SCENARIO BASED E-LEARNING TO IMPROVE PROBLEM SOLVING SKILLS

Usman Rashid and Esther Ventura-Medina.
School of Chemical Engineering and Analytical Science, The University of Manchester, United Kingdom
Corresponding Author Email: e.ventura-medina@manchester.ac.uk

BACKGROUND
Scenario based e-learning combines problem based learning with e-learning to provide interactive scenarios in a real life context that cannot be achieved through problem based learning or tutorial problems alone. This gives students the opportunity to develop their problem solving skills and knowledge whilst bridging the gap between a discipline and its practical applications in industry. Scenario based e-learning can address the challenge of motivating students as interactive scenarios are far more involving than tutorial problems and can show the practical applications of knowledge.

PURPOSE
This work explores whether or not the implementation of an innovative application of scenario based e-learning in the current provision of teaching and learning in the undergraduate Chemical Engineering programmes at CEAS can help to enhance the student's problem solving skills, motivation and understanding of engineering concepts.

DESIGN/METHOD
Two interactive chemical engineering scenarios were designed, developed and delivered to 220 undergraduate first year chemical engineering students. An innovative e-learning tool, SBLi, was used to develop the interactive scenarios in a chemical engineering industrial context. The scenarios covered course content from three undergraduate units, Chemical Engineering Design, Chemical Reaction Engineering and Transport Phenomena. The effectiveness of SBLi was evaluated through student's feedback questionnaires and individual interviews.

RESULTS
Feedback was collected through questionnaires and individual interviews from the students to evaluate the performance of scenario based e-learning. The feedback collected from students in this work showed that 85% of students thought the scenarios helped improved their chemical engineering knowledge and that it should be used in teaching chemical engineering. 82% of the students agreed or strongly agreed the scenarios had improved their problem solving skills. Students also found the exercise enjoyable and motivating.

CONCLUSIONS
The results of questionnaires and individual interviews showed that scenario based e-learning is a very powerful way of motivating students, improving their problem solving skills and enhancing their understanding of chemical engineering concepts.

KEYWORDS
Scenario-based learning, e-learning, problem-based learning.

Introduction

A very competitive job market and rapid technological change places a great emphasis on universities equipping engineering students with attributes that employers require to tackle challenges faced in industry. Problem solving skills are identified by graduate employers as one of the most important skills. IChemE highlights that a career in chemical engineering requires excellent problem solving and analytical skills (IChemE, 2011).

At present tutorial problems, enquiry and problem based learning are dominantly used to develop the problem solving skills of students in higher education. Scenario based e-learning combines problem based learning with e-learning to provide interactive scenarios in a real life context that cannot be achieved through problem based learning or tutorial problems alone. This gives students the opportunity to develop their problem solving skills and knowledge whilst bridging the gap between a discipline and its practical applications in industry. Scenario based e-learning could address the challenge of motivating students as interactive scenarios are far more involving than tutorial problems and can show the practical applications of knowledge.

Scenario based e-learning, sometimes referred to as scenario based learning in literature, has its pedagogical origins in situated-learning theory and problem based learning. It is based on the concept of situated cognition, which is the idea that knowledge cannot be developed and fully understood independent of its context (Errington, 2011). It allows students to immerse themselves in a realistic working environment situation requiring them to apply and develop their knowledge and problem solving skills. Authentic scenarios can help students appreciate the practical applications of knowledge and develop a deeper understanding of concepts studied.

Scenario based e-learning places students at the very centre of the learning process. It gives students a variety of options to explore in a realistic situation. Students are given greater control of their own learning as they can see the consequences of their own actions and decisions when working through the scenario. Also, feedback can be provided on their actions whilst they work through the problem. Students can engage in many different activities simultaneously in the scenario. This allows them to develop an understanding of the complexity of problems that they may face in industry. The focus is on the student exploring the different ways to reach a solution and learning from their mistakes rather than just achieving the correct answer (Errington, 2011).

Scenario based e–learning is mainly used at present in teaching subjects in the area of life sciences to deliver virtual lab experiments without the cost, time and safety constraints (Breakey, Levin, & Miller, 2008). Previous studies in literature have found that scenario based e-learning can help students learn course content and increase their motivation (Breakey, Levin, & Miller, 2008). Various authors suggest that the real momentum and focus to gain from the benefits of scenario based e-learning is still to come, particularly in engineering education disciplines (Siddiqui, Khan, & Akhtar, 2008), (Mancuso-Murphy, 2007).

Research into scenario based e-learning is still relatively new. Previous studies have been carried out in the area of life sciences and found scenario based e-learning to be an effective teaching and learning resource (Breakey, Levin, & Miller, 2008), (Meldrum, 2011). However a study on the application of innovative scenario based e-learning in the area of engineering has not been reported yet.

This work will explore the use of innovative scenario based e-learning as a way of motivating students, improving their problem solving skills and enhancing their understanding of engineering concepts.

Methodology

A five stage generic methodology suggested by Nadolski and co-workers (2007) was used in this work to design and deliver chemical engineering scenarios and evaluate the performance of scenario based e-learning. This methodology was used as the framework to develop two different interactive scenarios for 220 first year chemical engineering students. The scenarios covered and combined course content from the undergraduate units Chemical Engineering Design, Chemical Reaction Engineering and Heat Transfer. After the first scenario was delivered, feedback from the students was gathered in order to inform the development of the second scenario.

The methodology followed considers five stages as described below.

1. Case Idea Stage: In the case idea stage aspects related to the scenarios such as its target audience, purpose, structure and context were considered. The analysis at this stage created a realistic picture of what could be incorporated into the interactive scenarios. At this stage also the type of scenario was identified following the classification proposed by Errignton (2005) where three types of scenarios are considered; skill based, issue based and problem based. The scenarios used in this work were both conceived as problem based.
2. Case Scenario Design Stage: In the case scenario design stage a detailed script was made of every item to be incorporated into the interactive scenarios to provide a robust educational experience. Table schema documents as recommended in literature were used to record all scenario content at various virtual locations within the interactive scenarios (Nadolski, et al., 2007).
3. Case Development Stage: The case development stage included developing the media required for the scenarios and developing the interactive scenario using the scenario based learning interactive software (SBLi) software. The SBLi e-learning tool used in this study was developed at the Centre for Biological Information Technology at the University of Queensland. This tool has the advantage of being able to set pre-requisites in scenarios and therefore allows the creation of scenarios that have a large number of paths that can be explored by students. Students can also receive customised feedback depending upon the actions that they take. Students proceed through scenarios created using the SBLi software by visiting different locations, viewing and collecting items, interpreting the available information and taking actions. Video and audio clips can also be easily incorporated to the scenarios to make scenarios more realistic and enhance the learning experience. Media used in the scenarios such as videos, audio clips and images were created by undergraduate students at CEAS, University of Manchester, or taken from freeware sources such as Learning Commons.
4. Case Delivery stage: In the case delivery stage an internet server was set up to give the students access to the interactive scenarios. All students were given 10 days to complete each scenario. Individual usernames and passwords were created for each student so that they could use, save and return to their work on the SBLi software in the future. It was also possible to monitor students' activities such as number of access, times and length. A presentation was delivered to students to introduce them to scenario based e-learning and how to access and use the software. This innovation was delivered over one semester and was not part of the assessment of the unit. The scenarios were added to the e-learning provision of the unit.
5. Case Evaluation Stage: The case evaluation stage involved collecting and analysing feedback from students on their experience of scenario based e-learning. Student record data logs available from the SBLi tool were also analysed to see how and when students had worked through interactive scenarios.

Some research studies measure effectiveness of using of a new teaching or learning technique using control groups and test exercises (Siddiqui, Khan, & Akhtar, 2008). However using pre and post-tests are not necessarily a conclusive way to measure the improvement in problem solving skills as it is very hard to single out and conclude that the post-test scores are a result of the new teaching methodology (Beers, 2005). Other research studies measuring the effectiveness of new teaching or learning methodologies use feedback from students (Breakey, Levin, & Miller, 2008).

In this work, Likert scale questionnaires were delivered online to students at the end of each scenario in order to collect feedback from them. Likert scale questionnaires required the respondent to make a decision on their level of agreement with a particular statement on a scale of 1 to 5. Questionnaires have the advantage of being a quick and easy way to gather general feedback for a large number of participants. The questions in the questionnaires aimed to get information about what students thought on how scenario based e-learning could improve their problem solving skills, motivate them and help them develop a deeper understanding of engineering concepts. Some questions were also aimed at finding information on the usefulness of media in the scenarios and the usability of the software. Some open questions were also included for students to provide further comments on what they like the most and thought could be improved upon. In the first scenario students were given two weeks to complete the exercise and provide feedback whereas for the second scenario the time to complete the exercise and give feedback was one week. The evaluation questionnaire in both cases was embedded at the end of the scenario and handled through software that anonymized all responses.

In this work also individual interviews to a random selection of 15 participants were used to gather more detailed information on the students' scenario based e-learning experiences. The interviews were structured and based on a set of 8 questions that explored further some of the results found through the questionnaires but had the flexibility of following up other aspects as well. The main aim of the interviews was to shed light on the reasons behind some of the results obtained through the questionnaires. These two mechanisms were used to gather information to inform the argument of whether or not the use of SBLi enhances students' problem solving skills, motivation and learning experience.

A brief description of both scenarios follows.

Scenario 1 background

Students will play the role of a chemical engineer working at a company who also have a manufacturing plant and an R&D onsite facility. The student will assist the operations engineer in modifying processes to overcome problems and stringent environmental regulations regarding a neutralisation of hydrochloric acid in a part of the process. The student will first help the plant manager troubleshoot a reactor when it is found the product from the reactor is not meeting the specifications required. There will be a variety of possible causes to the problem that the student will have to explore before diagnosing the problem and putting forward a solution.

Upon diagnosing the problem and providing a solution to the reactor problem the student will then help troubleshoot a heat exchanger to ensure the outlet stream of the heat exchanger is at the required temperature. The student will be required to find the cause of the problem and then size a new heat exchanger to provide a solution.

Scenario 2 background

Students will play the role of a chemical engineer working as a design/process engineer at a company who also have a manufacturing plant. The student will help with the design and optimisation of a new distillation column needed on the process plant.

First the student will be required to carry out an optimisation of the operation to decide upon the design of a new distillation column. The student will be required to take into account tradeoffs between operating and capital costs. Various data and information at locations will provide the basis for calculations. An animation video of a distillation column will help the student develop their understanding of distillation column operation. The student will be required to perform calculations of ideal and real systems considering efficiencies. The student will be required to go to the meeting room and listen to two sales representatives talking about costs and efficiencies of different distillation columns. The student will have to make a decision and communicate to the plant manager which trays to buy and how much they will cost. Following this recommendation the student will be required to size a storage tank to hold the distillate product according to given specifications. This will require the student to carry out a mass balance on the distillation column and then convert mass to volume using molar volumes. The student will also be required to size the tank considering a safety factor. The student is then asked by the plant manager to determine the condenser duty and mass flowrate of cooling required. This will require the student to carry out mass and energy balances in the column. The student will have to gather data from the control room (temperature at which the cooling water is available) and the laboratory (relevant physical data of components). The student will find that the temperature fluctuates throughout the day and so they will be required to think about which temperature they should use to determine a suitable flowrate of cooling water. This will be the final task in the scenario.

Results and Discussion

The vast majority of responses to all closed Likert type questions were very positive. The Likert scale questionnaire had 13 questions in total.

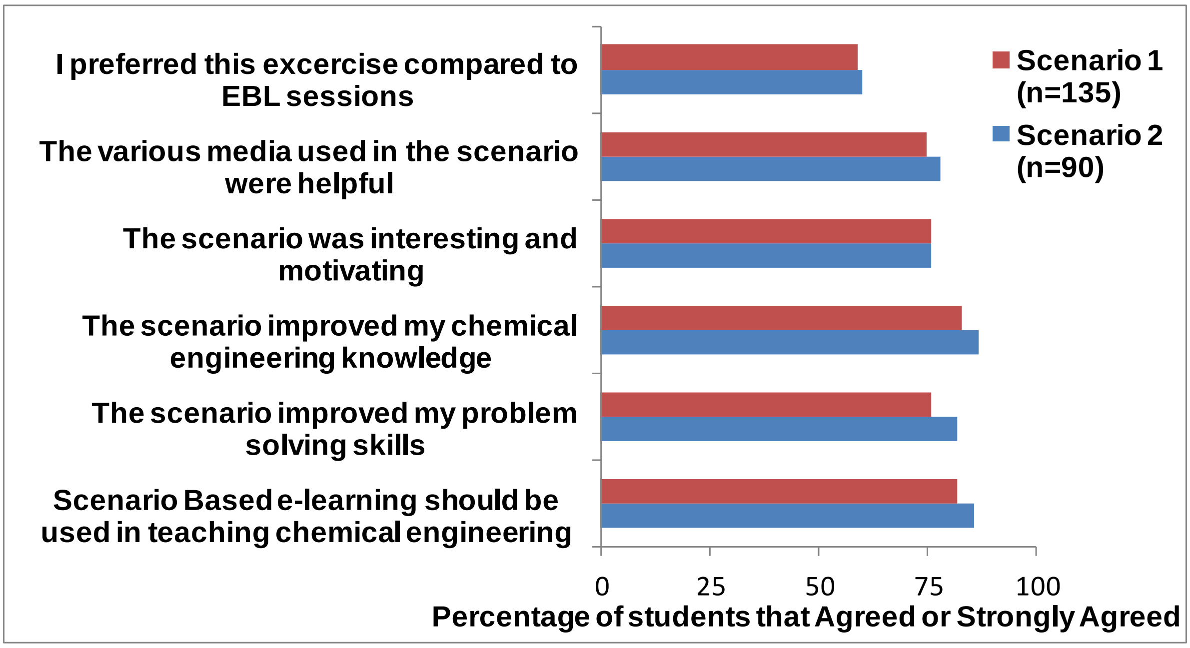

Figure 1 shows the results obtained as percent of participants who ‘agreed’ and ‘strongly agree’ to the statements of some key questions. Results to questions that were mainly focused on the learning experience are reported here but also results about usability of the software are available.

The feedback collected from students in this work showed that 85% of students thought the scenario helped improved their chemical engineering knowledge and that it should be used in teaching chemical engineering. Likewise, individual interviews with students found that students felt they had improved their understanding of concepts as they were able to see the physical meaning of engineering equations and parameters in the scenarios. Students also wanted to see more scenarios based e-learning exercises across other units as they felt the practical application of knowledge made the problems more realistic and helped them consolidate what they have learnt in lectures. These findings support the situated cognition theory which suggests that students' learning is enhanced when they learn in a real life context (Brown, 1989).

Media used in the scenarios was found to be useful by 77% of the students who completed the scenarios. Several students thought that they were unclear about how a distillation column worked prior to going through the interactive scenario, however after viewing the distillation animation video in the interactive scenario they had gained far better understanding of how a distillation column operates. This supports studies carried out by Hantsaridou and co-workers (2005) who also found that the media within interactive scenarios can help students understand complex concepts which they find difficult to grasp.

Students also found the instant feedback provided throughout the scenario very useful in both scenarios. Students thought scenario based e-learning had an advantage over problem based learning of being able to break large complex problems into a series of smaller interrelated problems. Kirschner, Sweller, & Clark (2006) suggested that problem based learning can place a large cognitive load on students and that scenario based e-learning can be used to reduce the cognitive load on students as complex problems can be broken down into smaller problems and also guidance can be provided throughout.

In this study 83% of students agreed or strongly agreed that the software SBLi was easy to use. This implies that students new to this tool and method of delivery would require minimal assistance in using the software to complete scenario based e-learning exercises. This is an advantage compared to enquiry based learning which requires group facilitators that can be difficult to get for large classes and potentially also expensive.

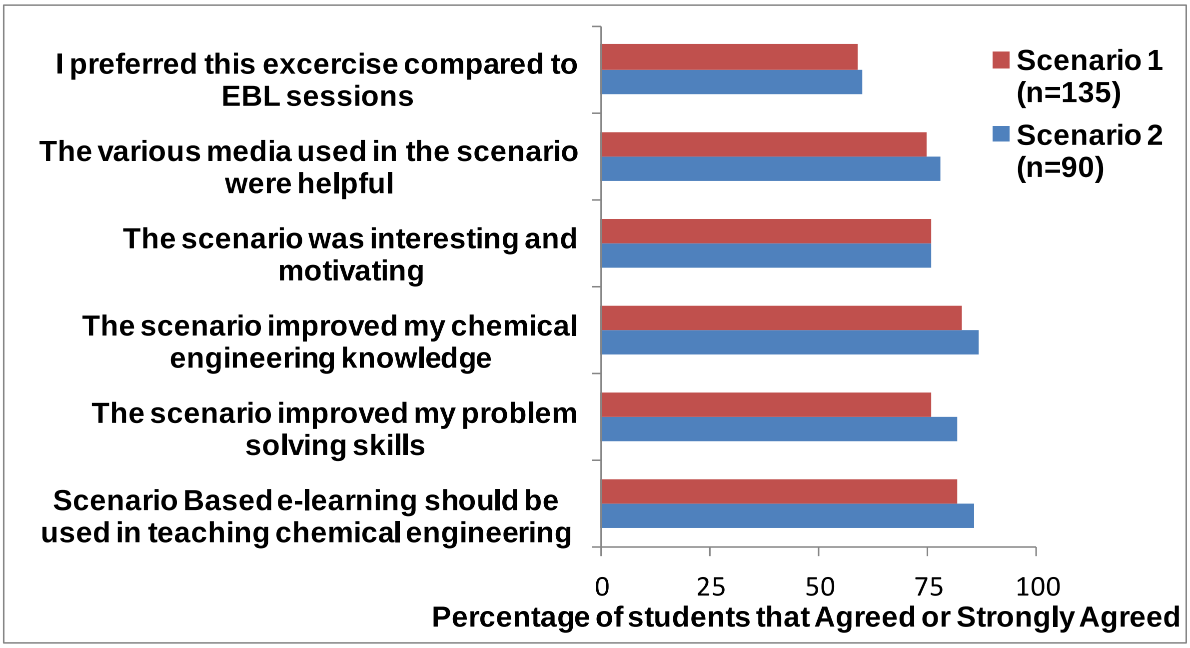

Figure 1 Results from students' evaluation questionnaires on overall aspects of the implementation of two scenarios. *n* represents the number of students who participated in the survey.

The results showed that 75% of students found the activity interesting and motivating. From the comments and discussion obtained during the interviews, students were motivated by the practical application of what they were learning in lectures. Some students also felt that working through problems by visiting different locations and communicating with different characters in the scenario made them feel like "real chemical engineers". Several students in the individual interviews also mentioned that they were motivated by the inclusion of how decisions affected profitability of a business in the second scenario. Students particularly liked the element of trading-off costs and meeting sales representatives to design the distillation columns in the second interactive scenario. These finding are in line with previous studies in literature that have also found that using the SBLi tool can help motivate students (Breakey, Levin, & Miller, 2008).

During the individual interviews some students also described the scenario as an enjoyable and challenging adventure game. They felt it was like an adventure game because they had to progress through the interactive scenario to solve the problem by visiting different locations and collecting different items. The results of this study also indicate scenario based e-learning could be used as a serious game in higher education to help students learn and develop their problem solving skills. This finding therefore supports a growing body of literature suggesting that serious games in higher education have the potential to promote learning (Westera, Nadolski, Hummel, & Wopereis, 2008).

Analysis of student logs showed that 65% of students had completed the scenario out of the usual university day time hours. Individual interviews with students revealed that they were able to work through scenarios at their own pace and preferred time. The results of this study therefore support literature that suggests e-learning tools can provide students with flexibility and allow them to work at their own pace promoting self directed learning (Babic, 2011).

The results of the questionnaire showed that approximately 82% of the students agreed or strongly agreed the scenario had improved their problem solving skills. In individual interview students said that during the reactor trouble shooting scenario (Scenario 1) they had to define problems, analyse the different factors that could be causing the problem and implement feasible solutions. Students also though that the first scenario highlighted to them how important it is to consider all the implications of a decision you are making based on your technical knowledge. This suggests that the scenarios were helping students deal with uncertainty and improve their critical thinking and decision making skills. The feedback regarding problem solving skills collected through individual interviews showed that students were going through the motions of problem solving as described in literature as defining a problem; analysing alternatives and implementing solutions (Adams, Kaczmarczyk, Picton, & Demian, 2007). This implies that students were developing their problem solving skills by completing the scenario based e-learning exercises. However, as the students were exposed to other learning activities at the same time it would be difficult to prove a quantitative difference in terms of their ability to solve problems as a direct consequence of using SBLi.

Although several students said the scenarios helped them think about the process of solving a problem there was some students that disliked multiple routes in the scenario that could be pursued to reach a solution. Students felt it would be sufficient to learn a single correct way of reaching a solution rather than actually focusing on the process of reaching a solution. This finding supports Adams and co-workers (2007) who suggest that students find it difficult to cope with uncertainty and often see learning as reaching correct solutions rather than improving the actual process of problem solving to reach a solution.

Negative comments made about scenario based e-learning were mainly about the quality of the graphics of media, length and difficulty of the scenarios. Some students thought the graphics in the scenario were poor. Embedding high quality media into scenarios is something that requires a lot of time and resources and therefore costs must be carefully assessed against the potential benefits that could be gained.

Some students thought the first scenario helped them think about ways to solve a problem however they were not sure if this would help them in the exam. This was because some students felt carrying out calculations would help them prepare for exams rather than focusing on the ways to solve a problem. This shows that some students think that activities are only worthwhile if they are directly related to the exam and measures of performance. It also demonstrates the importance of emphasising the real purpose of scenario based e-learning tools and how improving problem solving skills can be very beneficial for their future career.

Conclusions

Scenario based e-learning was successfully implemented in the current provision of teaching and learning in the undergraduate Chemical Engineering programmes at CEAS. In this study two scenarios were successfully designed and delivered to 220 first year undergraduate students using the SBLi software. Feedback was collected from students through questionnaires and individual interviews to establish if the use of SBLi as a learning resource motivated students to learn and enhanced their problem solving skills and understanding of engineering concepts.

The results of questionnaires and individual interviews in this work showed that scenario based e-learning is a very powerful way of motivating students. Students revealed in interviews that the scenarios made them improve their problem solving approach as they were required to consider several factors to find a cause of problems, analyse alternative factors and then implement feasible solutions. Students also said the scenarios made them deal with uncertainty and clearly emphasized the importance of considering the broader implications of decisions made using their technical knowledge. This shows that scenario based e-learning can be used to improve the problem solving, critical thinking and decision making skills of students. Student feedback also indicated that they learnt better in a realistic situation as it gave their knowledge practical meaning as well as the flexibility for self-directed learning.

Embedding scenario based e-learning in engineering curricula can help students to develop their problem solving skills and understanding of knowledge required to tackle the challenges faced in industry and also make a valuable contribution to the society as a whole.

References

Adams, J., Kaczmarczyk, S., Picton, P., & Demian, P. (2007). *Improving problem solving and encouraging creativity in engineering undergraduates*. Paper presented at the International Conference in Engineering Education-INEE*.* Coimbra, Portugal.

Babic, S. (2011). *E-learning environment compared to traditional classroom*. Paper presented at the 34th International Convention MIPRO. Opatija, Croatia.

Beers, G. (2005). The Effect of Teaching Method on Objective Test Scores: Problem based learning versus lectures. *Journal of Nursing Education, 44* (7), 305-309.

Breakey, K. M., Levin, D., & Miller, E. (2008). The use of scenario-based-learning interactive software to create custom virtual laboratory scenarios for teaching genetics. *Genetics, 179*, 1151-1155.

Brown, J. C. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18* (1), 32-41.

Errignton, E. (2005). *Creating Learning Scenarios: A planning guide for adult educators.* Palmerston North: Coolbooks.

Errington, E. (2011). Mission possible: Using near-world scenarios to prepare graduates for the professions. *International Journal of Teaching and Learning in Higher Education, 23*, 84-91.

Hantsaridou, A. P., Theodorakakos, A., & Polatoglou, H. M. (2005). A didactic module for undertaking climate simulation experiments. *European Journal of Physics, 26*, 727-735.

IChemE. (2011). A career in chemical engineering. Retrieved April, 03, 2012 from http://www.icheme.org/careers.aspx.

Kirschner, P., Sweller, J., & Clark, R. (2006). Why Minimal Guidance During instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-based, Experiential and Inquiry-based Teaching. *Educational Psychologist, 41*, 75-86.

Mancuso-Murphy, J. (2007). Distance education in nursing: An integrated review of online nursing students' experiences with technology delivered instruction. *Journal of Nursing Education, 46* (6), 252-260.

Meldrum, K. (2011). Preparing Pre-Service Physical Education Teachers for Uncertain Future(s): A Scenario-Based Learning Case Study from Australia. *Physical Education and Sport Pedagogy, 16* (2), 133-144.

Nadolski, R., Hummel, H., van den Brink, H., Hoefakker, R., Slootmaker, A., Kurvers, H., Storm, J. (2007). Emergo: methodology and toolkit for efficient development of serious games in higher education. Retrieved October 12, 2011 from

http://emergo.ou.nl/emergo/community/EN/media/EMERGOArticleISAGA2007NadolskiEtAlsubmitted.pdf
Siddiqui, A., Khan, M., & Akhtar, S. (2008). Supply chain simulator: A scenario-based educational tool to enhance student learning. *Computer and Education, 51*, 252-261.
Westera, W., Nadolski, R. J., Hummel, H. G., & Wopereis, I. G. (2008). Serious Games for Higher Education: A Framework for Reducing Design Complexity. *Journal of Computer Assisted Learning, 24* (5), 420-432.

Copyright statement