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Section I

Special Issue

Selected papers from the 2012 International STEM in Education Conference, Beijing, P. R. China

Guest Editor

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Ahmad Ibrahim	809–810	Editorial
Feng-Kuang Chiang	811–813	Guest Editorial
Peter Hudson, Lyn D. English and Les Dawes	814–821	Female Students' Interactions in a Middle School Engineering Project: A Case Study

Targeting females at high school or earlier may be a key towards engaging them in science, technology, engineering and mathematics (STEM) education. This ethnographic study, part of a three-year longitudinal research project, investigated Year 8 female students' learning about engineering concepts associated with designing, constructing, testing, and evaluating a catapult. There was a series of lead-up lessons and four lessons for the catapult challenge (total of 18 x 45-minute lessons) over a nine-week period. Data from two girls within a focus group showed that they needed to: (1) receive clarification on engineering terms to facilitate more fluent discourse, (2) question and debate conceptual understandings without peers being judgmental, and (3) have multiple opportunities for engaging with materials towards designing, constructing and explaining key concepts learnt. There are implications for teachers facilitating STEM education, such as: clarifying STEM terms, articulating how students can interact in non-judgmental ways, and providing multiple opportunities for interacting within engineering education.

Keywords: middle schooling; girls' education; engineering education; science and mathematics

Merilyn (Lyn) G. Carter	822–828	A Picture is worth a Thousand Words: A Cross-curricular Approach to Learning about Visuals in STEM
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Visuals are a central feature of STEM in all levels of education and many areas of employment. The wide variety of visuals that students are expected to master in STEM prevents an approach that aims to teach students about every type of visual that they may encounter. This paper proposes a pedagogy that can be applied across year levels and learning areas, allowing a school-wide, cross-curricular, approach to teaching about visuals, that enhances learning in STEM and all other learning areas. Visuals are classified into six categories based on their properties, unlike traditional methods that classify visuals according to purpose. As visuals in the same category share common properties, students are able to transfer their knowledge from the familiar to unfamiliar in each category. The paper details the classification and proposes some strategies that can be incorporated into existing methods of teaching students about visuals in all learning areas. The approach may also assist students to see the connections between the different learning areas within and outside STEM.

Keywords: visuals; visual literacy; pedagogy; STEM

Guo-Wei Chen and Chung-Shan Sun	829–832	Acceptance Level of Junior High School Students of Network Educational Games
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The development of network games has opened up a brand new era of digital learning and has also inspired another kind of educational model. Context learning with games not only achieves the objectives of education, but also makes learning as fun as playing games. If learners can learn through playing games, the model of traditional learning can become more vivid and interesting. By promoting educational games, we can bring about an evolution of the model of educational activities. The purpose of this study is to figure out the impacts of "concentration," "sense of control," and "sense of immersion" on junior high school students by investigating the acceptance level of network educational games on the "Educational Portal of Taipei City—Flying Sky Interaction Learning Campus" in Taipei City. This study also considers three background variations, including "gender," "grade," and "urban or rural" respectively. The results show that the acceptance level of the educational game websites is generally above average. We also find that the students in higher grades have greater self-control when it comes to the "sense of immersion." Therefore, we can adopt a new type of learning model in the future via the improvement of the content and interface of educational games.

Keywords: educational game; network game; digital learning

Kar-Tin Lee and Rod Nason	833–838	The Recruitment of STEM-Talented Students into Teacher Education Programs
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This paper begins by identifying three main reasons why many of the more STEM-Talented students at our universities do not consider enrolling in STEM teacher education programs. Then based on a review of the literature, a framework for addressing this dilemma is presented and discussed. This framework consists of a set of three principles together with eleven strategies for the operationalization of these principles. During the presentation of the framework, the roles of governments and of universities at the institutional, faculty/division and departmental levels in the operationalization of the framework are examined.

Keywords: teacher education; recruitment; pre-service teachers; STEM-literate

This paper reports on an instrumental case study that employed narrative and teacher change methodological and analytical frameworks to investigate Kenyan science teachers' views of the effect of student learning on their teaching. Interpretation of the teachers' views revealed that they: 1) gained an increased awareness and understanding of their students' science learning abilities that allowed them to take increased responsibility for own learning, 2) developed and accepted new understanding of their teaching roles, and 3) became more critical of how science pedagogy was modeled for them as former high school students and later, continuing practitioners. In the paper we demonstrate how the study's findings validate the emergent literature's support for contextualized science learning and teaching. The study's findings show that students' learning impacted the teachers' pedagogical practices. Therefore, we argue that students' learning and teachers' teaching are not mutually exclusive.

Keywords: teacher change; student learning; contextualized science; pedagogy

This paper is an exploration of conceptual change. It reports on a study which utilizes conceptual status elements, and explores the unique contribution of Slowmation Animation in the conceptual learning of preservice science teachers. 15 short animations were created by 55 participants in a single two hour tutorial class as a part of their methods training. Conceptual change was found to occur when their animation topic challenged their understandings of the processes within the scientific concept. The preservice science teachers reported an enthusiasm for Slowmation Animation as a method for learning how to learn, as well as for highlighting what they thought they knew, but didn't really know.

Keywords: conceptual change; slowmation animation; secondary science; preservice teacher education

Augmented Reality (AR) provides new possibilities for simulating teaching environments, experiencing teaching processes and promoting teaching interaction through certain teaching approaches, including virtual-real blended, real-time interactive or three-dimensional immersive. This paper first briefly introduces the present research status of implementing AR in education and then illustrates the 3D AR learning environment and the long-distance augmented video system. Furthermore, we explain a specific case in which the convex lens image-forming experiment was adopted as the material and we conducted an interactive and integrated image-forming experiment using AR technology to improve teaching. The case study was mainly to investigate the learning attitudes of the experimental group students by using AR instructional applications and to compare the difference in the learning achievements of eighth graders with the convex lens image-forming experiment in two learning environments. The mean scores of the experimental group increased more significantly than the mean scores of the control group; however, there appeared to be no significant difference in the mean scores between the two groups in post-tests. In addition, most students were found to have positive attitudes towards using AR for their learning in physics courses: they believe that AR instructional applications hold their attention and increase their learning motivation in physics courses. The results show that this learning environment that blends reality with virtuality will greatly stimulate the learning interests of students and promote their level of activity, suggesting significant potential for this learning application in practice.

Keywords: applications in subject areas; interactive learning environments; improving classroom teaching; augmented reality

Section II

Contributions in: Creativity, Problem-Based Learning, Motivation, Retention, Student Stress, Professional Skills, Oral Presentations, Ethical Reasoning, Assessment, Computing Engineering, Virtual Laboratories, Software Tutorials, Robot Simulation, Architectural Design, Physics & Engineering, Outreach

Recent studies regard Problem and Project Based Learning (PBL) as providing a learning environment which fosters both individual and group creativity. This paper focuses on the question: In a PBL environment, how do students perceive the interplay between individual and group creativity? Empirically, qualitative interviews were carried out with 53 students (12 groups) in Computer Science, Electronic Systems, Architecture and Design, and Medialogy at Aalborg University, Denmark. The data analysis shows that there are three aspects to the influences of a PBL environment on the interplay between individual and group creativity: (1) the project as "an extra member" in student groups; (2) tacit modes of collaboration in student groups; and (3) students have both domain-general and domain-specific understandings of creativity. These findings suggest the need for improved approaches to develop creativity in the PBL environment.

Keywords: interplay; individual creativity; group creativity; Problem and Project-Based Learning (PBL)

This paper presents the outcomes of a study of first-year engineering student perceptions of creative opportunities in engineering design tasks. The study was guided by three key questions: (1) How do first-year engineering students view creativity and its role in engineering? (2) What opportunities do students see for creativity in their engineering design projects? (3) How do various factors, including the course structure and the instructor, influence student choices to pursue creative opportunities? First-year engineering students participated in four surveys during the semester in which they were working on an engineering design project. Overall, the participants perceived many creative opportunities; however, the opportunities they saw at the beginning of their work were greater and broader, while once into their projects, the scope of their perceptions narrowed. Throughout the design project, the instructor, project constraints, and risks associated with exploring a creative design option influenced the participants' perceptions. The research outcomes can guide how instructors advise student decision-making and structure their design courses to facilitate creativity.

Keywords: creativity; engineering design; design education; first-year engineering

Josep M. Mateo-Sanz, Carme Olivé and Dolors Puigjaner 891–903 Two New Moodle Modules for the Enhancement of a Problem-Based Learning Approach

This paper describes two new Moodle modules that were developed to enhance a problem-based learning approach. One of the modules offers the possibility to easily customize student assessment. In particular, it enables the creation of questions containing random numeric variables, either scalar or vectorial, and whose answers are automatically computed regardless of the complex combination of numerical and logical operations involved in their calculation. The other module facilitates the subdivision of a problem into a common statement and a set of questions which are successively displayed in the browser. By combining these two modules, instructors can easily offer their students the opportunity to practice answering individualized quizzes anywhere and anytime. The analysis of the effect of the use of these two modules on students' performance revealed the existence of a strong link between the amount of online problems answered by students and their final grades. Typically, higher final grades were associated to higher regularity in answering individualized online problems. Moreover, it was shown that the use of individualized assessment quizzes tends to reduce academic dishonesty.

Keywords: problem-based learning; blended learning environments; Moodle modules; Statistics; academic dishonesty; constructivist learning

Zin Eddine Dadach 904–913 Quantifying the Effects of an Active Learning Strategy on the Motivation of Students

The main objective of this paper is to quantify the effects of an active learning strategy on the motivation of students in a process control course. In the first part of the investigation, the relative performance of students was used as a tool to gauge the effects of the active learning strategy on the motivation of students. The results indicate that the active learning strategy enhanced the performance of 38 (69%) students. For the second part of this quantitative method, the Dadach Motivation Factor 'DMF' was introduced in order to measure the effects of the active learning strategy on the motivation of students. Based on the requirement of the analysis (DMF > 1), the final results suggest that the active learning strategy has enhanced the motivation and increased the performance of twenty-two (40%) students. On the other hand, motivation did not have a significant role for the other sixteen (29%) students whose performance in the process control course (FGP) was higher than their average performance in the department (CGPA). The results of the quantitative approach were compared with the student survey.

Keywords: active learning; student's performance; Dadach Motivation Factor

Brandi N. Geisinger and D. Raj Raman 914–925 Why They Leave: Understanding Student Attrition from Engineering Majors

A large number of students leave engineering majors prior to graduation despite efforts to increase retention rates. To improve retention rates in engineering programs, the reasons why students leave engineering must be determined. In this paper, we review the literature on attrition from engineering programs to identify the breadth of factors that contribute to students' decisions to leave. Fifty studies on student attrition from engineering programs were included in the primary part of this literature review. In the second half of the work, an additional twenty-five studies that focused on methods of increasing student retention, were examined. Six broad factors driving students to leave engineering were identified by examining the attrition literature: classroom and academic climate, grades and conceptual understanding, self-efficacy and self-confidence, high school preparation, interest and career goals, and race and gender. Evidence from the retention studies suggests that successful efforts to increase retention act on one or more of these factors. A clear gap in the literature is that of economics: the costs associated with losing students, and the costs associated with implementing retention strategies, are virtually unmentioned.

Keywords: engineering education; STEM education; attrition, retention

Ali Rizwan, Muhammad Abbas Choudhary, Mirza Jahanzaib, Ali Imran, Umair Manzoor and Ammar Ali 926–932 Analysis of Factors Affecting the Stress Level of Engineering Students from Remote Areas

This paper presents an analysis, based on a questionnaire, of factors that affect the stress level of engineering students who come from remote areas. The questionnaire relates to the expectations that the students have gained from their native institutions as well as from their families. Randomly collected data from 200 students is analyzed. Six-sigma techniques of an Affinity diagram, Pareto analysis, SIPOC analysis, a Cause and Effect matrix and Scatter plots are used for the analysis. It is observed that the students' poor command of the English language, their lack of confidence and lack of knowledge about higher education are the most critical stress-causing factors.

Keywords: student stress; remote area students; Pakistan; Six-Sigma

A. Ashrif A. Bakar, Rosdiadee Nordin, Nasharuddin Zainal, Khadijah Alavi, M. M. Mustafa and H. Hussain 933–939 Nurturing Engineering Enthusiasm and Soft Skills in High School Students

In this paper, we present a study of an educational program to nurture engineering enthusiasm among high school students. In this program, we designed a one-year project-based learning program focusing on microcontroller applications, where selected high school students (15 to 16 years old) were guided by mentors consisting of engineering undergraduate students. The participants of this study were trained with microcontroller know-how and on the development of specific soft skills through hands-on modules. The objective was to foster their enthusiasm in engineering and cultivate several soft skills, such as communication, teamwork and life-long learning, which are essential for students to become good engineers. The outcomes of this program demonstrate that the high school students have shown positive enthusiasm towards engineering and have improved their soft skills.

Keywords: engineering education; high school students, microcontroller; hands-on, mentoring; project-based learning (PBL)

Luc de Grez and Martin Valcke 940–947 Student Response System and How to Make Engineering Students Learn Oral Presentation Skills

Feedback and assessment play an important role in teaching and learning. This study describes the implementation and evaluation of an innovative instruction format that builds on the integrated use of a Student Response System (SRS) for peer assessment of oral presentations of third-year engineering students. A large number of oral presentations were assessed and participants played both the role of assessor and assessee. First, the analysis results demonstrate that the psychometric qualities of the peer assessment approach supported by SRS are acceptable. Secondly, students' learning process and their perceptions about the learning process in this particular instructional setting were investigated. Results mirror a very positive student attitude towards SRS. The SRS was reported as an effective way of producing feedback for presenters, assessors and educators. The learning effect concerning assessment remained rather limited. Lastly, the relationship between personal characteristics, performance and assessment was studied. Results point to a significant positive correlation between self-efficacy and oral presentation performance.

Keywords: Student Response System; feedback; peer assessment; oral presentation skills; higher education; self-efficacy; learning from assessment

Little empirical research has been directed at team based ethical decision making, specific to engineering, and none (to the authors' knowledge) have studied the *process* of ethical decision making by engineers, an increasingly important issue given ABET's Criterion 3-f "... an understanding of professional and ethical responsibility". The objectives of this study are to: (1) investigate whether groups/teams of engineering students make "better" decisions than individuals when solving problems involving ethical issues, (2) evaluate and describe the processes used by the individuals and groups to solve problems that are ethical in nature, (3) and to assess those variables that potentially affect the quality of the resolution and the quality of the decision process. Two primary models: *Jones's Synthesis of Ethical Decision Making* descriptive model used in business and a normative *Harris, Pritchard, and Rabins (HPR) Model* widely used in engineering, combined with factors cited in the literature were used to form an *Ethical Decision Making in Engineering Model*. Using this model an experimental study involving both individuals and teams of engineering students solving ethical dilemmas was used to accomplish the research objectives. The results of this research suggest that teams achieve better results than individuals when resolving less complex ethical dilemmas. When complexity is increased both teams and individuals have difficulty obtaining satisfactory resolution; having completed an engineering ethics course also does not appear to improve the resolution. Processes that are used, as well as those significant factors identified, provide the engineering education community with an understanding about the degree to which a course in engineering ethics improves the ability and the quality of the resolution reached; and hence gives an improved understanding of professional and ethical responsibility.

Keywords: ethical decision making model; engineering students; engineering ethics

The rapid industrialization of the oil rich country of Saudi Arabia has led to the expansion of its engineering colleges. However, it is perceived by local industrial and academic sectors that changes in the curriculum are not dynamic enough to keep pace with a rapidly-changing marketplace. The objective of this study is to shed some light on these perceptions. This paper reports results of a study carried out in Saudi Arabia for the purpose of ranking generic competencies required from engineering graduates. A questionnaire was designed and sent to engineers working in industry or in academia. The questionnaire included fifty competencies that were grouped into four domains: knowledge and understanding, personal and professional skills, interpersonal skills, and practicing skills. The analysis of the survey data has identified the competencies that are valued by industry and academia. The overall analysis showed that non-technical and attitudinal competencies are being perceived as equally important as technical ones. This is consistent with studies carried out elsewhere in the world. However, some issues such as communication in English language and computer literacy are deemed equally important. The findings of this study may be helpful in identifying the critical soft skills that need to be carefully addressed in any tuning of the current engineering curriculum.

Keywords: engineering competencies; ranking; surveys; soft skills

A scheme for multiple-choice testing has been developed, based on simple probability theory, that takes into consideration partial knowledge and omissions of responses. It is tested against other methods which also take partial knowledge into account, namely, elimination testing for multiple-choice tests, as well as the conventional dichotomous method of scoring. The scheme is thought of as novel, in that it considers partial knowledge and omissions using a developed method based on probability theory. The results obtained were found to be quite similar to the 'more-complicated-to-use' elimination testing and lower results were found when compared with the conventional dichotomous method. Although the work here was undertaken to enhance testing within engineering education, there is no reason why this approach cannot be applied to any number of areas within science and arts subjects.

Keywords: scoring; multiple-choice assessment; computer-aided assessment

In recent years European universities have been adapting their curricula to the new European Higher Education Area, which implies the use of active learning methodologies. In most database courses, project-based learning is the active methodology that is widely used, but the authors of this paper face context constraints against its use. This paper presents a quantitative and qualitative analysis of the results obtained from the use of collaborative learning in both cross-curricula competences and subject-specific ones in the "Introduction to Databases" course at the Barcelona School of Informatics. Relevantly, this analysis demonstrates the positive impact that this methodology had, allowing us to conclude that it is not only project-based learning that is suitable for these kinds of courses.

Keywords: computing engineering education; database systems; collaborative learning

Seismic isolation and energy dissipation are used for improving the dynamic response of bridges. However, no general concept for selecting the most appropriate devices for each structure is available, therefore understanding the dynamic processes is important for the selection and design of proper energy dissipation system to improve bridges' dynamic behavior. This study is focused on an active training method for studying the behavior of bridges with base isolation systems under earthquakes. The proposed method includes creating and testing of bridges' numerical models in the classroom, and further results' analysis by the students, aimed at drawing practical conclusions under the teacher's supervision. To implement the method in the learning process, a Bridge Dynamics Laboratory was created in the Simulink environment. Original libraries of bridge's structural elements, anti-seismic devices and seismic loads were developed. Modeling bridges using these libraries is a simple procedure, being easily incorporated in the learning process during class teaching. Simulink allows the development of bridge models that visually reflect the real physical processes, involving the bridge structure, and provides the possibility of quick and convenient modification of any parameter characterizing the model. The learning process includes the representation and measurement of structural behavioral parameters, and their dependence on types and technical characteristics of the applied seismic protection system. Dynamic processes are studied based on modern standards. Time-history analysis is used to simulate the investigated bridge behavior under a selected earthquake. Implementation of the proposed method in the classroom teaching process of an undergraduate course is presented and explained.

Keywords: virtual laboratory; base isolation; bridges; seismic response; engineering education; Simulink

Dragoljub Novaković, Neda Milić and Branko Milosavljević 1013–1023 Animated vs. Illustrated Software Tutorials: Screencasts for Acquisition and Screenshots for Recalling

Previous studies in the domain of software learning did not reveal consistent results considering which type of visualisation is more efficient and effective for mastering software procedures. In this study, two independent units (A and B) for two procedures in the MS Excel application were made in two versions: an illustrated (screenshots) and an animated one (screencasts). Using a 2×2 -experimental design with the visualisation type (illustrated vs. animated) and counterbalanced learning order (A, B vs. B, A) as independent variables, 72 participants were randomly assigned to one of the four groups. For unit A, the animated version was assigned to groups 1 and 3, and the illustrated version to groups 2 and 4, and vice versa for unit B. The main conclusion deduced from results and confirmed with participants' choice of preferable version is that animated tutorials are finest learning solutions for software procedure acquisition, while illustrated tutorials are foremost for procedure recall.

Keywords: software tutorial; cognitive load theory; 'animation deficit'; acquisition; recalling

Jer-Vui Lee, Zahari Taha, Hwa-Jen Yap and Azeddien Kinshheel 1024–1036 Constructivist Game-based Robotics Simulator in Engineering Education

The aim of this study was to assess the learning environment of a constructivist game-based robotics simulator in engineering education as compared with a similar non game-based conventional robotics simulator. It was assessed in terms of students' perceptions of the simulation-based environment and attitudes toward robotics lessons using simulation. This study employed a quantitative method via two questionnaires: the six scales of Constructivist Simulation-based Learning Environment Survey (CSLES) and the one scale of Test of Robotics Related Attitudes (TORRA). The sample consisted of 114 undergraduate and fresh graduate students (age 22 to 25) who had attended a formal course of automation and robotics. They were randomly assigned into two groups: the experimental group ($n = 60$) and control group ($n = 54$). The experimental group used a game-based robotics simulator (G-IRSTS) and the control group used a conventional robot simulator (IRSTS). Using statistical methods, both CSLES and TORRA were found to exhibit good factor and reliability validity. The main finding of this study indicates that G-IRSTS is more effective than IRSTS in terms of Negotiation, Inquiry learning, Reflective Thinking and Challenge.

Keywords: constructivist learning; game-based learning; robot simulation, student perceptions

Sherif El-Fiki 1037–1046 Towards a Process-based Model for Teaching Architectural Design, with Reference to Design Studio One

The design studio often lies at the very heart of architectural education, being the pool in which the outcome of all other courses may holistically synthesise. In early educational studios, particular attention needs to be paid to the limited design experience that students may have already acquired, together with the amount of information they need to process within strict academic timeframes. This should also develop within an appropriate understanding and carrying-out of design as an integral, systematic and logical process. Thus, the present study primarily aims at developing a process-based approach to teaching 'architectural design I' that responds to the aforementioned challenges. The proposed model is described in two phases. The first phase comprises six steps that are planned as a medium for gradual and cumulative learning about the principles of architectural design. The second phase comes in four steps. It aims at introducing students to a systematic design process that they can pursue in their future academic and practical endeavours. The proposed model should help students to grasp the basic interdependent design principles, apply them within a systematic logical process, and gain independence in future design studies and professional development.

Keywords: engineering education; architectural design; design process; design principles

Aharon Gero 1047–1054 Interdisciplinary Program on Aviation Weapon Systems as a Means of Improving High School Students' Attitudes towards Physics and Engineering

A unique interdisciplinary program entitled 'Introduction to aviation weapon systems' was developed and implemented at a leading Israeli high school that is affiliated with the Israeli Air Force. The program integrated physics and engineering and dealt with the structure and principle of operation of weapon systems used in aviation. Twenty 12th grade students majoring in mathematics and physics participated in the program, whose objective was to enhance the students' interest in physics and engineering, demonstrate the use of these disciplines in aviation, and to stimulate their desire to continue with more advanced studies in these subjects. The research presented here used qualitative tools to characterize students' attitudes towards the program, as well as changes in their attitudes towards physics and engineering as a result of their participation in the program. Research results reveal that, in addition to the great interest the students exhibited towards the program, they believed that interdisciplinary learning that combines physics and engineering leads to a better understanding of physics. The research also shows that, following the program, the students' interest in physics and engineering increased, as did their desire to continue with more advanced studies in the subject.

Keywords: aviation; interdisciplinary education; high school students' attitudes towards physics and engineering; physics education