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Special Issue
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Innovative learning pedagogies are increasingly used in the west towards equipping graduating engineers with the set of skills and competencies essential for the engineer of the 21st century. The successful globalization of such pedagogies in the developing world is key to educational reform and the building of sustainable knowledge-based economies. In this paper, we report on the development of an exportable model for effective Problem-Driven Learning (PDL), a problem-based learning pedagogy, transfer across cultures. The system is demonstrated using a case study in transnational exchange and cooperation between Georgia Tech (GT) in Atlanta, Georgia, USA and Khalifa University (KU) in Abu Dhabi, UAE around the design of a biomedical engineering course delivered using PDL. Although the underlying framework of the innovative pedagogy was adopted from GT, various local elements were implemented to ensure cultural compatibility. The main hypothesis postulates that cultural consideration is critical to the successful globalization of a learning pedagogy. Cultural relevance and sensitivity are critical to effective cross-cultural transfer.

Keywords: Problem-Driven-Learning (PDL); engineering education; cross cultural transfer; 21st century skills; Globalization

The Aalborg model of PBL supports development of process-skills and -competences. For engineering students it encourages project-management as a way for student-groups to achieve efficiency and effectiveness in their study-projects. This article looks into how the development of discussion skills relates to learning and project-management. Through content analysis of groups' written reports on their process-analysis which groups undertake in order to reflect and improve efficiency and effectiveness, it is concluded that the discussions are central in the development of process-skills and competences. Following grounded theory group interviews focusing on the discussions which groups undertake in their pursuit of problem-solutions fulfilling assessed real-world needs as well as meeting the requirements of the educational program, it is concluded that discussions serve as a media for achieving learning and as a tool for developing skills essential for professional engineering practice.

Keywords: PBL; process competences; project management; project-group; social learning; discussion

Developing sustainable development (SD) mindset and professional skills, such as problem solving, team working and communication skills, are crucial for engineering graduates of the 21st Century. Cooperative Problem Based Learning (CPBL), which is the infusion of Cooperative Learning (CL) principles into the Problem-Based Learning (PBL) cycle, had been shown to enhance learning while developing the desired professional skills and positive behavior. This paper describes a mixed method study on the impact of an Introduction to Engineering course on first year students as they go through three cycles of CPBL to solve a sustainability related problem. In the first part of the research, an exploratory study was conducted by analyzing reflective journals submitted by the students at the end of each CPBL cycle using thematic qualitative data analysis technique to determine the major themes in skills developed. The analysis show strong emergence of professional skills and SD. To determine the level of behavior change in SD for students who took the course, a quantitative study was then conducted. Although the students initially faced difficulties in developing the skills, by the end of the third stage, the students realized that they have managed to attain important skills and SD behavior essential as engineers of the future.

Keywords: problem-based learning; professional skills; sustainable development; reflective journals; cooperative learning

Grading individual students in teams or projects has always been problematic. To accurately gauge individual learning outcomes, students' grades need to be based on what they have learned as an individual within the team or project context. However, within engineering team-based projects, individuals have traditionally been assigned a grade heavily influenced by the team's project outcomes. Final year engineering projects (FYEP) suffer from similar problems. While typically in the Australian context, the projects are conducted by individuals, they are still conducted using the philosophy of PBL. To provide a reliable indicator of student capability and program quality and standards, FYEPs must be coherent, valid and reliable instruments for student assessment and program evaluation. This paper considers two Australian engineering education projects, one recently completed and one current, that investigate the issues of; how can individuals who learn in a team environment be assessed as individuals?, how can the outcomes from final year engineering projects be used to demonstrate the standards required by various state and professional accrediting agencies? And what are the issues that prevent staff effectively assessing the learning outcomes of individual students who learn in the project environment? The paper outlines an assessment model that was trialled and discusses the issues arising. The difference between this form of assessment and others in engineering education is that it assesses the learning outcomes of the individuals as opposed to assessing the product of the team. The paper also discusses the results from the first stage of data gathering on final year projects in Australia. The conclusion is that assessing the product rather than the learner degrades the opportunity to use projects as evidence of learning, but continues because it is easier for academic staff.

Keywords: assessment; teams; PBL; engineering

Problem-Based Learning pedagogies that require high levels of inquiry and hands-on engagement can enhance student learning in engineering. Such pedagogies lie at the core of studio-based design education, having been used to teach architects since the Renaissance. Today, design assignments and studio-based learning formats are finding their way into engineering programs, often as part of larger movements to implement Student-Centered, Problem-Based Learning (PBL) pedagogies. This spectrum of pedagogies is mutually supportive, as illustrated in the University of Michigan's SmartSurfaces course where students majoring in engineering, art and design, and architecture collaborate on wickedly complex and ill-defined design problems. In SmartSurfaces and other similar PBL environments, students encounter complex, trans-disciplinary, open-ended design prompts that have timely social relevance.

Analyzing data generated in studio-based PBL courses like SmartSurfaces can help educators evaluate and track students' intellectual growth. This paper presents a rubric for measuring students' development of increasingly refined epistemological understanding (regarding knowledge and how it is created, accessed, and used). The paper illustrates use of the tool in evaluating blogs created by students in SmartSurfaces, which in turn provides evidence to help validate the rubric and suggest avenues for future refinement. The overall result of the exploratory study reported here is to provide evidence of positive change among students who learn in PBL environments and to provide educators with a preliminary tool for assessing design-related epistemological development. Findings of this study indicate design-based education can have powerful effects and collaborating across disciplines can help engineering students advance in valuable ways.

Keywords: problem-based learning; student-centered learning; design-based learning; epistemology; architecture education; design studio pedagogy; engineering education; cognitive development

Very few institutions have a problem based learning (PBL) curriculum at an institutional level and there is therefore limited experience with change in systemic PBL models. Aalborg University (AAU) practices an institutional PBL model, and in 2010 a rather comprehensive curriculum restructuring took place at the Faculty of Engineering and Science. The original PBL model assessed some of the courses and projects together, whereas since the reform there is separate assessment of each course and of the project. This article reports the findings from a study of how students have experienced this curriculum change. An explorative mixed method study was used that included qualitative focus group interviews with 10th (final) semester students about their experience of the change. Based on the qualitative study, a questionnaire was sent to all 10th semester students from computer science, software engineering, and architecture and design. The findings indicate that the students always prioritize the projects but with the reforms they experienced a significantly lower degree of integration and coherence of the various elements in a semester. Furthermore, the alignment between project supervision and project exam has increased in the new curriculum as the exams of courses and projects are separated.

Keywords: curriculum development; PBL models; alignment; projects

A shift from teaching to learning is characteristic of the introduction of Problem Based Learning (PBL) in an existing school. As a consequence the teaching staff has to be trained in skills like facilitating group work and writing cases. Most importantly a change in thinking about teaching and learning will have to be realized. In the implementation of PBL it makes a difference how the core features of the problem and the role of the facilitator have been defined. This paper will present components of a PBL faculty-development training programme and discuss the relevance with respect to a faculty development strategy.

Keywords: faculty development; PBL training; Change to PBL

Students' participation in the PBL group discussions has always been associated with the role of facilitators, who are responsible for the effectiveness of tutorial sessions. Facilitators should be aware of how their students participate in small-group discussions and thus adopt suitable facilitation techniques to encourage active student participation. However, determining students' levels of participation in a PBL small-group discussion is a very subjective matter. As a result, it is difficult to assess the effectiveness of particular techniques or approaches that are used for facilitation. Therefore, the objectives of this paper are as follows: first, examine students' participation in PBL small group discussions; and second, propose an appropriate technique of facilitation, with respect to the group members' participation levels. Participants for the study comprised the first-year polytechnic electrical engineering students, who were undergoing ten-week PBL according to the fourteen-step procedures. These students participated in small-group (four to five members) discussions to solve five electrical engineering problems in a two-week block period. The students' participation was observed and videotaped, as well as getting students to use a fixed reflective journal to record their thoughts after attending all the tutorial sessions. Our findings revealed that four classifications can be used to explain students' level of participation namely, behaviour (active-passive), oral (silent-talkative), group skills (Excellent-poor), and confidence (high-low). These classifications can be grouped into several combinations in order to explain the students' levels of participation in small-group PBL discussions. Premised on the findings, several suggestions are proposed to develop a facilitation technique: to create an environment conducive to discussion sessions and encourage active student participation.

Keywords: problem-based-learning; facilitation; students' participation; engineering education; electrical engineering

This study focuses on determining the elements of problem solving strategies that occur during Project-based Laboratory (PB Lab) teaching and learning (T&L) activities. Problem solving strategies are defined as strategies which significantly relate to the elements involved in problem solving procedures that guide students to solve problems during T&L activities. Four groups, each of which consists of five students and one PB Lab facilitator, were observed. Seven PB Lab facilitators were interviewed. The respondents are from the Bachelor of Electrical Engineering (Power) (SEE) program in the Faculty of Electrical Engineering, Universiti Teknologi Malaysia. This qualitative research employed the thematic analysis technique in determining the themes related to the elements of problem solving strategies that occurred during the PB Lab activities. The results of the analysis have indicated that there are five main processes associated with the problem solving elements that took place during the PB Lab course activities, which led to enhancing the students' problem solving skills in the laboratory context.

Keywords: problem solving startegies; problem solving process; teaching and learning (T&L); project-based laboratory (PB Lab)

Engineering education accreditation bodies emphasize the need for competencies beyond technical expertise. Critical thinking is one of these competencies, which is also considered as a precursor for the development of other competencies such as multidisciplinary collaboration, problem-solving skills and lifelong learning. There is an urgent need to enhance engineering students' critical thinking and one way to do this is to make use of active, student-centred learning approaches such as Problem Based Learning (PBL). This study aims to provide a model for understanding and enhancing critical thinking in a PBL environment. The development of the model takes its point of departure from a conceptual model for critical thinking that is concretized in a PBL context by including theoretical as well as empirical perspectives. The empirical study was conducted at the Faculty of Engineering and Science, Aalborg University (Denmark), which has more than 30 years of experience in educating engineers in a PBL environment. Based on the results, a model for critical thinking in a PBL environment is outlined emphasizing a problem-solving process grounded in open and real life problems as well as a self-directed, collaborative and team-based learning environment. The model also includes recommendations to overcome challenges detected in the empirical study, especially those related to the scaffolding of group collaboration and the use of theory in a self-directed learning environment based on real life problems.

Keywords: engineering education; critical thinking; problem based learning; decision making

Section II

This work presents the results of the implementation of a gamification system to two classes in a database course for engineering on computational technologies students. The results are obtained from a pretest-posttest methodology in a focus group with 20 students and a control group with 20 students. This study was made during a whole semester and the analysis comprises learning gains and the students' grades. The study shows that learning gains in both groups are similar but in analysis, it is stated that both groups have specific characteristics that point to advantages in the implemented gamification system and that propose new research questions in the subject. On the other hand, the analysis on learning styles is complemented with a study on motivation aspects that have supported the students' learning process. This work presents a new perspective on research over the learning technique because the majority of the studies published explore the relationship only between game characteristics and motivation, in contrast the present research offers the advantage of an experimental design over a whole semester in terms of learning gains and learning styles.

Keywords: gamification; learning gains; motivation; learning styles; engineering education

Recently, several studies have been published that have shown the need for greater student engagement within engineering education. These studies indicate that when students are exposed to pedagogies that stimulate student engagement, such as active learning, student performance is better than with more traditional forms of instruction. One form of active learning that is starting to grow within engineering education is the use of games and gamification. In the spring of 2014, we were able to compare two sections of a sophomore Introduction to Chemical Product Design class to determine the effectiveness of game-based learning on student learning outcomes. The first section received content delivered utilizing active learning techniques. The second section received content utilizing the same form of delivery but included classroom based games and a game-based portal for homework assignments. Each section was evaluated in the same manner, and the instruction in each section was provided by the same two faculty members. Throughout the course, students completed clicker questions on class content, and at the end, they reviewed content in a class session administered using the clickers. Students were also responsible for completing a semester design project that included both a written and oral component. Analysis of the clicker responses demonstrated that the students in the game-based class performed statistically similar to or better than those in the control group throughout the semester. In the last class review session, retention of material appears to have been better in the game-based class, where several learning objectives demonstrated a significantly higher outcome. Student performance on the semester design project also exhibited similar trends. As the sample sizes are relatively small in this study, the results are preliminary but do demonstrate a trend towards enhanced learning outcomes when content is delivered utilizing game-based pedagogy.

Keywords: game-based learning; student learning outcomes; games; engineering education

Quang Tuan Le, Akeem Pedro, Hai Chien Pham and **Chan Sik Park**   457–467   A Virtual World Based Construction Defect Game for Interactive and Experiential Learning

In the construction process, defects occur inevitably and repeatedly, making significant contributions to cost overruns and time delays. Many studies have focused on quality education to reduce the reoccurrence of defects. So far, most of them have emphasized the necessity of teaching about defects in construction classes without considering how to take advantage of new technologies such as virtual worlds in order to improve the education process. In recent years, Virtual World (VW) has been successfully applied as a pedagogical tool in the medical field, with applications in nursing training, healthcare education, and other areas. The concept of VW is still new and there are few studies on the topic in the construction discipline. With this regard, this study proposes an online 3D VW platform, which allows students to participate in role-playing, dialogic learning, and social interaction for construction defect education. In this approach, a construction defect game-based learning system using VW platform is developed. The system comprises of the following three modules: (1) A Construction Defect Learning Module (CDL) which delivers lecture based quality information within the virtual environment to teach students about common defects and their prevention methods; (2) A Defect Inspection Game Module (DIG) where students identify and correct defects in a virtual construction site; (3) A Construction Activity Game Module (CAG) which allows students to engage in construction activities within the virtual environment and recognize actions which may lead to defects. The game system is tested with real scenarios in order to address the system's potentials and limitations. The study emphasizes the advantages and benefits of VW that can provide students with the real construction defect experience through learning by doing. Finally, this paper discusses the extensibility of the system to training program for workers in advance of working in construction site.

Keywords: construction defect; virtual world; second life; interactive and experiential learning; construction education

Robert W. Songer and **Kazunori Miyata**   468–478   A Playful Affordances Approach to the Design of Gameful Learning

Typical applications of gamification in education use either game mechanics to encourage positive engagement behaviors or full games to deliver educational content; however, both approaches raise some concerns. Game mechanics can distract from the intrinsic enjoyment of activities while full games construct learning contexts that may be significantly different from the real-world contexts of the targeted subject matter. This paper aims to highlight issues of behavioral conditioning and knowledge transfer in instructional design that uses gamification by examining foundational theories and recent studies. We propose a design approach called "gameful learning" that focuses on integrating intrinsically rewarding, playful aspects of game-like experiences into authentic learning activities. Authentic learning activities relate real-world contexts to classroom learning while the desired motivational outcomes of playful experiences are shown to be more fulfilling than extrinsic rewards. We then investigate playful experiences in a game-based learning activity integrated into a business English class at a Japanese technical college. In the activity, mixed teams of Japanese and Singaporean students (N = 47) competed at negotiating for resources required to establish businesses within the specified time limits. The results of our analysis show the experiences of arousal, contest, and discovery were the most prevalent in the game. Levels of arousal and thrill showed the strongest positive correlations to enjoyment, implying the students had approached the activity with a playful attitude rather than a serious one. The Japanese students' reported levels of engagement in the contest and experiences of achievement correlated strongly with their sense of challenge. These results and their implications for the development of a playful affordances model as a tool for the design of gamification and game-based learning activities are the focus of this paper.

Keywords: gamification; gameful design; play; game-based learning

Avinoam Tzimerman, Yale T. Herer and **Avraham Shtub**   479–490   Supply Chain Education—the Contribution of Gamification

Supply Chain Management is taught in many business and Industrial Engineering programs. In this paper we present our experience in using gamification in several university courses in this domain. More importantly, we present gamification design principles. In these courses we used the Supply Chain Simulator (SCS)—a new and innovative web based computer gaming/simulation application. Its goal is to enable students to gain a better understanding of supply chain management by providing a gaming oriented, virtual environment experience, enabling the simulation of a large variety of realistic and pragmatic situations. The instructor can build an unlimited number of scenarios. Students learn how to simultaneously consider diverse supply chain aspects such as costs, ordering policies, transportation modes, capacity, and uncertainty. Advanced students learn how to design and develop supply chain scenarios based on real or imaginary situations. This training approach using simulation has already been used to bring gamification into a number of courses and the students' satisfaction has been consistently positive. Gamification develops students' analytical abilities in conjunction with providing tangible experience in handling practical potential challenges in a fun gaming environment. We argue that gamification tools should be focused on a single domain and allow wide modelling flexibility within this domain.

Keywords: Gamification; Simulation Based Training; Engineering Education

Victor Potier, Catherine Pons-Lelardeux, Michèle Lalanne and **Pierre Lagarrigue**   491–500   Making Complexity Fun—Machining Procedures in Mechanical Engineering

Gamification can be defined as the development of playability of an object or a situation that was not initially playable. When it comes to learning machining procedures in mechanical engineering, the game appears to be an effective way to handle procedures' high level of complexity. Through the study of the serious game Mecagenius, we shall defend the thesis that gamifying the acquisition of cognitive and technical knowledge allows its complexity to be better grasped and matters to be simplified, on one hand by the use of gameplay mechanics, on another hand by leveling several types of complexity in multi-layers game levels. Encouraged to try and involved by the level design, we will show how learners handle more and more complex operations.

Keywords: machining; training; learning game; gamification; complexity; mechanical engineering

Oriol Borras-Gene, Margarita Martinez-Nuñez and **Ángel Fidalgo-Blanco**   501–512   New Challenges for the Motivation and Learning in Engineering Education Using Gamification in MOOC

The phenomenon of MOOC (Massive Online Open Courses) is increasingly experienced and is giving rise to new scenarios and challenges with several features that are different from previous approaches to online education. In the field of engineering education, Information and Communication Technologies are making continuous innovation in methods of teaching and learning for students. Engineering Education institutions, like the Technical University of Madrid (Spain), are expanding their online offerings and making a more effective use of technologies for learning.

This research presents a gamification cooperative MOOC model (gcMOOC) that can be applied in the design of this type of course. Using an explanatory sequential mixed methods design, which integrates the quantitative and qualitative methods, the study investigates the factors that influence motivation, collaboration and learning in gcMOOC.

This work also suggests a set of practical recommendations and tools to improve the motivation, learning level and completion rate of participants in MOOC course in Engineering Educational when the gcMOOC model is implemented. The results of this study state that the incorporation of virtual communities and gamification methodologies increase participant learning motivation in engineering MOOC courses. Additionally, these gamification tools aid students to deepen their learning and involve them in the course increasing their motivation and the completion rates in MOOCs.

Keywords: MOOC; Gamification; Social Networks; Cooperative Learning; Game Badges; Motivation; informal learning

Students' motivation and engagement are important factors for actual learning. By using game-thinking and game elements in an education context we can attract learners' attention, increase their motivation and engage them to participate more actively in their learning process. In this work we present a gamified experience to teach Artificial Intelligence to computer science engineers. The inclusion of a competition and other game elements in the course has proved to be fun for the students, they attend more to class, they look for the continuous improvement of their work, no one copies and the level of assignments handed in is high.

Keywords: artificial intelligence education; gamification; motivation; students' competition

Learning programming is difficult and it presents a great challenge for both students and teachers. The goal is to increase success rate for novice programmers. Students lose their confidence and motivation when they encounter difficulties such as programming environment, language syntax knowledge, problem understanding and debugging. Programming languages are artificial and require high level of abstraction, which is not easy for young students. It is also common knowledge that many adults have more difficulties with learning programming than children. In order to make the difference, we introduced game making course for university undergraduate novice programmers and examined the effect of making games on attitude and motivation for elementary and high school children as well. The objective of using games in this context is to make students learn something serious and difficult like programming while doing something fun like making and playing games. Teachers with a strong understanding of the subject matter they teach are more likely to produce successful students.

Keywords: novice programmers; Scratch; visual programming languages; gamification

Gamification is the use of game mechanics and strategies in non-game contexts. Currently, gamification is an emerging trend in many application fields, including education. Many gamification initiatives use points, badges and leaderboards as a way to motivate and incent participants to alter their behavior. Some gamified systems use analytics to measure and monitor users' actions and social components to increase the user motivation. Most of them, fails to keep the user involved over the long term. To solve this problem, the entire gamification process should be considered from a highly personalized view. In this sense, intelligent tutoring systems (ITS) have the propriety of adaptation to the user characteristics. Moreover, ITS have been shown to improve student achievement and enhance learning, but one of the main problems found is the inappropriate use of these systems by the students, perhaps due to boredom, lack of interest or motivation and monotony. So, in this paper we present gITS, a conceptual architecture proposal for an ITS that includes gamification elements as key components of the system. Furthermore, we analyze typical gamification approaches, highlighting some issues that should be considered when designing gamification systems.

Keywords: gamification; ITS; GBL; personalization

The objective of the paper is to present application of some artificial intelligence (AI) principles and techniques for design of a simulation system for teaching concepts in transportation engineering. The AI techniques can support development of key features of the simulation system, such as a road system, a vehicle, rectilinear and curvilinear motion, braking patterns, etc. By adopting a simulation system for learning, students, as users of the system, can actively participate in constructing graphic scenarios that illustrate different concepts in transportation engineering. The simulation system can support visualizations of various scenarios, which illustrate concepts often presented as simple equations in a traditional lecture hall setting. In addition to discussing application of the AI techniques for designing the simulation system, the paper also presents an overview of research studies related to gamification of educational software systems and its application in transportation engineering education.

Keywords: simulation software; artificial intelligence techniques; transportation engineering education; video game

Virtual reality simulators represent an affordable alternative for teaching and learning specific skills in environments not available in reality for educational purposes. Their goal is to provide a simulated environment where students can practice real tasks in a safer way and with no real consequences in fields as engineering or surgery. For a simulator to become a more complete teaching and learning tool, it should also include the expert knowledge required to provide instant feedback to the user. SHULE is a framework for building haptic simulators to be used with educational purposes that includes expert knowledge. In order to increase users' motivation, we have also considered game features in the framework design, development and integration with other tools. This process includes the elements needed to provide a challenging goal for the simulator with the correct amount of uncertainty that would increase user's curiosity enough to keep on using it until certain skill is achieved. Simulators produced with SHULE can be integrated with a Learning Management System (LMS) such as Moodle by means of web services. Their functionality offers the teacher the possibility to create new activities to be performed at the simulator, and also offers the students the possibility to see the results of their simulator sessions in the LMS.

Keywords: haptic simulator; e-learning framework; gamification

In this paper, we propose a novel approach to e-learning website conversion optimization using gamification. Insight into contemporary trends of attracting, retaining and inviting website users into action, known as conversion, and the concept of applying game elements in non-game context have led us to utilize these concepts in e-learning. In our actual case, gamification has been applied on student conversion rate improvement. Analysis of current website analytics has identified several gaps between expected and present state. In order to improve conversion, website structure has been modified and several gamification concepts have been introduced. Course of computer networking and telecommunications, held on Faculty of organizational sciences was used for evaluation. During the duration of the course, web traffic was monitored. Also, at the end of the course, a survey targeting gamification impacts on learning motivation and outcomes was conducted. Experiment results show conversion improvement, as well as better student motivation and learning outcomes.

Keywords: gamification; e-learning; VLE; website conversion improvement

Jelena Minović, Božo Drašković and
Ivan Stošić

574–581   Gamification of Bioeconomic Prey-Predator Model

In this paper we present educational game developed with major aim to educate and raise awareness of people about ecological issues in reserves of nature. In order to fulfil this aim, we decided to implement simulation game based on prey-predator model. Another part of the game are flesh cards, with questions and answers targeting specific problems and species in nature reserves. Case study given in this paper is Special nature reserve Uvac from Serbia. This is the only one reserve in Europe which is the habitat of griffon vulture, which is endangered species, very important for protection of nature, preventing expansion of various infectious diseases. Developed game shows what would happen if there is no enough prey population (carcass in the case of Uvac) and also when there is no enough predator population (griffon vulture in this case).

Keywords: gamification; prey-predator model; ecology; Special Reserve of Nature Uvac