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Ahmad Ibrahim

1 Editorial

Davy D. Parmentier, Bram B. Van Acker,
Jan Detand and Jelle Saldien

2–18 Framework to Redesign Products with Focus on Design for Assembly Meaning: A PBL Case Study

In many companies and especially in companies producing small series of products, manual assembly is highly needed for its flexibility. Complexity of manual assembly tasks is increasing in these companies and operators need to be supported. A framework was developed to facilitate designers to design for assembly meaning, a product design approach that aims to improve the intuitiveness of the assembly process and tries to lower the need for procedural instructions. In this paper, a project based learning (PBL) case study was used to assess the framework. In this study, twenty-eight students redesigned six light fixtured based on the analysis of the assembly process and in close cooperation with the company. The results of a survey taken from the students showed that the framework was valued by many students within a PBL setting. Moreover the solutions designed by the students to foster a more intuitive assembly were valuable, mostly feasible and showing a variety of solutions. The added value of offering a framework to design for meaning in assembly and to implement this in a PBL setting with access to a company, operators, products and prototyping facilities was also illustrated. The framework, method and tools are all discussed within the context of project based learning.

Keywords: product design; assembly; project based learning

Lisa B. Bosman, Kurt Paterson and
Margaret Phillips

19–30 Integrating Online Discussions into Engineering Curriculum to Endorse Interdisciplinary Viewpoints, Promote Authentic Learning, and Improve Information Literacy

Engineering is very much an applied discipline where math and science concepts, skills, and tools can be used to design products or processes with new and/or increased value. Research suggests active learning is an effective method for teaching and learning in the engineering classroom. Moreover, students continue to express increased satisfaction when taught using this experiential pedagogical approach. One approach to active learning gaining traction in the engineering classroom is the use of online discussions. The purpose of this paper is to offer a structured approach for engineering educators to develop online discussion prompts aimed to prepare engineering students for entering the workforce; this structure approach includes an intentional and purposeful focus on three core elements: (1) interdisciplinary viewpoints, (2) real-world and authentic experiences, and (3) information literacy applications. A mixed methods analysis provides evidence towards student exposure and awareness to the three core elements of interdisciplinary viewpoints, real world and authentic experiences, and information literacy applications. In addition, students reported a positive experience participating in online discussions, and improvements in student perception changes related to blended learning and self-regulated learning.

Keywords: undergraduate; information literacy; mixed methods

Luis Ballesteros-Sánchez, Isabel Ortiz-Marcos
and Rocío Rodríguez-Rivero

31–43 Investigating the Gap Between Engineering Graduates and Practicing Project Managers

The trend of the projectification of organizations to achieve their business objectives is currently a reality. In this context, a growing number of engineers are having their working roles redefined as project workers and managers. This study examined what is the main gap existing between engineering graduates and project management profiles in terms of personal competencies needed to successfully lead projects. Through the participation of 183 individuals (88 engineering master's students and 95 current project managers), using personal interviews and a survey, it was possible to assess eight competencies (emotional management; self-belief; commitment; communication; conflict management; resource management; team leadership, and; professionalism), and determine major differences between both groups. All personal competencies mean scores have shown to be higher for project managers than for engineering graduates. Five competencies are found to differ significantly for project managers than for engineering graduates: conflict management, team leadership, communication, emotional management, and professionalism. As a conclusion derived from this study, it is recommended to foster development of certain competencies from the early stages of engineers' education and project managers' careers. Special emphasis should be placed on strengthening conflict resolution, leadership and communication.

Keywords: leadership; project manager; competence; project management; engineering

Justin L. Hess, Athena Lin, Grant A. Fore,
Tom Hahn and Brandon Sorge

44–64 Testing the Civic-Minded Graduate Scale in Science and Engineering

Education is a prominent modality for preparing the future workforce to engage as ethical practitioners in their future careers and as good citizens within society. Thus, we need contextually valid ways of measuring individual's civic growth in higher education, especially in US engineering education where ethics is a required component for accreditation. The primary objective of this study was to test and validate the Civic-Minded Graduate (CMG) Scale, an increasingly used measure of civic-mindedness outside of STEM, with science and engineering students. In Phase 1, we used principal component analysis to identify a potential factor structure of the CMG Scale based on responses from 434 first-year engineering students. In Phase 2, we utilized confirmatory factor analyses and sought to confirm the Phase 1 extracted solution with two distinct student samples. Based on these analyses, we were able to extract and confirm a five-factor CMG solution. The novel factors included: (1) Valuing Community Engagement, (2) Confidence in Building Consensus, (3) Civic Knowledge and Skills, (4) Empathic Interpersonal Communication, and (5) Civic

Intentions and Obligations. In the discussion, we unpack what these novel constructs represent. In addition, we argue for their alignment with broader considerations in science and engineering education research and practice. Finally, we recognize future research that is needed to further solidify these findings.

Keywords: Keywords: civics; civic mindedness; quantitative; factor analysis

Marwa Hassan Khalil

65–85 Idea Generating Techniques in Architectural Design Education: Exploring Students' Perceptions

In architecture education, addressing idea generation techniques and creative problem solving skills has always been important for creativity in architectural design. Students are always looking for structured approaches to come up with novel ideas that help them in solving their challenges, especially architectural design problems. Such problems are considered wicked problems; therefore there is strong demand for courses in architecture curricula that provide students with tools to develop as creative thinkers. The objective of this study is to explore students' perception of Thinkertoys, which are practical and hands-on techniques, as effective thinking tools to generate ideas and breakthroughs that are often needed to creatively solve architectural design problems. The study adopted an interpretive qualitative approach that combines different data gathering methods. The number of students involved in the main phase of the study was 38 students. The data was analyzed to identify the impact of the proposed idea generation techniques on the students' thinking skills and their ability to solve complex design problems. A thematic analysis revealed five important overarching themes: skeptical nature, willingness to initiate, flexible attitude, generative behavior and self-criticism. Such themes are believed to be crucial to creatively solve ill-defined and tangled problems. The findings of this study are expected to provide useful insights that could inform pedagogical initiatives aiming to foster creativity in architectural design education.

Keywords: idea generation techniques; Thinkertoys; creativity; design education; architectural design

Ning Fang and Seyed Mohammad Tajvidi

86–95 The Effects of Computer Simulation and Animation (CSA) on Student Learning and Problem Solving in Engineering Dynamics

This paper aims to study the effects of computer simulation and animation (CSA) on student learning and problem solving in Engineering Dynamics, a second-year foundational undergraduate engineering course required in many engineering programs. Two new CSA modules were developed, focusing on Newton's second law of motion and the principle of angular impulse and momentum, respectively. A significant amount of qualitative verbal data generated from 24 student participants' think-aloud activities was analyzed based on five of the six categories in the cognitive process dimension of Revised Bloom's Taxonomy: remember, understand, apply, analyze, and evaluate. The research findings from the present study reveal that compared to traditional textbook style (TTS) instruction, CSA enabled students to perform mental activities more frequently in the "understand" category during learning, and more frequently in all five categories (remember, understand, apply, analyze, and evaluate) during problem solving.

Keywords: Computer simulation and animation (CSA); traditional textbook style (TTS) instruction; learning; problem solving; Engineering Dynamics

Rachel McCord Ellestad and Holly M. Matusovich

96–114 Metacognitive Engagement During Problem Solving While in Naturalistic Homework Study Groups

Metacognitive regulation is a required activity when attempting to solve well-structured word problems. The purpose of this study was to understand the ways in which undergraduate engineering students engage in metacognitive regulation while working on homework in naturally formed study groups. Using ethnographically informed participant observations, three naturally formed groups were observed as they engaged in self-structured work around well-structured engineering homework problems. Using the Naturalistic Observations of Metacognition in Engineering (NOME) protocol, metacognitive regulation behaviors were identified throughout the observations. Behaviors like using a homework format (planning), checking an answer with a peer (monitoring), and discussing reasonableness of a solution (evaluation) are a few of the examples observed by participants. Descriptions of the regulatory behaviors as well as rankings of the rate of engagement are discussed. Metacognitive monitoring activities were observed most frequently while metacognitive evaluation activities were observed least frequently. Implications for research and practice are discussed.

Keywords: observations; metacognitive regulation; problem solving; ethnography

Fermín Sánchez-Carracedo, Esther Trepát and Alejandra Barba-Vargas

115–132 Successful Engineering Lecturing based on Neuroscience

Many engineering professors teach their classes without having received previous training in psycho-pedagogy and neuroscience. While a few of them have received some form of pedagogical training during their academic career, the vast majority have not acquired any training in the field of didactics, that is, in the science of teaching. Teaching is a difficult task, and teaching effectively is even more difficult. Much literature exists on different teaching-learning methodologies that have been empirically tested in engineering studies. However, practically none of these works make reference to the main factor in any learning process: how does the human brain learn? This paper analyses learning from the perspective of its three main phases (motivation, attention, memorization), and how these phases should be addressed in a lecture, since many of the Engineering classes at universities around the world are given as lectures. The current knowledge of neuroscience is used in the paper to provide twelve recommendations on how a lecture should be successfully given in Engineering Degrees. For the selection of these twelve tips, we use two criteria: they must be relevant in a lecture, and they must have a neuroscientific basis, which is explained in the framework of the paper. The relationship between the twelve tips and the seven principles of good practice in undergraduate studies enunciated by Chickering and Gamson has also been established. The relation of each tip with the learning phases to which it refers is explained, and an example of how to apply it in a lecture is given. This paper presents a new way of working in engineering education: how to apply the knowledge provided by neuroscience to the teaching-learning process. This work provides some ideas about how this can be done in a lecture, but it is also necessary to conduct experiments to validate the effectiveness of the twelve tips proposed herein. It is likewise necessary to carry out similar work for other teaching methodologies such as PBL, flipped classroom or service-learning. The future of education cannot be developed without taking into account the functioning of the human brain or by applying educational practices that are unsupported by scientific evidence of their effectiveness.

Keywords: neuroscience; neuroeducation; motivation; attention; memory; emotions, human brain; lectures

Desmond Bonner and Michael C. Dorneich

133–146 Increasing Female Middle School Student Interest in STEM: Requirements for Game-Based Learning Applications

This exploratory work developed requirements to build games to increase female middle school students' interest in Science, Technology, Engineering, and Mathematics (STEM). In middle school, students typically begin to determine career interests. Female students have many barriers to full participation in STEM, including stereotypes, role socialization, interests, and attitudes which can influence confidence in areas such as mathematics. Game-Based approaches are designed to overcome barriers, allow experimentation with difficult concepts, and engage students. However, many games are designed for the "default" male user, leaving female preferences unaddressed or as secondary issue. Six requirements (Protagonist, Mechanics, Socialization, Fun, Uncertainty, and Story) were developed from relevant literature, surveys, and consultation with STEM outreach organizations. The requirements were developed to identify factors which may make a game engaging to a wider audience that include female middle school students. The requirements were used to develop SORCERESS OF SEASONS, a game designed to develop computational

literacy in middle school students. An evaluation with 15 middle school students provided feedback on requirements, learning, and STEM interest. Both female and male middle school students showed an increase of basic computational knowledge comprehension, and increased interest in STEM careers, with females reporting a larger gain. The results suggest that the requirements may be helpful when developing games to increase student interest in STEM.

Keywords: game-based learning; STEM; programming; computational literacy; middle school education

Walter C. Lee, Ben D. Lutz, Holly M. Matusovich and Sreyoshi Bhaduri 147–162 Student Perceptions of Learning about Diversity and its Place in Engineering Classrooms in the United States

Engineering students must be prepared to function as professionals in increasingly diverse societies. However, addressing diversity is primarily relegated to efforts focused on underrepresented groups, rather than being meaningfully integrated into engineering education curricula. The purpose of this study is to advance understanding of how students in the United States (U.S.) perceive the relationship between learning about diversity and engineering classrooms. Given the strong focus on technical skills in U.S. engineering and the role that student attitudes and resistance play in educational reform, educators may need to carefully integrate such topics. We used an exploratory, qualitative research design to investigate engineering students' perceptions of and task values for engaging with learning tasks associated with diversity-focused education. We interviewed 41 students, both undergraduate and graduate, from a university in the U.S. using Eccles' expectancy value model to inform data collection and analysis. When discussing diversity-focused education in engineering, students: (1) focused on issues of culture related to diversity and engineering; (2) recognized challenges associated with learning and teaching; and (3) varied in the nature of and degree to which they perceived value for such content. If educators are strategic, there are opportunities to more effectively incorporate topics and address issues related to diversity in engineering courses. In addition to clearly demonstrating the value of diversity, educators will also need to address uncertainty regarding the structure of such a task as it may increase the likelihood of disengagement.

Keywords: diversity; inclusion; motivation; instruction

José Alberto Benítez-Andrades, Isaiás García-Rodríguez, Carmen Benavides, María Mercedes Reguera-García and Pilar Marqués-Sánchez 163–171 Cooperative Work among Computer Engineering and Health Sciences Undergraduates: A Case Study

This work describes an interdisciplinary experience carried out with computer engineering and health sciences (nursing) students. The objective of the experience was to improve the ability of engineering students to interact with professionals from other fields and to increase the ability of nursing students to make decisions related to new technologies within their professional field. The study involved nine groups of between four and six students with equal numbers of engineering and nursing students in each group. The students of each group worked together to solve problems put forward by nursing professors. The study involved 3 of engineering professors and 3 of nursing professors. The outcome of the experience was assessed by a satisfaction questionnaire and by the results obtained after evaluating the students. It was concluded that there was an improvement in skills of both the nursing and computer engineering students. Furthermore, through social network analysis, it was possible to observe an increase in the communications among the interdisciplinary groups as proposed at the beginning of the study.

Keywords: cooperative learning; interdisciplinarity; interdisciplinary learning; nursing informatics; teamwork

Muhammad Rashid 172–184 A Systematic Approach of Data Preparation for ABET Accreditation

This article presents a systematic approach for the preparation of assessment data. The process begins by carefully identifying the tasks for the preparation of required data. Subsequently, the identified tasks are mapped on appropriate resources. Finally, an explicit interface between various resources is defined. It has been shown that the presented approach in this article, demonstrated with various implementation examples through different aspects of an engineering program, increases the awareness between various faculty members about their responsibilities related to the accreditation process. Furthermore, it facilitates the program coordinator to interact with the entire faculty for the collection of required data.

Keywords: ABET accreditation; ad hoc approach; assessment data; student outcomes; systematic methodology

Wen-Jye Shyr, Chia-Hung Chen, Yu-Xiang Wang, Chen-Liao Chen, Der-Fa Chen and Chieh-Lun Cheng 185–194 Establishing Competence Indicators to Guide Teaching Automotive Coating Techniques

The purpose of this study is to establish the competence indicators to guide automotive coating techniques. First, based on literature review, the connotations of relevant technical competencies in the field of automotive coating techniques were analyzed, and then, a questionnaire for the competence indicators of automotive coating techniques was prepared. After the content validity of the questionnaire was reviewed by field experts, the questionnaire for the competence indicators of automotive coating techniques was completed. In this study, ten experts and scholars related to automotive coating techniques were invited to establish the Delphi panel, including teaching experts and competent experts in charge of automotive coating techniques. Then, the Delphi questionnaire survey was performed. Finally, the modes, means, standard deviations, quartile deviation, and other statistical methods were used in the stability analysis and consistency analysis of expert opinions. The findings of this study show that, in the field of automotive coating techniques, the competence indicators consist of four levels, the automotive coating materials technique, the operational technique of automotive coating equipment, the color matching technique of automotive coating, and the automotive coating repair technique, and includes 20 competence indicators. According to the statistical data from questionnaire surveys, the means of different indicators were ranked to reveal the importance of automotive coating material technique, operation technique of automotive coating equipment, automotive coating color matching technique, and automotive coating repair technique.

Keywords: automotive coating technique; competences analysis; Delphi

Gregory Theyel, Allan Baez Morales, Evangelia Bouzos and Prashanth Asuri 195–203 Enhancing Senior Engineering Student Projects by Incorporating Needs Assessment, Manufacturing Engineering, and Pilot Testing

How can the senior engineering student project experience be enhanced so students gain a more complete understanding and appreciation of the entire technology development process, develop more skills needed in their first jobs, and become more capable of developing projects that meet their client's expectations? Interview data from managing engineers about the skill needs of newly hired engineers and interview data from students who completed their senior engineering project reveal gaps – such as customer needs assessment, manufacturing engineering, and pilot testing – between the skill needs of new hires and their senior engineering project experience. Workshops were implemented to address these gaps and a second round of student interviews reveals the gaps were bridged.

Keywords: senior engineering student projects; technology development; workshops; needs assessment; manufacturing engineering; pilot studies

Mirjana Kranjac, Srdjan Tomic, Jakob Salom, Tatjana Ilic-Kosanovic, Damir Ilic and Stanko Bulajic 204–214 New Methodology of Teaching a Smart City Concept: A Case Study

Building smart cities requires educational programs that would offer students an up-to-date knowledge to be gained by developing their practical skills and, especially, by means of solving “living” problems. This paper presents a newly developed methodology of teaching students through research and creation of solutions that can be immediately implemented. The authors describe the

suggested teaching approach by presenting a case study in which the problems and solutions of a real city, Belgrade, are explored. Students developed an online survey with questions addressing the main problems in the city. The citizens' view of the problems in the city was the basic input for students in designing a new smart city concept. Compared to the traditionally trained group of students, the satisfaction with the teaching results of the newly trained 126 students divided in two groups, was higher.

Keywords: teaching methodology; education; smart city; practically oriented; survey

Wen-Jye Shyr, I-Min Chen, Chun-Min Ho 215–222 Teaching Geophysics of Earthquakes and Building Structures for Disaster Prevention: A Case Study
and **Jing-Chuan Lee**

This study applied interactive teaching model to teaching geophysics of earthquakes and building structures for disaster prevention education. The proposed teaching model was first carried out through the interactive thematic interpretation of earthquake education, such as building structure safety, earthquake disaster prevention introduction, building structure model making, and vibration platform testing experience. The objective of the paper is to investigate the impact of a seminar and experiential learning activities on the awareness and disaster prevention literacy of middle school students. Students from grade 5 to grade 9 are selected as the participants. After a 4-hour interactive thematic interpretation, the course of the earthquake-resistant concept of buildings and the teaching of model making were conducted, where the students worked together to build a structural model of a 2-storey building for earthquake simulation test. Finally, the student learning outcomes of earthquake resistance awareness and disaster prevention literacy were evaluated. The overall evaluation results showed that, (1) the course and experience activity could achieve the teaching objectives, (2) students were able to accept experiential learning, and (3) students agreed that this activity could effectively enhance their disaster prevention awareness, and they would like to learn more about the issue.

Keywords: teaching models; interactive teaching; disaster prevention education

Anne Wallisch, Juan Carlos Briede-Westermeyer and Marianela Luzardo-Briceño 223–243 Fostering User-Empathy Skills of Engineering Students by Collaborative Teaching

This research analyses the impact factors on developing user-empathy, by presenting collaboration experiences between engineering students and elderly people, in particular, analysing the aspect of communication. This collaboration began, by aiming to assess the development and impact evaluation of a participative and multi-disciplinary co-creation model, set up to design new products for self-reliant elderly in the Biobío region in Chile. Within a two-year period, several co-creation workshops with different interaction formats were conducted. The workshops were extremely valuable, not only in terms of design solutions, but also the participating students soon developed a high degree of empathy for the participating elderly, as representatives of a user group that was initially foreign to them. Empathy for their target users helped the students, not only with regard to determining requirements, but above all, with the design of an interaction that allowed suitably integrating elderly people into the design process. Examining these interactions revealed key elements of the learning process as well as the generic and specific success in teaching competences, an aspect that is directly sought by the industry. Based on these results, implications are derived for teaching user-empathy to engineering students as well as for curricula design.

Keywords: design engineering; engineering education; soft skills; co-creation; project-based learning; collaborative learning; learning outcomes

Fabrizio Vergine, Lucía Capdevila and Nikos J. Mourtos 244–269 Assessing Students' Ability to Develop a Systematic Approach to Learning

This study presents an evaluation of aerospace engineering students' ability to develop a systematic approach to acquiring new engineering knowledge. The study involves 480 first-year, junior, senior and graduate students. Students reflected on their learning process and evaluated its effectiveness using their performance on tests as a measure. Their perceptions were then contrasted with their actual performance in each course. This comparison allowed for an evaluation of students' ability to reflect accurately and helped identify specific learning activities, which produced desirable learning outcomes. These activities form the basis for proposed course design elements, aimed at improving students' lifelong learning skills. The results of the current study can be easily adapted in any engineering or science discipline, and could possibly be generalized for non-technical disciplines as well.

Keywords: lifelong learning; self-directed learning; course design; aerospace engineering

Sung-Hee Jin, Mina Yoo, Xuenan Cui and Ji-Eun Choi 270–277 Impact of Class Scheduling on Learning Achievement of Computer Engineering Students

Class scheduling in engineering education should be considered in terms of student success, as well as the efficiency of instructors and educational institutions. Class scheduling methods include block scheduling, which allocates class hours for one week into one class, and spaced scheduling, which divides class hours into two or three sessions over a week. Many studies have addressed the educational benefits of block and spaced scheduling, but few studies have shown that changing the number of classes per week has any significant effect on learning. This comparative quantitative study aimed to compare the effect of block and spaced scheduling methods on undergraduate students' understanding and application of engineering knowledge. Object-oriented programming classes of four hours were scheduled in two ways: (1) block scheduling of four hours of lectures on Friday, and (2) spaced scheduling with two hours of lectures on Monday and two hours of practice on Wednesday. The results of this study showed that main effect of the class scheduling methods was not statistically significant for learning achievement, learning engagement, perceived learning outcome, and course scheduling satisfaction between the two groups. Based on the research results, class scheduling was discussed from the perspective of learning opportunities, and educational implications for class scheduling in engineering education were presented.

Keywords: class scheduling; block scheduling; spaced scheduling; spacing effect

Jacek Uziak, M. Tunde Oladiran, Kurt Becker and Marian Gizejowski 278–286 Assessing Chalk & Talk and Power Point Presentation Techniques for Teaching Engineering Courses

The paper discusses the curriculum delivery modes to promote teaching and learning of engineering in universities. The current modes of instruction are the traditional chalk & talk and PowerPoint presentations. The latter completely depends on the rapid growth and adoption of modern ICT in enhanced teaching classrooms and environments. The study is based on the literature and extended teaching experiences of the authors in different universities in Africa, Europe and North America. Anecdote information obtained from fellow academics and consultation with students were also used in the paper. The discourse covered the advantages and disadvantages of each method. Because of the complex nature of engineering education, either of the delivery modes may not be adequate to cover all courses or topics required in a program for professional accreditation. As a result, it is recommended that instructors should use a hybrid technique consisting of chalk & talk and PowerPoint, having determined which area of the course will benefit significantly from either technique

Keywords: engineering education; lecture delivery methods; PowerPoint; chalk & talk

Andrés Díaz Lantada and José L. Martín Núñez 287–297 Strategies for Continuously Improving the Professional Development and Practice of Engineering Educators

Lifelong learning plays a fundamental role for all engineering professionals, including engineering educators, as the working context is now international and rapidly changing. The training and professional development of engineering educators are hence of vital importance for letting universities serve society. In this study, the main challenges for the promotion of well-trained and

change-oriented engineering educators are methodically analyzed, as linked to preparing the future generations of engineers. A systematic analysis of such challenges is performed and helps with the finding of unsolved or critical aspects, which can be grouped into main problems. After studying them, a collection of actuations or potential solutions, together with a set of tools for checking their progress, are put forward. Key strategies directly involve teachers themselves and their teaching methodologies, implicate students and the relationships with educators, take advantage of available resources and are dependent on the surrounding environment. Their effects are discussed, based on authors' experience, and considering the information from the studies carried out by numerous colleagues worldwide.

Keywords: engineering education; engineering educators; lifelong learning; teaching practice; quality and continuous improvement