted to build on the success of this trial and expose some of the benefits of the PBL methodology to our students at an earlier stage when they are more receptive to new approaches. In fact a number of them have already experienced such techniques in their secondary education.

Scenario based learning (SBL), Project based learning (PjBL), and Problem based learning are subsets of a larger class of learning techniques broadly know as enquiry based learning [2]. These learning techniques all emphasise a student centred approach where the students take ownership of their learning and are active participants in the process. They all require the students to develop the research skills and methodologies that are associated with the particular discipline. The role of the academic changes from that of the 'oracle' dispensing knowledge to that of a 'facilitator' whose role is to guide and support the students in their own learning.

At one end of the spectrum is problem based learning where 'the problem', which generally has a predetermined outcome, is used to direct the students to both acquire and assimilate the necessary knowledge in the process of solving it. In PBL the solution may be less important than the new knowledge gained during the process. At the other end of the spectrum is Project based learning, where 'the problem' is more open ended and the focus is on the application and assimilation of previously acquired knowledge, in the development of a solution. Project based learning is very focused on the production of an end product. Scenario based learning lies somewhere in the middle of this spectrum and different scenarios may be more 'problem' or 'project' like. The word scenario is used to denote several distinctive aspects of this learning mechanism.

Firstly, the scenario is seen as an integrated part of the entire course structure and not a mechanism for delivering an entire module as in PBL. Scenario based learning aims to get the students to draw on the experience, knowledge and skills that they have already acquired or been exposed to in lectures and laboratories across the entire course and apply this to a scenario that has not previously been encountered. This also means that the traditional lecture course element, albeit modified, remains. This eases the concerns of sceptical academics and is in line with research that suggests that PBL is no better at delivering knowledge than lectures [3].

Secondly, the scenario is designed to place the students in a realistic situation, where the problem is fairly open and as such the outcomes are undetermined. In this sense scenario based learning draws inspiration from the experiential model [4] and the situated cognition [5] theories of learning. The experiential model emphasizes the need for concrete experience in the learning cycle as Kolb conceived it, that is, the experience that comes with actively participating in and solving a problem. Situated learning stresses the importance of placing learning in realistic and authentic contexts. It draws particularly heavily on the apprenticeships model [6] where students learn on the job under the guidance of colleagues and a mentor. The social aspects of learning are also emphasised in situated learning. This is the learning that arises from interaction with and observation of other team members. This has a particular resonance with a discipline such as engineering, which until relatively recently, before becoming an academic discipline, was taught solely in this manner and where practitioners predominately work in teams.

Flora and Cooper found that students achieved the best results when they are taken on a journey starting initially with expository experiments where instructions are provided and the outcome known, followed by a more PBL type experiment, where the outcome is known but process is designed by the students, and then are finally given the opportunity to experience a PjBL design project [7]. The course structure, proposed here, with lectures, expository laboratories, and several scenarios, that employ elements from both PBL and PjBL, attempts to produce such a learning environment.

III. Scenario Design and Implementation

For the first trial of this program in the 2008-09 academic year we were able to run three scenarios in the first year and two scenarios in the second year, as summarised in Table 1. Unfortunately we were not able to restructure the lecture courses to deliver to the scenarios, however, in order to mitigate this we designed the scenarios to align to the current course structure as much as was practical.

TABLE I. Summary of trialed scenarios.

Title	Description
Scenario A: Electromagnetic lifting	Redesign an electromagnet to maximize the lifting force using only a single battery.
Scenario B: Java based image coding for airport security.	Develop a piece of software in java to scramble and descramble passenger images using a secret key.
Scenario C: The Transistor Radio Kit	Design and build a radio that could be assembled by hand in a third world country and powered off the grid.
Scenario X: Call Detection System	Design, build and test a system that is able to non-intrusively acquire the signal from a phone line and determine the number that has been dialled.
Scenario Y: Due Diligence Report on Broadband Access Solutions	Research, assess and compare the performance, practicality and economic implications of three potential next generation broadband access technologies.

The scenarios were run as group projects with 4-5 students in each group. Group projects allow the students to develop team working and management skills that employers value highly. They also provide an environment for collaborative learning where group members are able to learn off each other [3]. In addition group projects and reports makes running these

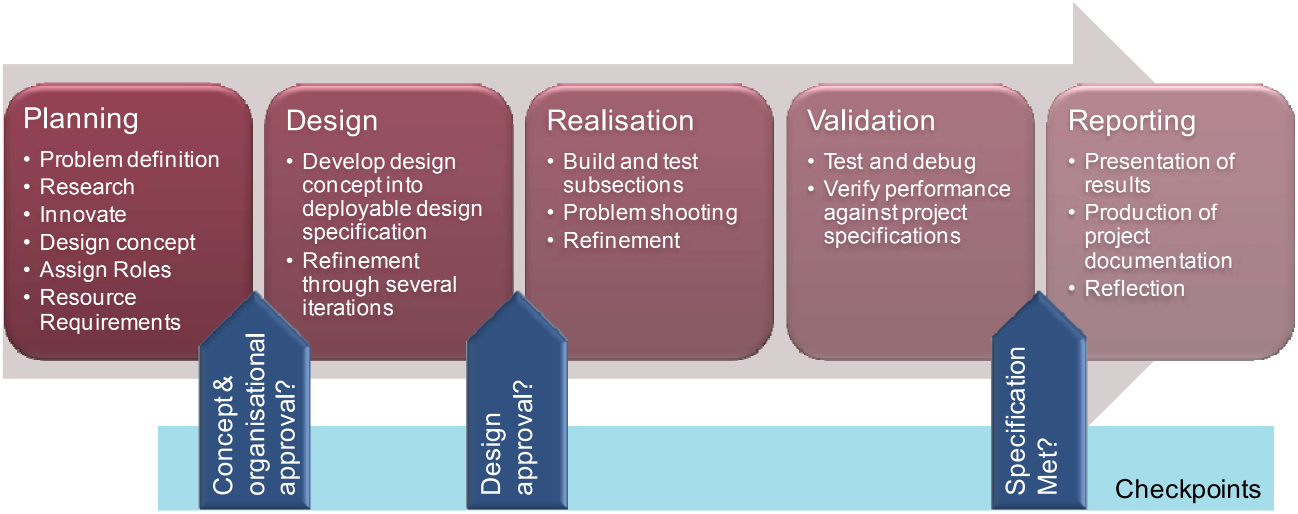

Figure 1. Generalised Scenario project model.

projects practical and reduces the marking load. The groups were changed for each scenario to ensure that individual students did not feel overly penalised by being in a group that they perceived as poor.

Each scenario was run over a week, during which there were no lectures and thus they could concentrate solely on the scenario. The students were presented with a problem on Monday morning and were given until the following Monday morning to submit the final deliverable. The scenario structure and timeline was based around the project model, shown in Fig. 1, which was adapted from Svensson et al. [8] to suit a week long project. In particular checkpoints (or milestones) were introduced to ensure that the students were making appropriate progress, to encourage particular types of activities such as brainstorming and to provide formative feedback.

IV. Assessment and feedback

One of the aims of introducing scenarios was to bring alternative forms of assessment and increased opportunities for feedback into the undergraduate program. Increasing the diversity in assessment helps to reduce the reliance on unseen examinations as the primary assessment mechanism and provides a more diverse range of situations in which the students can demonstrate their mastery of the subject [9]. The scenarios use both formative and summative forms of assessment that are intended to guide and enhance the students learning process and ensure that feedback is an integral part of the process.

Each scenario used a slightly different method of summative assessment ranging from individual or group based technical reports, oral or poster based presentations, through to critical review and comparison of another group's technical approach with that of their own. The type of assessment was chosen to be as authentic as possible and thus contribute to the realism of the scenario. For example, in Scenario Y, the summative assessment was based on a presentation of the group's findings and recommendations, and submission of a due diligence report to the board of the fictional company that had commissioned the research study. In addition for each scenario the students had to submit an individual reflective commentary.

For each of the reports the students were given a report template (MS word) that contained the suggested report structure and a marking grid. The marking grid was closely aligned with the published assessment criteria. Further guidance was also given in terms of the purpose of each section, the elements it should contain and the aspects that should be explained or described. Again, these are clearly linked to the assessment criteria given to the students. The group/individual reports and the reflective commentaries were submitted online as MS word documents using "Moodle". The submitted reports were downloaded, marked and then uploaded back into Moodle, completely electronically, to minimize the turnaround time and thus provide timely feedback. Feedback was provided using the comment function in MS word inserted where relevant in the report. The embedded marking grid was used to provide additional comments specific to the assessment criteria and to give an overall assessment of the report.

In addition to the summative assessment, formative assessment was also used throughout the week by introducing checkpoints into the scenario week schedule. These checkpoints were used by the facilitators to monitor progress and provide feedback to the groups. Generally there would be two checkpoints one early in the week (either Monday or Tuesday) to ensure that the group had organised themselves and one later. The first checkpoint took the form of a short discussion with the group in which the group would present the current state of the design plans and their approach for achieving those plans. This included ensuring that the group had put in place an organisational structure i.e. group leader, had assigned tasks to each group member and had developed a time plan for the week. This first checkpoint also often occurred at an important decision point, where the group needed to justify a choice to the facilitator in order to progress to the next stage, e.g. in Scenario A the students needed to justify their choice of battery and wire gauge to the facilitator before they were given the wire to construct the coil.

The second checkpoint (generally on Thursday afternoon) involved presentation or demonstration of the group's solution to the scenario. To make this more interesting/motivating for the students this was often arranged as a competition in which all groups were present e.g. who could lift the heaviest weight in scenario A or the first to recover the unknown phone number and call the unknown phone it in scenario X. However, the results of these competitions did not contribute in any way to the grade that the students received. In addition to the excitement and motivation that the element of competition provides the exposure to the solutions of the other groups and the comments provided by the facilitators at these sessions provides feedback which can be incorporated into the final report. This is particularly evident in the presentation session of Scenario Y, where the other groups who are the audience get to see the work of their colleagues and the questions/suggestions that are provided by the board/facilitators, as well as question the presenters themselves.

All scenarios made use of 1-2 page reflective commentaries in which the students were asked to:

- Comment on or give details of their own input into the design process and summative tasks.
- Reflect on a personally significant aspect of the task.
- Identify and critically evaluate those aspects of the scenario that they consider successful and those that were less successful. Suggest how things might be improved in subsequent scenarios.

The purpose of the reflective commentaries was twofold firstly, and rather bluntly, they provided a mechanism for assessing the input and contribution of the individual students to the group based scenario. Secondly, and more importantly they get the students to reflect on and analyze those aspects of the process that worked well and those that didn't and to take these thoughts forward to improve their own performance in the subsequent scenarios. In addition, the commentaries provide a wealth of feedback with respect to what the students liked about the scenario, what their concerns where and what aspects of the scenario design they thought worked well.

V. Student Evaluation

Student evaluation of the scenarios was obtained in a range of ways the first and most immediate form of feedback came from informal chats, during and after the scenario, with tutorial groups and various students in the departmental corridors. The general feeling from these was that we had certainly developed something that they found enjoyable and challenging, however, there were a number of concerns expressed over effective group working strategies and fairness of awarded grade based on group work. Common responses included:

"We had one group member who barely turned up and when we tried to assign him/her a task it was not completed so someone else had to do it making it hard to complete the task. Will this penalise the other group members?"

"I hope I get a better group next time."

After each scenario the students were asked to complete a simple online feedback to the following questions:

1. What aspect(s) did you like most about this scenario?
2. What aspect(s) did you not like about this scenario?
3. What would you change to improve this scenario?

The analysis and presentation of the findings, from this style of questionnaire, is somewhat more challenging due to the unconstrained nature of the responses. Common themes in the responses to each question have been identified and scored based on the number of occurrences normalised to the total number of respondents. To get an overall feeling for whether the feedback was generally positive or negative, and what areas worked well and those that needed improving the categories identified in the 'like', 'change' and 'dislike' responses are plotted against the frequency of response to each of the identified themes. A negative value is assigned to 'change' and 'dislike' comments to indicate that this is an area that needs to be improved in future and give way of visualising whether the feedback is generally positive or negative.

VI. Case Studies

A. Scenario A: Electromagnetic lifting

This scenario aims to enhance the learning of basic concepts from electro-magnetics, circuit analysis, and mathematics. Students are required to design and build an electro-magnetic system to see which team can lift the heaviest weight. At the end of the week an Olympic weightlifting style competition is was held to test the designs.

One of the difficulties and major question raised by staff with running a practical scenario, such as this, where the students are expected to construct something is: 'Can you achieve something that is realisable, draws on the taught material and is sufficiently challenging within a week?' In order to make this scenario practical to run in a week the design was constrained by restricting the mechanical design of the electromagnet and limiting the choice of battery to either a 9V PP3 or a 1.5V C battery. The students were provided with a wide range of possible wire gauges to wind the coil with. These restrictions whilst constraining the possible solutions somewhat meant that by the Thursday afternoon when the testing competition was due to take place all groups had produced an electromagnet.

This scenario is essentially an optimization problem where the students need to determine and apply appropriate theory to produce a mathematical model of the system. They need to use both, tabulated and experimentally determined parameters in the model, and make various assumptions. The optimum solution, determined from the model, is then constructed and tested. In this case the optimum solution involves choosing the optimum wire gauge and battery.

In order to ensure that the students applied their theoretical knowledge to this problem and didn't just use trial and error experimentation a checkpoint was used on Tuesday. The students had to justify their choice of wire gauge and battery based on their theoretical calculations. They were then given their chosen wire and battery. This worked particularly well as all groups produced a theoretical model showing an optimal solution. Interestingly, at this checkpoint most were not convinced that it was possible to lift the weight that their models predicted (in the range of 40-80 kg) and were quite surprised when the best group lifted 53kg on the competition day. This observation highlights the importance of giving students the opportunity to apply and test theory.

The findings from the student evaluation of this scenario are illustrated in Fig. 2.

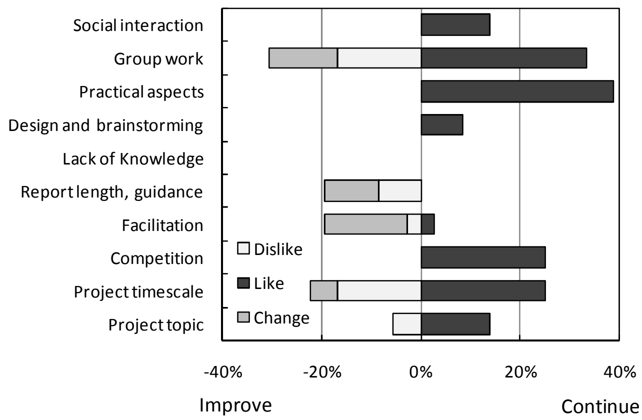

Figure 2. Scenario A: student response rate by theme (Total responses = 36).

Immediately we see that the feedback is generally more positive than negative. Surprisingly, given earlier comments, the students particularly valued the group work and social interaction involved with this. The 'dislike' and 'change' group work comments were related to issues arising with poor co-ordination between group members leading to a breakdown in efficient group working, or trouble with group members who did not contribute. The design, practical application and competition elements of this scenario were unanimously liked. As this was their first university project report students expressed some apprehension towards what and how much was required. They did not seem to appreciate the close alignment between the provided report structure, associated marking grid and assessment criteria. The students were fairly neutral on the quality of the facilitation that they received from the academics and would prefer to have more rather than less facilitation.

Generally the students were happy with the one week timescale and focusing solely on the project for the week, however, some students felt it could have been slightly longer.

B. Scenario B: Software development for identity recognition in an airport security system in Java

This scenario involved writing a program to apply mathematical transformations to an image in order to first scramble the image and then descramble the image. This scenario was designed to build on the mathematics and programming modules. Before commencing this scenario the students had completed their first year programming module in Java. The scenario requires the application of two main skills: algorithm development and programming. The first stage, algorithm development, requires the students to turn the problem statement into a series of commands that a computer can execute. This involves working out a method that can be used to apply the mathematical concepts such as rotation to an image that is constructed of pixels. The second stage, programming, requires the students to convert the algorithm into a formal programming language, in this case Java.

Algorithm development is a very generic skill that is fundamental to most problem solving tasks, however, in the context of computer programming it often gets entwined in the syntax of the programming language, which results in confusion amongst students. To reduce this confusion a checkpoint was used to break the week into two parts. On Monday and Tuesday each group of students was given a working space with a white board and it was suggested that they did not begin programming until after the Tuesday afternoon checkpoint. At the checkpoint the groups needed to explain, to the facilitators, their high level project design showing how the various parts of the program would work together and describe the algorithms that they had developed to implement each part.

The student evaluation, shown in Fig. 3, of this scenario indicates that the project topic was liked and the students enjoyed the group work. The main issue with group work was the fairness of work allocation and reward for actual contribution to the project. More worryingly are the comments related to a lack of prior knowledge. However, within the scenario week most groups produced a working solution which tends to suggest that the scenario was pitched at the right level and they did in fact have sufficient knowledge to complete the task.

In this scenario, unbeknown to the students, the groups were engineered to have at least one strong programmer, based on the assignment results from the programming course. This strategy was chosen to maximize the potential for collaborative learning especially for the weaker programmers. Student feedback from their reflective commentaries indicates that this was particularly successful for developing the programming skills of the weaker programmers, and the team management skills of the stronger programmers as the following comments indicate.

Comment from strong student.

"As I do have previous programming experience I did my best to explain algorithms, object oriented programming, Java and general programming basics to the team members. It was a rewarding teaching experience, as most team members did understand my explanations and learnt from them."

Comments from weaker students.

"During the course of the scenario, I had the opportunity to learn from my group members as I approached them for help whenever I was stuck on a task."

"Once the Scenario B teams were announced, I instantly felt relieved. I was never good at programming to begin with and there in my group is 'student A', a good programmer and someone who really can get the job done. I now have a new insight into programming as I did not realise simple codes are enough to program something I presume as difficult."

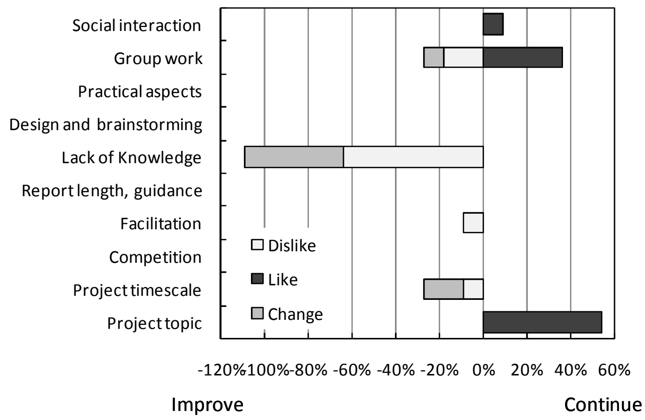

Figure 3. Scenario B: student response rate by theme (Total responses = 11). Note, the same categories used in figure 2 are used here for comparision.

However this did result in some issues with work load distribution and input into the project, with the more capable team members contributing far more. This scenario was designed to have elements suitable for the weaker students, more challenging elements for the stronger students. The problem with this is that the stronger students often perceive their contribution as been more significant to the project. To improve on this the testing of the software solutions will be designed to be more incremental, so that weaker groups will be able to meet some of the specifications and stronger groups will be challenged by the more advanced specifications. As with the previous scenario a few students would have liked it to be slightly longer.

C. Scenario Y: Due Diligence Report on Broadband Access Solutions

This scenario was introduced to the second year students in the form of a memo from the board of a company that was commissioning them to carry out a due diligence report on the technological, economic and social merits of three different technological solutions, and to inform the company which solution had the most potential.

This was a paper based study that required the students to use and apply their knowledge from the communications courses, and carryout further research into aspects of each technology. The introductory session included a presentation from an industrial expert who gave the students an overview of the problem and introduced some of the regulatory, economic and social issues involved in this problem.

The thought behind the design of this scenario was to give the students a free range and as such there were only two formal contact and evaluation sessions planned for the week as well as submission of a final group report. The first was an informal chat with each group on Tuesday afternoon at which they had been instructed to describe how they had organised themselves in terms of dividing the problem between the group members and their schedule for the week. The second was a 12 minute presentation to the board on the Thursday afternoon, where the board asked fairly challenging questions. There were also one hour facilitation sessions if the students wished to avail themselves of them on Monday afternoon, Tuesday and Thursday morning, however, few made use of these.

During the running of this scenario a number of things were learnt. Firstly, it was a observed that during the presentation from the industrial expert the students still appeared somewhat shell shocked by the task that had just been introduced and weren't altogether sure what they were meant to do or what relevance this presentation necessarily had to the task. Thus at the end of the presentation they did not ask many questions and as such did not make the best use of the opportunity.

Secondly, the Tuesday afternoon check point was intended to ensure that the students had thought about the issues involved and got themselves sufficiently organised to be able to meet the Thursday afternoon presentation deadline. Ideally they should have as a group developed a framework with which to analyze and compare the three company's technologies. In practice by this stage most of the groups had simply divided the tasks four ways using the obvious split of tasks, i.e. each company, and the social and economic impacts, as set out in the memo. This meant that rather than working as a team towards a common goal, they tended to immediately split the tasks and then retreat into their own silos to research and write their own sections of the presentation and final report. As a consequence both the presentation and the final group reports tended to be somewhat disjointed rather than a coherent piece of work that lead to a single conclusion. Thus in this project it is important that each group works together to create a well structured plan and schedules regular group meetings with all members present.

To ensure that the groups develop such a strategy and work as a team the following changes are planned. The first day will be much more structured. After the introduction the groups will have a group brain storming session before lunch, then the presentation from the industrial expert, a group reassessment session to incorporate what they have learnt from the expert presentation, followed by a formal feedback session with the facilitators. At the Tuesday checkpoint the students need to present the framework and criteria that they plan to use to assess the three solutions, along with a justification of the criteria chosen. This Justification will also be part of the final report.

VII. Conclusions

The trial has shown that it is realistic to complete a practical engineering design project - 'from concept to product', that both excites the students and enhances the material covered in lectures, within a week.

The use of staging and checkpoints throughout the week was particularly successful in guiding and providing feedback so that the students applied the knowledge and theory gained from lectures to the design problems. This was reflected in the quality of the reports, which are actually more important than the actual solution/device produced, far exceeding the expectations of the staff involved in assessing them. It was also reflected in the need to provide more structure in Scenario Y to encourage a more collaborative approach to the assessment of the technologies. Student feedback on the week long project timescale was also generally positive.

The group working aspects of the scenarios were particularly successful, despite the reservations, based around contribution, that come with using group work for summative assessment. The students particularly liked social aspects of this learning process. In particular, it was clear that the weaker students gained enormously by learning from their peers and the stronger ones learnt much about leading a team. Daily group progress meetings will be introduced in future scenarios to encourage a more collaborative approach. Peer assessment for moderation the individual marks will also be introduced to ensure that the credit received more accurately reflects the contributions of the individuals to the team performance.

The student feedback on the scenario topics, practical and design aspects was very positive. Their engagement and participation in the scenario weeks was high with the competitions generating a real excitement amongst the groups.

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