Scenario-based eLearning to promote active learning in large cohorts -Students' perspective

Abstract

This work presents results from an investigation on the students' perspective of the use of scenario-based (SBL) e-learning and their performance in a first-year core chemical engineering module in a Scottish university. SBL is a pedagogy that promotes active learning by bringing to the classroom practical and industrial experience. When combined with online delivery, SBL can be used to increase students' engagement in large cohorts. The scenario developed and used in this work was delivered via the Scenario-Based Learning Interactive (SBLi) tool. A survey was used to capture students' insights on the activity and the use of the software. These data were then analysed in combination with students' exam performance. Two cohorts with around 100 students each participated in this study over two years (with 91% response rate in the evaluation questionnaire). They indicate that students fully engaged with this form of learning as it links module content with real industrial applications. There is, however, a significant difference between female and male students in terms of the enjoyment they derived from the computer-based activity with male students preferring the activity over tutorials with opposite results for females. There is no relationship between the perceived level of difficulty of the scenario and the exam performance in either cohort. The majority of students identified that they developed their problem-solving and analytical skills through doing the scenario activity. In general, the students found the software difficult to use which suggests the need to explore other tools for the delivery of scenario-based activities.

Keywords

scenario-based learning; interactive learning environments; active learning; computer-based instruction; professional skills

1. Introduction

The Royal Academy of Engineering's report, Educating Engineers for the 21st Century,[1] concludes that industry needs graduates with "practical experience of real industrial environments" that can "apply theoretical knowledge to real industrial problems". Therefore, universities are urged to incorporate experience-led components in their courses. A more recent report by Lucas *et al.*[2] discusses the importance of using pedagogies that mimic the working habits of engineers in order to prepare students better for their career. Active learning methods, like scenario-based learning (SBL), can help to bridge the gap between university and professional knowledge by giving students exposure to the workplace realities using simulations of real work environments.[4,5] Additionally e-learning technologies can be particularly useful in implementing SBL as they offer flexibility and interactivity.[6] E-scenarios also allow self-pace learning and remote access to large number of students.

This work evaluates the enhancing of engineering students' learning experience in large classes by using scenario-based eLearning as an approach to develop skills for a workplace setting. The main aims of using a scenario were to motivate and engage students' in their learning, due to the fun, interactive and learner-centred nature of the activity, and to give the students an opportunity to develop higher order skills, through solving complex problems set in a real-world, messy environment.

The work uses the EMERGO toolkit,[7] based on serious games, to design an online scenario and Scenario-Based Learning Interactive (SBLi)[8] to develop and deploy the scenario to over 100 students simultaneously. We then investigate students' engagement, enjoyment and skills development. The research questions explored in this work are: a) whether students prefer online activities to others that are more traditional and, b) what is students' perception regarding the value of this online activity in relation to their skills development. These questions were explored via a questionnaire. This paper presents the analysis of students' preferences for online scenarios and their perception on their own skills development.

2. Background

It has been recognised for some time now that authentic activities are an important element in learning as they provide the learner with a reference point from which a practitioner will normally act.[9] Hence, a novice can learn concepts (knowledge) within the context of their use (action) from an expert and gradually acquire authentic expertise. This process of enculturation is a common approach in learning at all levels of society as people learn, through observation and practice, and then behave according to the social norms of the group they belong. According to Collins *et al.*,[10] the concept of 'cognitive apprenticeship', which is similar to the idea of craft apprenticeship, involves the development of knowledge through the continued use of authentic learning activities and social interactions so that students can be enculturated to practice. Brown *et al.*[9] further argue that disregarding the "situated nature of cognition" denies education of a useful purpose.

Lave and Wenger[11] proposed the theory of Situated Learning based on the idea that learning is a contextual process that occurs within complex social situations. Therefore, Situated Learning argues against the idea that knowledge can be acquired independently of the context in which it might be used. One of the challenges of considering knowledge as separate from action is that of transfer. Transfer refers to the use of knowledge in a situation that might require it (i.e. knowing when to use the abstract information acquired). Hernández-March *et al*.[3] reported that employers perceived practical application of knowledge ("practical training") as one of the weaknesses of university graduates. Situated Learning theory recognises cognition as part of the world experienced.[12] Therefore, it is contended that learning is a contextual process and that knowledge cannot be completely separated from the situation in which it will be used.

Situated Learning[11] provides a view on learning different from the one offered by other theories based on purely cognitive processes.[13] However, there is a large body of empirical evidence about learning which suggests that some skills might be better learned outside a social context as dealing with the social context will have a higher cognitive load on the learner.[14] It has been argued that the issues associated to the effectiveness of learning concepts in an abstract manner might be more indicative of the way in which instruction takes place in the classroom rather than of the actual idea of abstract instruction.[14]

Dahlgren *et al*.[15] compared students' transition to working life in three university programmes (i.e. Psychology, Political Sciences and Mechanical Engineering). They found that the Psychology programme seems to prepare students to enter directly into a work life, whereas in Engineering there still seems to be a gap in graduates' work readiness. The authors point that one clear difference between these two programme is the pedagogy used. The Engineering programme delivers core fundamental knowledge in the first two years through standard didactic approaches adding collaborative and project elements only in the final two years. On the other hand, the Psychology programme uses problem-based learning throughout the whole degree, starting in first year. Johri and Olds[16] provide ideas for bridging engineering education research and educational theories to classroom practices highlighting that it is key for educators to consider how to facilitate skills development through learning environments that prepare students for future workplaces.

Higher education has seen a significant shift from *teacher-centred* to *student-centred* (active learning) approaches in teaching and learning. Additionally, the rapid change in information technologies and the increasing presence of 'the digital' offer opportunities for incorporating e-technologies within learning methods. Coller and Scott[17] reported that students taking a game-based module, as opposed to a lecture-based module, are more engaged with the material and have deeper learning experiences. The authenticity of the tasks makes the students think and behave similarly to the way a professional does. Hasna[18] argued that education in chemical engineering needs to embrace eLearning in order to reflect industry realities and to help deal with "apathetic students". The paper further argued that this will help change the students' mindset from being students to becoming graduate engineers. Rashid and Ventura-Medina[19] found that SBL is a good pedagogy to motivate students to learn and develop their problem solving skills. Therefore, mixing active learning and digital tools in pedagogical approaches could have tremendous potential for developing not only the contextual disciplinary knowledge but also transferable skills required in graduates.

3. Method

This paper explores the use of SBL delivered via SBLi to 248 first-year chemical engineering students over two years in a Scottish university. The e-scenario developed covers chemical engineering basic principles applied to a gas-processing industrial setting. This section presents the design and the development of the online scenario (section 3.1), a summary of how the scenario was delivered and evaluated (sections 3.2 and 3.3), and a description of how the data collected were analysed (section 3.4). Please note that, throughout the paper, the words "class" and "module" are used interchangeably.

3.1 Online scenario design and development

This section describes the design framework and the methodology used for developing the scenario. The aim of the scenario was to mimic the realities of an engineer working in an industrial environment. Therefore, engineers currently working in an industrial setting were consulted about relevant topics and issues that could be used for the case study development. This consultation with industry provided the basis for a theme on which various scenarios could be developed so that they would fit different disciplinary content within engineering. The topic chosen for the development of the scenario presented here fits the key learning objectives of a first-year chemical engineering class.

The scenario was developed taking into account the students' perspective in the learning process by including in the design team a senior chemical engineering student with previous industrial experience. The staff responsible for the delivery of the class were also involved in the design and development process to ensure that the learning objectives of the modules were aligned with the scenario activity. These three perspectives, industry, students and academics, provided a rounded view to inform the scenario design.

The ideas were developed considering that the application of games to learning can be useful to design online scenarios. EMERGO, the methodology proposed by Nadolski and co-workers[7] to create "scenario-based serious games", was used in this work. EMERGO considers different stages in building scenarios as shown in Figure 1.

[Figure from file "Figure 1" here]

The EMERGO methodology suggests that the development starts with the analysis of the need, requirements and alternatives that help shape the Case Idea. This is then followed by establishing the framework for the scenario with a description in greater detail of the activities associated to the scenario and the context in which these are placed (Case Scenario). A storyboard emerges at this point allowing to progress to the Case Development stage that follows.

The Case Development is in general the point in which all materials, actions and outcomes are incorporated in the scenario delivery platform to create the scenario itself. This stage also requires testing of the functionalities and the scenario to ensure that it works as intended. The following stage is the implementation stage at which point the scenario is delivered or deployed for students to use (Case Delivery). Once this stage has been completed then the final stage of the overall development takes place with the Case Evaluation of the scenario. This final stage helps to establish if the scenario worked as intended and whether or not it fulfilled the requirements set in the Case Idea stage.

The Case Idea used in this study was based on the design of a gas terminal in a development project associated with the exploitation of a new gas field. The extracted gas, mostly methane, is piped from the wells to the onshore gas terminal, where it is processed. The Case Scenario deals with the design of the gas storage area, looking at safety and environmental considerations in case of an emergency that requires the relief system to be activated. The storyboard emerging in this scenario places the student in the role of an engineering intern solving technical problems. Through a series of tasks within the scenario, which included interpretations of process flow diagrams and use of relevant data, the intern has to make assumptions using 'engineering common sense'[20] whereby concepts such as pollution and safety have also to be considered. This also provides an opportunity for the student to apply a 'systems approach' to the problem. The scenario was aligned with the intended learning outcomes (LOs) for the chemical engineering class, in particular those based on performing calculations that are fundamental in the discipline (e.g., material and energy balances) and requiring the use and interpretation of information from engineering diagrams.

The LOs relevant to the scenario were stated as:

LO1: Understand the importance of mass balances in chemical engineering systems and be able to perform appropriate mass balances for system information provided;

LO2: Understand the importance of energy balances in chemical engineering systems and be able to perform appropriate energy balances from system information provided;

LO3: Understand how to interpret process flow diagrams provided, including being able to construct and annotate such diagrams.

The chosen SBLi tool affects the Case Development stage and has a bearing on the Case Delivery. There are several tools available to deploy online scenarios such as Moodle Lesson, MS Office PowerPoint, SBLi and the EMERGO toolkit. The SBLi was the tool of choice in this work due to its user-friendly navigation and the fact that it can be used both offline and web-based.[21] Moodle Lesson and PowerPoint do not allow the user to have an overview of the scenario locations other than the current view, which makes the navigation of the scenario difficult. SBLi and EMERGO, applications that have been developed for online scenario delivery, offer more user-friendly interfaces. All four tools can deploy web-based scenarios, but only SBLi and MS Office PowerPoint can also be used offline.

The Case Development involved the creation of media files (pictures, videos, audio and documents) which were then embedded in the SBLi platform chosen for scenario delivery. Questions related to the tasks were also embedded throughout the scenario as a self-assessment tool for the students.

Screenshots of the SBLi interface for this scenario are shown in Figure 2. The SBLi interface consists of four windows that allow navigation through the scenario (see Figure 2-a):

- the top left window (Location window) shows all the locations available in the scenario,
- the top right window (Environment window) shows the current location,
- the bottom left window (Actions/Collections window) has the list of possible actions and collected items,

- the bottom right window (Content window) displays instructions and information relevant to the current location.

[Figure from file "Figure 2" here]

This technique can be translated to any discipline and any industry setting after properly researching problems that are relevant to the specific context and that are aligned with the expected learning outcomes of the course.[22] Once the case has been defined (Case Idea, Case Scenario), the developer of the scenario will require to be acquainted with the chosen software platform to implement and deliver the activity.

The Case Delivery and Case Evaluation are now described in detail in the following sections (3.2 and 3.3).

3.2 Scenario Delivery

The scenario was delivered to undergraduate students at a Scottish university, as part of a first-year class on "Basic Principles in Chemical Engineering", in 2016 and 2017. Approximately 80% of the students taking this class were enrolled in the Chemical Engineering Department, while the remaining students were enrolled in the Chemistry Department. The scenarios are one part of the class activities and complement other work that the students do in tutorials and lectures.

The scenarios were distributed through the SBLi player available in university computers. The scenario activity was delivered in a computer cluster (one computer per student) in the last timetabled tutorial of the semester, in preparation for the final exam. All instructions on how to use the software were given within the online scenario, right at the beginning, including a brief explanation of the SBLi interface (Figure 2) and how to navigate through the scenario. Reading through these instructions was a prerequisite for starting the scenario. Even though the activity did not have any weight in the final mark for the module and attendance was not compulsory, the attendance to the activity was high: 93% in both 2016 (137 students participating) and 2017 (111 students participating).

The scenario was completed by 90% of the students in 1 hour and a half. As the scenario was not delivered through a web-based interface, it was not possible to track scenario completion using the SBLi software. Therefore, students were asked to submit screenshots of intermediate scenario steps as evidence of their progress. Over 99% of the students taking part in the activity submitted the screenshots, and stayed until they finished the scenario.

Three lecturers supervised and supported the learners during the duration of the Case Delivery. During the activity, the students were free to collaborate with other students or to consult the lecturers. Three members of staff carried out informal observations of the activity. They agreed that there was a high level of interaction between students during the scenario activity and that most students were engaged and on task, discussing methods to proceed through the scenario.

3.3 Scenario Evaluation

The Case Evaluation was carried out using an online student questionnaire following scenario completion and students' marks in the class final exam. The constructs explored in the questionnaire were based on the EMERGO toolkit[7] for scenario evaluation. The departmental ethics committee granted ethical approval for the study.

The questionnaire was used to explore the students' preference for online activities and their perception on the value of this specific activity in their skills development. As an exploratory questionnaire the aim was to gather information on opinions and preferences without a hypothesis to test.[23]

A number of evaluation methods and instruments are available in the literature in relation to SBL implementations. However, the focus of the majority of these evaluations is about the usability of online scenarios.[24-27]

Focusing on students' attitudes towards online scenarios, Tait *et al*.[28] have used a questionnaire with five constructs (ease-of-use, interactivity, realism, confidence, overall attitude) to evaluate the use of an e-learning scenario in nursing education. However, Tait's study did not capture the full range of aspects explored in the current study (e.g., skills development). Therefore, a questionnaire for three constructs (engagement, enjoyment and preferences; skills development; software user-friendliness and overall scenario) was developed.

The questionnaire consisted of a combination of sliding-scale questions (scale from 0 to 10), multiple-choice questions (one or multiple selection), open-ended questions and five-point Likert-scale statements (Strongly Disagree (SD), Disagree (D), Neither Agree Nor Disagree (NAND), Agree (A), Strongly Agree (SA)). The questionnaire also collected students' demographic data identifying their first language, student status (overseas or home student), gender and age, as well as programme of enrolment.

All students were asked to complete the questionnaire immediately after finishing the scenario in order to collect a large sample of data that would be representative of the cross section of the student population. This will help in supporting any generalizations or relationships regarding students' preferences and opinions and in turn inform future practices and research.

This paper focuses on the results from the questions presented in Table 1. Although the questionnaire could be done anonymously, students were asked to provide their registration number to link their exam mark to questionnaire results for the purpose of the Case Evaluation. Those results are presented in section 4.

[Table 1 here]

3.4 Data analysis

This section describes the data analysis methods used with the results from the evaluation questionnaire. No analysis was done on results from open-ended questions.

The Likert-scale responses were coded from 1 to 5 (SD – 1, D – 2, NAND – 3, A – 4, SA – 5) for data analysis.

Cronbach's alpha for 2016 and 2017 questionnaire responses combined (228 responses) was used as a measure of internal consistency for the three different constructs shown in Table 1 (Table 2). Nunnally[29] suggests that alpha should have a minimum value of 0.7 in exploratory research and 0.8 in basic research. The values of Cronbach's alpha in Table 2 were all above 0.8 showing a high level of internal consistency.

Insert [Table 2] here

Cronbach's alpha for Q19 to Q22 was calculated separately from Q17 and Q18, as these two questions had a different scale. For Q19-Q22, Cronbach's alpha was 0.70. It was noticed that removal of Q22 would increase Cronbach's alpha to 0.81. Q22 assessed students' perception of the scenario difficulty while Q19-Q21 assessed an overall evaluation of the scenario, software or activity. The value of the correlation of Q22 with the summated scores of Q19-Q21 was low (0.11), indicating that Q22 is not measuring what Q19-Q21 are.

Cronbach's alpha was not calculated for Q17 and Q18 as Eisinga *et al.*[30] reported that coefficient alpha is inappropriate for a two-item scale. Instead, Spearman's rho correlation coefficient was calculated and found to be 0.73, indicating a strong relationship[31] between Q17 and Q18. The correlation between these two items was statistically significant (two-tailed, $p<0.001$). Spearman's rho was used as the Likert-scale items have an ordinal scale and thus non-parametric tests are more appropriate.[32]

A preliminary data analysis was performed using single-item bar charts, diverging stacked bar charts and mean and standard deviation. Single-type item distributions were produced and compared for Likert-type questions. Harpe[33] reports that item-by-item analyses may be acceptable during questionnaire development as long as formal inference at the item level is not performed. The 5-point Likert scale data are shown in figures to show the distribution of the scores, as the data are ordinal in nature. Likert-type responses were also presented using diverging stacked bar charts, as suggested by Robbins and Heiberger.[34] For sliding scale questions (Q19-Q22) mean and standard deviation were calculated. As Q19-Q22 data are interval data, it was felt that reporting their mean and standard deviation was an appropriate way to summarise them, and it was more succinct and immediate than showing the distribution in a graph.

For each of the three constructs measured using a Likert-scale, summated (aggregated) scales were calculated for Q1-Q6 (Construct 1), Q7-Q15 (Construct 2), Q17-Q18 (Construct 3). The Kolmogorov-Smirnov test was used to check the normality of the distributions. The significance value was less than 0.05 for all sets of summated scales confirming that all distributions were not normal. Therefore, the non-parametric Mann-Whitney (MW) U-test was used to test for statistical significance ($p<0.05$) either for single item comparison[32] or for summated scale comparison.[28] Q12 and Q19 to Q22 were further analysed to search for any trends with students' exam marks.

4. Results and Discussion

This section presents results of the students' evaluation questionnaire and class performance in the exam. The questionnaire completion rate was 96% in 2016 and 85% in 2017. Table 3 shows the demographic composition of the 2016 and 2017 cohorts. Some questions have a number of responses higher than nq, the number of completed questionnaires.

[Table 3 here]

The students were asked if they had any previous experience with SBL activities. In both 2016 and 2017 above 84% of the respondents said they did not have any previous experience.

The 2016 summated (aggregated) scores for Q1-Q6, Q7-Q15 and Q17-Q18 were compared to the 2017 scores using the MW U-test. There were no statistically significant differences between 2016 and 2017. These results further confirm the reliability of the questionnaire.

4.1 Students' Engagement, Enjoyment and Preferences

The students' perception in terms of enjoying the activity was appraised by Q1 to Q6 (see Table 1). Figure 3 shows the Likert scale results for the Strongly Disagree (SD) and Disagree (D), Strongly Agree (SA) and Agree (A). The percentage for Neither Agree Nor Disagree (NAND) can be calculated as difference. The figure shows that the results are similar for 2016 and 2017.

[Figure from file "Figure 3" here]

The data in figure 3 show that the students responded very positively to the use of the scenario and reported it to be enjoyable and engaging:

- Over 83% found scenarios to be an engaging way of supporting the learning of the class material (Q4)
- Over 75% of students enjoyed the scenario because of its real-life component (Q5)
- Over 70% in 2017 and over 60% in 2016 found the scenario to be an enjoyable learning experience (Q6)

The majority of students (over 65%) would like other classes to use scenarios as a learning resource (Q2) and over 55% of the students felt that scenarios should be a compulsory activity in the class (Q3). However, only about 45% of students prefer scenarios to traditional tutorial problems. Therefore, it seems that students do not want to abandon the traditional style of practice (i.e. tutorials) but would like to use scenarios as an extra resource, in addition to tutorial problems, and would like other classes to make use of scenarios. These results are evidence that students appreciate having a variety of learning resources.

Our results agree with those found in the literature. Breakey *et al*.[35] reported that the majority of students thought that the online scenario was a useful addition to the course and they particularly enjoyed the interactive aspect of the activity. Naser-ud-din[36] reported high acceptance rate of the SBLi scenario and great interest of students towards this type of learning. Blackburn[37] noticed an increase in students' engagement and participation and the data gathered suggest that using the scenario as a teaching tool was an enjoyable experience for the students. Siddiqui *et al*.[38] observed an increase in students' motivation after using simulation-based e-scenarios.

4.2 Students' Perception to their Skills Development

The students' perception of how the scenario activity developed their skills was appraised in the Likert Q7 to Q15 (see Table 1). Figure 4 shows the Likert scale results. Once again, the results are similar for 2016 and 2017.

[Figure from file "Figure 4" here]

The data in figure 4 show that the majority of students felt that the scenario activity was useful in terms of improving their learning skills and their understanding of the class material:

- Over 60% of the students felt that the scenario enhanced their learning in the class (Q7)
- Over 75% of the students felt that the scenario helped them to consolidate their understanding of the class content (Q8).

Students in this study have the perception that the use of the online scenario positively impacted their learning (Q7 and Q8) contrary to what was reported by Seddon *et al.*[39]

The responses to the following statements:

- "In order to proceed through the scenario I had to reflect on what I knew" (Q13)
- "I found the use of the scenario a helpful way of improving my problem solving skills" (Q11)
- "My ability to analyse problems and situations improved as a consequence of doing the scenario exercise" (Q14)
- "My problem solving skills were improved as a consequence of doing the scenarios" (Q15)

show that over 70% of the students felt that the scenario had developed their higher-order thinking skills, such as problem solving, reflection and analysis. In particular, the response to the statement in Q13 shows that over 90% of the students agreed or strongly agreed that they had to reflect on what they knew. This indicates that students had to be actively engaged throughout the activity, and could not work mechanically through it. The responses to the other three statements also produced similar results in responses, thus confirming the reliability of the survey results.

The scenario was developed as a consolidation tool to reinforce and link concepts already covered in the lectures. Nevertheless, according to the results given by Q12 ("In order to proceed through the scenario I had to learn new concepts") about half the cohort agreed or strongly agreed that they had to learn new concepts while doing the scenario. This could be an indication of the different level of expertise of the student who developed the scenario, a 5th-year student with a good grasp of Chemical Engineering concepts, and the level of expertise of some 1st year students, who might not realise that some concepts are broad and can be used to answer different questions, or can be applied to problems that, at first sight, might look unfamiliar. Similarly, as the theory of Situated Learning indicates, if the concepts were learnt earlier in the semester in a context further removed from engineering practice, students could now fail to see their application in a more practical context. Table 4 shows the mean exam mark (which counts for 70% of the class overall mark) for each Likert category for Q12 in 2016 and 2017. In 2017 it seems that the weaker students (lower exam mark) agreed that they learned new concepts while doing the scenario, while the stronger students were already comfortable with the concepts used in the scenario and did not perceive them as new. However, the same data for 2016 do not show any trends with respect to the Likert categories chosen for Q12.

[Table 4 here]

The scenario was built around an industrial application. The real-world element was appreciated by the students:

- Over 90% of students agreed that the scenario helped them to see connections between lecture content and engineering practice (Q10)
- Over 60% in 2017 and over 70% in 2016 were interested in finding out more about relevant industrial applications as a consequence of doing the scenario (Q9).

With regard to the type of skills that were developed by using the scenario, Figure 5 shows the results from Q16: "From the list below select the thing(s) that you developed by doing the scenario". The students were allowed to choose one or more options among: Problems Solving, Analysis, Application of Concepts, Careful Reading, Selecting Relevant Information, Knowing what Formula to Use, Decision Making, Reflecting on Conclusions.

[Figure from file "Figure 5" here]

The results are similar for 2016 and 2017. In both years the highest scoring skill, chosen by over 75% of the students, was "Problem solving", followed by "Analysis", chosen by about 70% of the students. "Application of Concepts", "Careful Reading", "Selecting Relevant Information" and "Knowing which Formula to Use" were chosen by 55 to 70 % of the students.

"Decision Making" and "Reflecting on Conclusions", which are related to the higher learning objectives in Bloom's taxonomy,[40] such as Synthesis and Evaluation, were chosen by less than 40% of the students. The authors feel that the scenario was built so that students were constantly asked to make decisions, so it is somewhat surprising that the students felt that they did not develop "Decision making" while doing the scenario. It might be that the students' perception of the meaning of "Decision Making" is different from the authors', and might have thought that they were not making decisions as their decisions did not have a big impact on the overall scenario.

Our results agree with the literature: students' cognitive skills are perceived, either by students or by tutors, to have improved after using scenarios. Blackburn[37] reported that the scenario had a positive influence on student understanding of subject matter. Rashid and Ventura-Medina[19] gathered students' views after delivery of an e-scenario. Students felt that the scenario made them improve problem solving, critical thinking and decision-making skills. Siddiqui *et al.*[38] used simulation-based e-scenarios. They observed, from questioning the students, that students applied basic cognitive skills (such as knowledge, comprehension and application) and a few of them were able to use intermediate cognitive skills, such as analysis.

4.3 Overall Software and Scenario Evaluation

The students were asked to give their opinion on how user-friendly the scenario (Q17) and the SBLi software (Q18) were. Figure 6 shows the results for these two questions. The students were not satisfied with the navigability of the scenario and SBLi software.

[Figure from file "Figure 6" here]

The results of the Likert-scale questions were generally similar for 2016 and 2017, but it seems that the 2017 cohort found both the scenario and the SBLi software more difficult to navigate and use than the 2016 cohort. These results are in agreement with those shown for Q1 (Figure 3) that indicate that the 2017 cohort received the scenario activity less positively than the 2016 cohort.

An overall evaluation of the SBLi software and scenario was carried out with the sliding scale questions, Q19 to Q22 (see Table 1). Table 5 shows the mean and standard deviation of the results of Q19 to Q22 for 2016 and 2017.

[Table 5 here]

The scores suggest that the scenario activity was well received by the students (with a score of about 7 out of 10 for Q20), but the SBLi software did not score as high (only about 6 out of 10 for Q19). This result agrees with the findings for Q17 ("The scenario was clear to navigate") and Q18 ("The SBLi software was easy to use"), shown in Figure 6, for which about 25-35 % of the students disagreed with the statements. The scenario activity might be improved if a different kind of software was used as the interface for the scenario. Despite this issue, the students had a positive overall experience, rating it at about 7 out of 10 (Q21).

Table 5 shows that the mean scores in 2016 are similar to those in 2017, except for Q22. Hence, the MW U-test was carried out for Q22. The results show that the 2016 and 2017 medians were statistically different ($p<0.05$). On average, the students found the scenario slightly difficult, giving a median score of 7 out of 10 in 2016 and median score of 6 out of 10 in 2017.

The results of Q19 to Q22 where analysed further. For each year, the students were grouped depending on their examination marks (mark boundaries in percentage: 30 to 49, 50 to 59, 60 to 69 and 70 to 100). These mark boundaries reflect the UK undergraduate grading system: 70% + is First class, 60-69% is Upper Second class, 50-59% is Lower Second class, 40-49% is Third class and below 40% is a fail. Third class and fail were combined because of the small data sample size for these mark ranges. Box plots were generated for the scores in Q19 to Q22 for each group to explore any relationship between students' ability and scores in each question. The box plots for 2016 and 2017 are shown in Figures 7 and 8 respectively. No relationship between scores and students' exam marks was observed in the four sliding questions. This result shows that the scenario activity caters well for all students, irrespective of their ability. This is in agreement with previous work reporting that SBL improves learning in both high and low ability students.[39]

[Figure from file "Figure 7" here]

[Figure from file “Figure 8” here]

4.4 Gender Differences

The results of the Likert-scale questions for 2016 and 2017 results were combined and bar charts produced to compare the distribution of responses for females and for males. In 2017, four students did not disclose their gender in the survey. The number of responses for these are given in Table 6.

[Table 6 here]

There were no clear differences between females and males' bar charts except for Q17, Q18, Q1 and Q3 (Figure 9):

Q17 - The scenario was clear to navigate
Q18 - The SBLi software was easy to use
Q1 - I prefer the use of scenarios more than tutorial problems
Q3 - This scenario or similar ones should be a compulsory activity as part of the class

Figure 9 shows the bar charts for Q17, Q18, Q1 and Q3. From Figure 9c (Q1) it seems that males prefer scenarios, over tutorial problems, more than females. Figure 9d (Q3) agrees with Figure 9c (Q1), as it seems that males prefer to make the scenario a compulsory activity more than females.

[Figure from file “Figure 9” here]

Following this observation, a one-sided MW-U test was performed for the summated scale for Q1-Q6 (2016 and 2017 scores combined). The test was significant ($p< 0.05$) thus confirming that the distribution of males' scores is towards more positive answers (SA and A) for Construct 1 (Students' engagement, enjoyment and preferences).

Figure 9b (Q18) and Figure 9a (Q17) seem to indicate that females found the SBLi software easier to use and the scenario clearer to navigate, respectively, when compared to males.

A one-sided MW-U test was performed for the summated scale for Q17-Q18 (2016 and 2017 scores combined). The test was significant ($p<0.05$) thus confirming that the distribution of females' scores is towards more positive answers (SA and A) for Construct 3 (Software user-friendliness and overall scenario). Therefore, it seems that females' “dislike” for scenarios is not due to difficulties in using the SBLi software or the scenario. Cai *et al.*[41] discussed in their meta-analysis that, even with the pervasive presence of technology in recent years, literature indicates that males show a more positive attitude towards technology than females, in particular in relation to their confidence in using it (self-efficacy) and the societal use of technology (belief). Our results agree with those presented by Cai *et al.*[41] in terms of the more favourable attitude towards technology of males when compared to female students. However, our results indicate that this difference is not due to a difference in self-efficacy as measured by how difficult students found the scenario.

A two-sided MW-U test was performed for Q22 to detect differences between males and females (2016 and 2017 data combined) and no significant statistical difference ($p<0.05$) was found. Therefore, in our case, both female and male students found the scenario equally difficult.

5. Conclusions

An industrial-based scenario was successfully used as a learning activity in a first-year engineering class allowing to explore students' engagement with online scenario-based learning and students' perception on skills development. The scenario, which was designed using the EMERGO toolkit for serious-games and delivered via the SBLi tool, was evaluated via a questionnaire and students' performance in the class for two cohorts of students in 2016 and 2017.

In general very similar results were found in both sets of data for the 2016 and 2017 cohorts with around 100 students each. The results of the evaluation questionnaire show that students appreciate a variety of resources as part of their learning activities. The majority of students enjoyed learning with the scenario activity, mostly because of its real-life context, and indicated they would like to have more scenarios as an extra activity alongside tutorials. However, it was interesting to find that there was a difference in levels of enjoyment of the activity between the female and male students with the latter reporting a preference for the scenario over the tutorial problems in contrast with their female counterparts.

In terms of the students' perception regarding their skills development, the majority of students saw the scenario as a way to consolidate their knowledge and enhance their skills. Results show that students were actively engaged while doing the scenario and had to use reflection, draw on previous knowledge and connect concepts in order to progress the solution of the problem presented in the scenario. For the 2017 data, students' perception on whether or not concepts used in the scenario were new seems to be related to their exam performance, with weaker performers perceiving that the scenario included new concepts and stronger performers seeing it more of a consolidation activity. The fact that the scenario connects lecture content and real-world engineering applications seems to enthuse students to find out more about industrial practice. The majority of the students (over 70%) perceived that 'Problem solving' and 'Analysis' were the skills they developed the most by doing the scenario.

Although the results are supportive of the use of scenarios as a key element to deliver disciplinary knowledge in a practical context, it is important to note that this study did not measure directly cognitive development. The results presented here are students' self-reports based on their own perception of their learning. Therefore, any future addition of online scenarios in this course would be only considered as activities supporting rather than substituting current delivery. Likewise, it is difficult to draw conclusions about the advantages of contextual learning over abstract learning.

In terms of wider teaching practice, it is important to mention that to ascertain how the use online scenarios might impact on students' learning it will be necessary to monitor directly students' level of engagement (e.g., time spent, decision making processes) with the activities.

This requirement places a demand on the scenario delivery platform as it needs to be capable of capturing students' interactions while doing the activity.

Our results indicate that the scenario was not always clear to navigate and the SBLi software was somehow difficult to use. This suggests that a different software interface to develop and deliver scenarios may need to be considered in future.

Overall, the students found the activity a positive learning experience regardless of their level of performance in the class. The fact that the vast majority (93% of the cohort) of students participated in the activity and its evaluation (91% of the activity participants) gives confidence in the validity of the results (225 questionnaire responses).

Finally, the successful design, implementation and delivery of online scenarios places significant demands on resources (e.g., staff time, technology access and support). In this regard, it is essential to select a platform that can provide a good user experience and it is stable to ensure the long-term sustainability of this approach.

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Tables

Table 1: List of questions/statements included in the evaluation questionnaire. Key of type of question: (L) - Likert, (S) - Sliding, (M) - Multiple choice, (O) - Open-ended

Construct	**Questions/Statements**
Students' engagement, enjoyment and preferences	● Q1 - I prefer the use of scenarios more than tutorial problems (L) ● Q2 - I would like other classes to use scenarios as a learning resource (L) ● Q3 - This scenario or similar ones should be a compulsory activity as part of the class (L) ● Q4 - The scenario is an engaging way of supporting the learning of the class material (L) ● Q5 - I enjoyed the scenario because it had a real life component (L) ● Q6 - Doing the scenario was an enjoyable learning experience (L)
Skills development	● Q7 - The scenario enhanced my learning in this class (L) ● Q8 - The scenario helped me to consolidate my understanding of the class content (L) ● Q9 - As a result of doing the scenario, I am now interested in finding more about relevant industrial application (L) ● Q10 - The scenario helped me to see connections between lecture content and engineering practice (L) ● Q11 - I found the use of the scenario a helpful way of improving my problem solving skills (L) ● Q12 - In order to proceed through the scenario I had to learn new concepts (L) ● Q13 - In order to proceed through the scenario I had to reflect on what I knew (L) ● Q14 - My ability to analyse problems and situations improved as a consequence of doing the scenario exercise (L) ● Q15 - My problem solving skills were improved as a consequence of doing the scenarios (L) ● Q16: "From the list below select the thing(s) that you developed by doing the scenario" (one or more options): Problem solving, Analysis, Application of concepts, Careful reading, Selecting relevant information, Knowing what formula to use, Decision making, Reflecting on conclusions (M, O)
Software user-friendliness and overall scenario	● Q17 - The scenario was clear to navigate (L) ● Q18 - The SBLi software was easy to use (L) ● Q19: If you were to review this activity, what score would you give out of 10 to the SBLi software? (S) ● Q20: If you were to review this activity, what score would you give out of 10 to the scenario? (S) ● Q21: If you were to review this activity, what score would you give out of 10 to the experience overall (S) ● Q22: What score would you give to the level of difficulty of the scenario content (0 being too simplistic and 10 too difficult)? (S)

Table 2: Cronbach's alpha for responses to 2016 and 2017 (combined) questionnaires

Questions	Aspect	Cronbach's alpha
Q1-Q6	Students' engagement, enjoyment and preferences	0.86
Q7-Q15	Skills development	0.85
Q19-Q21	Software and overall scenario evaluation (11 point sliding scale)	0.81

Table 3: Key characteristics of the students in 2016 and 2017 (n=number of participants in the activity, nq=number of completed questionnaires)

		2016	**2017**
	n	137	111
	nq	131	94
Gender	F	31 %	31 %
	M	69 %	69 %
Age	17-21 years	98 %	99 %
	22-26 years	2 %	1 %
Student status	UK	97 %	96 %
	European	3 %	1 %
	Overseas	0 %	3 %
First language	English	95 %	94 %
	Other	5 %	6 %

Table 4: Mean and standard deviation (StD) of exam marks out of 100 for students answering in each of the Likert categories for Q12 in 2016 and 2017 (D/SD Disagree/Strongly Disagree; NAND Neither Agree Nor Disagree; A Agree; SA Strongly Agree). (n=number of respondents for each category)

	2016			**2017**		
	n	mean	StD	n	mean	StD
D/SD	27	70	15	9	72	15
NAND	34	73	18	38	63	16
A	57	68	14	41	63	18
SA	13	69	20	6	50	23

Table 5: Mean and standard deviation (StD) of the results from the sliding scale questions Q19 to Q22, for 2016 and 2017 (n=number of questionnaire respondents)

	2016 (n=132)		**2017 (n=96)**	
	Mean	StD	Mean	StD
Q19	6.21	1.98	5.90	1.91
Q20	7.02	1.56	7.06	1.79
Q21	6.94	1.55	6.71	1.87
Q22	7.01	1.39	6.24	1.37

Table 6: Number of questionnaire responses for females and males in 2016 and 2017

Year	**Females**	**Males**
2016	41	91
2017	29	68
2016 and 2017	70	159

Figure Legends

Figure 1: Stages of the scenario-based serious games methodology (EMERGO) as proposed by Nadolski *et al.*[7] The development considers possibilities for iterations at any stage.

Figure 2: Screenshots of the SBLi interface for this scenario. **(a)** shows the introductory screen for the scenario with instructions for familiarisation with the interface and for navigation. **(b)** shows an example of a task within a location. **(c)** shows an example of a self-assessment question. **(d)** shows the feedback to the self-assessment question.

Figure 3: Students' enjoyment of the activity for: **(a)** 2016 (132 respondents) and **(b)** (2017) (97 respondents). The x-axis shows on the left-hand side the percentage for Strongly Disagree (SD) and Disagree (D) and on the right-hand side the percentage for Strongly Agree (SA) and Agree (A). The percentage for Neither Agree Nor Disagree (NAND) is not shown, but can be calculated by difference.

Figure 4: Students' perception of how the scenario activity developed their skills for: **(a)** 2016 (132 respondents) and **(b)** (2017) (97 respondents). The x-axis shows on the left-hand side the percentage for Strongly Disagree (SD) and Disagree (D) and on the right-hand side the percentage for Strongly Agree (SA) and Agree (A). The percentage for Neither Agree Nor Disagree (NAND) is not shown, but can be calculated by difference.

Figure 5: Students' opinion of which type of skills were developed by using the scenario. Results for 2016 and 2017 for Q16 "From the list below select the thing(s) that you developed by doing the scenario (you can select one or more option(s))". The x-axis is the percentage of participants that chose that particular option, out of the total number of participants (132 in 2016 and 97 in 2017).

Figure 6: Students opinion with regards to how user-friendly was the scenario (Q17) and the SBLi software (Q18) for: **(a)** 2016 (132 respondents) and **(b)** (2017) (97 respondents). The x-axis shows on the left-hand side the percentage for Strongly Disagree (SD) and Disagree (D) and on the right-hand side the percentage for Strongly Agree (SA) and Agree (A). The percentage for Neither Agree Nor Disagree (NAND) is not shown, but can be calculated by difference.

Figure 7: Students' ability and scores for questions Q19 to Q22 for 2016. **(a)** Box plot for Q19 results. **(b)** Box plot for Q20 results. **(c)** Box plot for Q21 results. **(d)** Box plot for Q22 results. The question scores were grouped depending on different exam marks (mark boundaries given under each box: 30-49, 50-59, 60-69, 70-100). There were 15 students with marks 30-49, 19 students with marks 50-59, 26 students with marks 60-69, 71 students with marks 70-97. The black dot is the mean of the data in each box.

Figure 8: Students' ability and scores for questions Q19 to Q22 for 2017. **(a)** Box plot for Q19 results. **(b)** Box plot for Q20 results. **(c)** Box plot for Q21 results. **(d)** Box plot for Q22 results. The question scores were grouped depending on different exam marks (mark boundaries given under each box: 30-49, 50-59, 60-69, 70-100). There were 22 students with marks 30-49, 15 students with marks 50-59, 24 students with marks 60-69, 33 students with marks 70-97. The black dot is the mean of the data in each box.

Figure 9: Comparison between females and males responses for Q17 **(a)**, Q18**(b)**, Q1**(c)**, Q3**(d)** (2016 and 2017 results combined). The x-axis shows the Likert-scale choice (SD=strongly disagree; D=disagree; NAND=neither agree nor disagree; A=agree; SA=strongly agree) and the y-axis the % of females (out of a total of 70) and the % of males (out of a total of 159).