The International Journal of Engineering Education

Contents

Contributions in: Assessment, Social Capital, Motivation, Team Work, Transferable Skills, STEM Teaching, Capstone Design, Design Based Learning, Technology in Education, Software Engineering, Agricultural Engineering, Mechanical Systems, Nanotechnology, Digital Communications

Computer-aided design (CAD) logs provide fine-grained empirical data of student activities for assessing learning in engineering design projects. However, the instructional sensitivity of CAD logs, which describes how students respond to interventions with CAD actions, has rarely been examined. For the logs to be used as reliable data sources for assessments, they must be instructionally sensitive. This paper reports the results of our systematic research on this important topic. To guide the research, we first propose a theoretical framework for computer-based assessments based on signal processing. This framework views assessments as detecting signals from the noisy background often present in large temporal learner datasets due to many uncontrollable factors and events in learning processes. To measure instructional sensitivity, we analyzed nearly 900 megabytes of process data logged by our Energy3D CAD software as collections of time series. These time-varying data were gathered from 65 high school students who solved a solar urban design challenge using Energy3D in seven class periods, with an intervention occurring in the middle of their design projects. Our analyses of these data show that the occurrence of the design actions unrelated to the intervention were not affected by it, whereas the occurrence of the design actions that the intervention targeted reveals a continuum of reactions ranging from no response to strong response. From the temporal patterns of these student responses, persistent effects and temporary effects (with different decay rates) were identified. Students' electronic notes taken during the design processes were used to validate their learning trajectories. These results show that an intervention occurring outside a CAD tool can leave a detectable trace in the CAD logs, suggesting that the logs can be used to quantitatively determine how effective an intervention has been for each individual student during an engineering design project.

Keywords: computer-based assessment; instructional sensitivity; data-intensive research; computer-aided design; time series analysis; engineering design; educational data mining; learning analytics

This paper focuses on a single aspect of learning management systems, i.e. knowledge assessment. The developed web application enables simple knowledge testing by providing the means for creating exam questions carefully. Questions used are MCSA—multiple choice, single answer. Guidelines for creating these questions are presented, while some additional well-established and reputable practices in education such as instant feedback (error and correct answer display) are implemented. The application differentiates between groups of users such as students and teachers, each with its own rights and obligations. Special attention is given to cheating prevention and application abuse. Both functionality of the application and user satisfaction were tested. The results obtained imply the need for this kind of tool in education.

Keywords: cheating prevention; instant feedback; knowledge assessment; web based exam

In 2009, the Canadian Engineering Accreditation Board (CEAB) called for the assessment of 12 graduate attributes in all Canadian accredited engineering programs. As part of this process, data are required from a variety of stakeholders, including the faculties responsible for teaching the host of courses offered in Canada's diverse engineering programs. This paper describes the second year of a three-year study in the Faculty of Engineering at the University of Manitoba that explores how the CEAB graduate attributes are manifested and measured in its curricula. The four attributes targeted were Problem Analysis, Use of Engineering Tools, Communication Skills, and Ethics and Equity. Fifteen instructors from each of the Departments of Biosystems, Civil, Electrical and Computer, and Mechanical Engineering considered the presence of these attributes in one of their engineering courses taught in the academic year 2012–13, using a self-administered checklist. Findings indicated that the traditional attributes in engineering were assessed more frequently than the professional attributes, and that specifically, there was little assessment evidence of Ethics and Equity and the *Oral* focus of Communication Skills. There was some evidence of formative assessment, but generally assessments were limited to traditional quantitative, summative assessments. Competency levels were expressed in a variety of ways, highlighting the need for the development of a common language for assessment. The study underscores the different roles assessment can take and the complexity of sustaining a faculty-wide, outcomes-based assessment protocol.

Keywords: engineering graduate attributes; outcomes-based assessment; accreditation; engineering curricula; course-based attribute checklist

Spatial ability is an important skill in different scientific and technological areas with a highly visuo-spatial specialization, such as engineering, architecture or technical education. In fact, spatial skills are embedded in a curriculum that promotes a holistic understanding of engineering graphic tools, techniques and processes. Therefore, a great deal of the research relative to engineering is centred on spatial skills. However, the mechanisms through which engineers may present a better spatial ability are not completely understood. We aim to assess whether students who have studied technical drawing in High School and study the first course of engineering present improved spatial performance in distinct cognitive processes involved in mental rotation ability. We

compare the spatial ability of engineering students who have studied technical drawing with students of philology whose pre-university studies were not oriented towards engineering. We assess visual and memory components of spatial ability in the two groups by means of a visual perceptual speed test and two types of short-term memory tasks, one for visual and one for spatial information. A mental rotation task was also administered. Although the results show no significant differences between Engineering and Philology students in a mental rotation task, a more detailed study revealed that the formers' visual perceptual speed and short-term retention of spatial information was significantly better. In conclusion, first-year engineering students, whose pre-university studies include technical drawing, present better visual discrimination and spatial memory than philology students.

Keywords: technical drawing; spatial ability; memory; visual discrimination

Shane Brown, David Street and **Julie P. Martin**   813–821   Engineering Student Social Capital in an Interactive Learning Environment

College student access to resources has been shown to be important for learning, cognitive development, retention, and other outcomes. The framework of social capital, or resources embedded in social networks that are accessed by members of a network, captures the essence of this resource acquisition. One important source of social capital related to academic achievement is the interactive classroom environment, but social capital development in this setting has not been studied. The purpose of this research is to examine factors that influence social capital development in a setting where tutors are used in the lecture environment. Subject matter difficulty, approachability and accessibility of faculty and classroom environment were all factors that impacted students' choices related to accessing available social capital in this environment. Results can inform both social capital theory, in terms of development in an academic setting, and tutoring in comparable interactive learning environments.

Keywords: social capital; active learning; tutoring

Julie P. Martin, Matthew K. Miller and **Denise R. Simmons**   822–836   Exploring the Theoretical Social Capital "Deficit" of First Generation College Students: Implications for Engineering Education

This paper investigates social capital, that is, resources accrued through relationships, of engineering students based on their generational status in college. We administered a "Name and Resource Generator" instrument adapted from the field of sociology to a sample of 1,410 engineering undergraduates from five U.S. universities. Quantitative analysis of results revealed many statistically significant differences in the social capital characteristics and accessed resources for First Generation College students (FGC) compared to Continuing Generation College (CGC) students. While some of these results were theoretically anticipated, we also present unique findings regarding (1) the prevalence of available and accessed resources for FGC students, and (2) the type of individual (known as an "alter") providing the engineering-related resources. The retrospective nature of the study allowed us to draw conclusions about the nature of these resources and alter types both during and before undergraduate engineering studies. These results represent a significant theoretical contribution that engineering education stakeholders can use to enhance outreach, recruitment and retention efforts to help grow and diversify the field.

Keywords: social capital; first generation college students; resources; alters; engineering

Kathryn F. Trenshaw, Geoffrey L. Herman, Kerri A. Green and **David E. Goldberg**   837–847   Fostering Motivation as a Class Objective in a Large Engineering Class for Second-Year Students: A Narrative Approach

Self Determination Theory (SDT) states that intrinsic motivation (IM) in a particular context is supported by increasing an individual's sense of autonomy, relatedness, and competence with respect to that context. When instructors use IM-supportive methods, they promote learning of class content. This research seeks to describe through narratives how students' motivation changes in response to a pedagogy designed with fostering intrinsic motivation as a primary class objective. After being observed in the classroom of an IM-supportive class conversion, students were interviewed to document their narratives. Interview transcripts were coded to describe students' motivational orientation throughout the class. The majority of interviewed students demonstrated increases in intrinsic motivation for studying the class content. The interviews revealed that individual choice, interpersonal relationships, and constructive failure were critical in moving students toward intrinsic motivation. While the IM-supportive learning environment did not affect all students equally, the common themes of individual choice, interpersonal relationships, and constructive failure provide deeper insights into how to improve and assess students' motivational changes in technical engineering classes.

Keywords: Self Determination Theory; intrinsic motivation; sophomore slump; class design; narrative inquiry

Nicholas D. Fila and **Michael C. Loui**   848–861   Structured Pairing in a First-Year Electrical and Computer Engineering Laboratory: The Effects on Student Retention, Attitudes, and Teamwork

This paper describes a simple technique, structured pairing, for organizing student teams in engineering instructional laboratories. This technique was adapted from pair programming, which was previously found to improve student confidence, satisfaction, and retention in computer science. A study of structured pairing was implemented in a large required course for first-year students in electrical and computer engineering. Six laboratory sections implemented structured pairing, and the other seven laboratory sections operated in a traditional way (i.e., unstructured team interactions). Data were collected from a student survey, two focus groups, and course enrollment records. Structured pairing students reported significantly higher confidence in laboratory tasks and satisfaction with the course and teamwork experiences. Focus group data indicated that structured pairing students experienced reciprocal scaffolding (i.e., students acknowledged that they learned from each other). Short-term retention in engineering did not differ significantly between structured pairing and traditional section students. These findings suggest that structured pairing is a more engaging and motivating alternative to traditional laboratory teaming methods.

Keywords: cooperative learning; pair programming; laboratory; assessment; mixed methods

Pedro Sánchez, Bárbara Álvarez and **Andrés Iborra**   862–875   Improving Transferable Skills in Engineering Education through a Pre-Incubation Semester

Entrepreneurship is a powerful tool for economic growth as it facilitates the creation of new companies and jobs, opens up new markets and demonstrates new skills and capabilities. Investing in the promotion of entrepreneurship and education for engineers is one of the best return investments that countries around the world can make. This study describes the experience of a programme for the pre-incubation of start-ups in a Spanish public university, for the training of entrepreneurs, and how it has influenced the improvement of their transferable skills. A survey for entrepreneurs was carried out during the 2012/2013 academic year. The analysis considered 14 engineering graduates. A questionnaire was conceived to analyse how entrepreneurs perceived the benefit of the pre-incubation programme in improving their business management and professional skills, and how their transferable skills benefited from the programme. The survey was administered at the beginning and at the end of the programme. The results indicate that students' overall perception of functioning effectively as a member of a team and using methods to communicate with the engineering community, had significantly improved by the end of the pre-incubation programme. Other transferable skills, such as management and business practices, should be reinforced with enhancement of the programme. Universities should organize pre-incubation programmes because they serve as experimental platforms for the development and improvement of transferable skills, valued in an economic crisis where entrepreneurship is seen as one of the most attractive solutions for employment.

Keywords: engineering education; entrepreneurship; transferable skills

Ibrahim Zeid, Jessica Chin, Claire Duggan and Sagar Kamarthi   876–887   Engineering Based Learning: A Paradigm Shift for High School STEM Teaching

In the US there is a huge gap between the demand and supply of the workforce trained in STEM areas. This gap is in part created by the fact that school-age children in the US show less interest in STEM subjects. Engineering-based approaches have been shown to improve student motivation for STEM subjects, but there is a need for a structured teaching methodology to make engineering-based pedagogy implementable in high school level education. This paper introduces a new teaching model, dubbed Engineering-Based Learning (EBL), to allow both teachers and students to follow a structured approach to teaching and learning STEM subjects in high schools. The building blocks of the EBL model are the engineering design process, computer-aided design, and capstone design experience, which is typically required in an ABET-accredited college engineering curriculum. EBL has been implemented and tested over a three-year research project in urban high schools, including but not limited to Boston Public Schools serving students from diverse backgrounds. The project has developed an effective two-week summer professional development program, called CAPSULE, to train teachers in EBL methodology. Teachers, who are trained in this program, have implemented EBL in their STEM classes. The project trained 82 high school STEM teachers (grades 9–12) from 45 school districts, and 62 distinct high schools. Over a period of three years, more than 4500 students have been taught by teachers trained in the engineering-based learning program. The results of student surveys and teachers' feedback reveal several observations: EBL is an effective new methodology for high school STEM teaching; EBL can help students learn, absorb, and retain STEM topics and concepts; there is a positive change in how students perceive STEM subjects and careers; and EBL is a bridge that can address the disconnect between theory and application in STEM classes.

Keywords: STEM; engineering design; teaching model

Ibrahim Mohedas, Shanna R. Daly and Kathleen H. Sienko   888–900   Design Ethnography in Capstone Design: Investigating Student Use and Perceptions

In today's global markets engineers need to design products for a wide variety of stakeholders and cultures. Engineering students, therefore, must learn how to design products that meet the needs of the stakeholders and are appropriate for the cultures in which they will be used. Human-centered design guides students in developing design ideas that achieve this goal. This approach has proven to support innovation, increase product uptake, reduce errors, and focus the design on the user experience in addition to product functionality. Design ethnography is an important component of human-centered design and has been shown to be effective for understanding the true, and sometimes hidden, wants and needs of stakeholders and for informing design decisions. While the utility of design ethnography has been promoted within business and product innovation literature, student learning of design ethnography techniques has lacked study. This exploratory study sought to address this gap by characterizing the ways students use design ethnography methods during a capstone design experience as well as their perceptions of these methods within their design projects. Design report documents and semi-structured interviews were used to explore student practices and perceptions. Students used various design ethnography techniques including interviews (both structured and semi-structured), informal conversations, observations, and surveys. These were used throughout the design process (from problem definition to testing and validation), however, the methods were most frequently used when defining the problem, developing user requirements, and translating these into engineering specifications. Although there were numerous instances of successful uses of design ethnography, the focus of this study was on obstacles encountered when implementing these techniques to inform their design decisions. Semi-structured interviews revealed that students perceived both benefits of and frustrations with using design ethnography. However, the benefits that students perceived were often superficial in nature and the frustrations they encountered often stemmed from the challenges associated with open-ended problem solving. The results illustrate the need for the development of effective tools and pedagogy to support students when learning and practicing design ethnography.

Keywords: design ethnography; human-centered design; user-centered design; design pedagogy; immersion; capstone design

Viljan Mahnič and Tomaž Hovelja   901–915   Teaching User Stories within the Scope of a Software Engineering Capstone Course: Analysis of Students' Opinions

Agile software development methods assume that user requirements are formulated as short user stories written on paper note cards. Students often seem to be suspicious about this approach, finding user stories not precise enough to describe the desired functionality. Therefore, practical experience is needed to overcome initial doubts and impart good understanding of the potential benefits and limitations. This paper describes how user stories are taught within the scope of the software engineering capstone course at the University of Ljubljana, Slovenia, and provides an in-depth analysis of students' opinions on the basis of several surveys that have been conducted since the 2009/10 academic year. The analysis indicates that students' opinions are mostly positive and significantly improve after they gain more experience. Students successfully grasp the main concepts and understand the advantages and limitations of user stories. However, better students are more confident about potential benefits and keener to use user stories in practice. Students' satisfaction can be largely attributed to proper instruction of the course, which stimulates learning through problem solving and requires close cooperation among students, the Product Owner, and the ScrumMaster.

Keywords: user stories; agile methods; Scrum; software engineering

Sonia M. Gómez Puente, Michiel van Eijck and Wim Jochems   916–928   Exploring the Effects of Design-Based Learning Characteristics on Teachers and Students

In design-based learning (DBL) projects, engineering students are to gather and apply knowledge while working on the design of artifacts, systems and innovative solutions in project settings. The characteristics of the projects, the design elements, and the role of the teacher are pivotal components within the DBL framework that foster students' design problem-solving process. This article investigates the changes and effects of DBL characteristics on students in solving design problems. In addition, our study explores the effects of a professionalization program on DBL teachers and supervisors. We conducted a survey of teachers' and students' perceptions about DBL characteristics. We then observed teacher, supervisor, and student actions during DBL group settings in solving design problems. We triangulated the findings with student interviews on design problem-solving steps. Semi-structured interviews with teachers served to analyze the effects of these DBL characteristics on the students and any changes in project implementation. Main conclusions are that in gathering and applying knowledge, students take a broader approach in exploring problems and searching for design alternatives as a result of open-ended, authentic, and hands-on activities within DBL. DBL characteristics foster and enhance students' ability to gather and apply knowledge in solving engineering design problems.

Keywords: design-based learning; open-ended; authenticity; solving design problems

Renata Burbaitė, Kristina Bespalova, Robertas Damaševičius and Vytautas Štuikys   929–936   Context-Aware Generative Learning Objects for Teaching Computer Science

The paper introduces context-aware Generative Learning Objects (GLOs) to support wide-scale reusability and automatic adaptability in teaching Computer Science (CS) topics. We introduce the theoretical background of the approach to support adaptation through transformations based on the principles of Design-for-Reuse and Design-with-Reuse, which are well known in Software Engineering (SWE), and validate the approach in the robotics-based CS course. We automatically adapt GLOs to the specific context of teaching using transformation tools (refactoring tool and meta-language processor) to transform a set of context-aware GLOs into usable LOs within the educational Arduino robotics environment.

Keywords: generative learning object; context modelling; e-learning; computer science education

Antonio Garcia-Cabot, Eva Garcia-Lopez, Luis de Marcos, Luis Fernandez and **Jose-Maria Gutierrez-Martínez** — 937–949 — Adapting Learning Content to User Competences, Context and Mobile Device using a Multi-Agent System: Case Studies

E-learning has revolutionized the education field. This fact, and the rise of mobile technology has led to the emergence of m-learning. There have also been new challenges such as adapting the learning content to the students' context and mobile devices, as a student could be anywhere with a mobile device and in a specific context. This paper presents a new multi-agent system for solving these challenges which has been used in two case studies in a Master of Software Engineering course. The first case study presents the results of the experiments carried out with two simulated students with different profiles, contexts and characteristics. The second case shows the usage results of the system using different real mobile devices. The results showed that the learning content is selected based on the context specified by the student and the characteristics of the mobile device used. It was also observed that some of the learning content was not supported by the mobile devices due to its format.

Keywords: adaptation; multi-agent system; mobile device; context; competences; m-learning

Andrés Mejías Borrero, José Manuel Andújar Márquez and **Marco A. Márquez Sánchez** — 950–963 — Digital Electronics Augmented Remote Laboratory: DEARLab

A new concept of a remote lab that allows the implementation and measurement of all types of digital electronics design, known as the Digital Electronics Augmented Remote Laboratory (DEARLab), is presented in this paper. This remote lab allows remote wiring of the elements of real circuits, so that DEARLab deals neither with models nor simulations. The prototype remotely implemented by the user is a real circuit with all the real signs (voltage and current levels) that circulates through real circuit elements inserted into a real breadboard located in a real lab, so that the implemented prototype presents the common drawbacks of real circuits (delays, faulty elements, etc.). DEARLab allows the user to feel as if they are being present at the physical lab, whose capacities are enhanced by virtual elements that interact with their real counterparts by means of augmented reality. DEARLab has been subjected to validation as an educational tool. The first results show high acceptance by the students.

Keywords: digital systems; augmented reality; remote labs, digital electronics; breadboard; digital electronics prototyping, educational tool

Igor Franc, Ivan Stankovic, Irina Branovic and **Ranko Popovic** — 964–976 — Ontology Based Model of Digital Forensic Virtual Lab and Curriculum Design

Digital forensics (DF) is a discipline that uses investigative methods to find digital evidence and prepare it for legal proceedings in computer crime cases. Since this is a relatively new teaching subject in higher education institutions, syllabi and curricula are not yet standardized. In this paper we present an ontological approach to DF curriculum design, and discuss its implementation in a virtual digital forensic laboratory. The virtual educational environment is designed for the generic study of digital forensics, and is based on ontology and a composite-component approach. Basic components of our virtual DF are objects to be related, put into new compositions and placed in a library; relationships between all of the components are defined in ontology. Based on gathered experience, we designed and described DF curricula for undergraduate, graduate and Ph.D. studies that are tailored to our needs, but at the same time can be used as the starting point for introducing digital forensics courses at universities.

Keywords: digital forensics; ontology; curriculum design; 3D model; component-composite model; education

Shannon M. Lloyd and **Ketra A. Schmitt** — 977–991 — Survey of Approaches for Including the Impact of Technology on Society in Canadian Engineering Undergraduate Curricula

Increasingly, engineering educators are called on to include the technology-society interface in undergraduate engineering education, but little consensus exists on precisely how to present or treat technology and society in the classroom. However, it is generally recognized that the topic should be taught from a multidisciplinary or interdisciplinary perspective and integrated into the engineering curriculum. Within Canada, engineering programs are required to complement technical content with several complementary studies topics, including impact of technology on society. Canadian engineering programs have generally required a single, stand-alone course on each complementary study topic. Recent changes to the accreditation requirements seem to indicate an increased emphasis on the technology-society interface as well as the need to integrate the topic across the curriculum. We characterize current approaches for fulfilling the impact of technology on society requirement and discuss the disciplinary perspectives used by Canadian universities. Our findings indicate that many are still meeting the requirement solely with a stand-alone course. However, several have made progress toward more fully integrating impact of technology on society into the curriculum.

Keywords: CEAB; engineering accreditation; complementary studies; outcomes-based education; professional responsibility; inter-disciplinary education

Katherine M. Steele, Samantha R. Brunhaver and **Sheri D. Sheppard** — 992–999 — Feedback from In-class Worksheets and Discussion Improves Performance on the Statics Concept Inventory

The Statics Concept Inventory (SCI) is used to evaluate students' conceptual understanding in introductory mechanics courses. Previous studies have shown that although performance on the SCI improves at the end of a course, performance is often still unsatisfactory with scores well below 100%. In this study, we sought to determine if providing feedback on conceptual topics through in-class worksheets and discussion would improve students' performance on the SCI. To test this hypothesis, we designed eight multiple-choice worksheets, each inspired by a different topic on the SCI, for use during an introductory mechanics course. In order to evaluate the impact of the worksheets on SCI performance, we divided the eight worksheets into two groups and each group of worksheets was deployed in a different offering of the course. Each worksheet was completed at the end of a class period and, at the beginning of the next class period, the instructor led a discussion of the results and common misconceptions on each worksheet. Students took the SCI at the beginning and end of the course and the change in SCI scores for topics with and without worksheets were compared. Results from both course offerings indicated that the in-class worksheets were effective at improving performance on the SCI, as SCI scores improved significantly more for topics that had worksheets than the topics that did not have worksheets. Furthermore, overall SCI performance at the end of each course was greater than in previous courses. These results suggest that a quick and easy-to-implement addition to the curriculum using in-class worksheets and next-class discussion were effective at providing feedback on conceptual topics, exposing misconceptions, and improving performance on the SCI. The worksheets developed as part of this study are available on-line for other instructors to use (http://del.stanford.edu). The SCI is also free to use and can be found at cihub.org.

Keywords: concept inventory; statics, assessment; feedback; conceptual understanding

Francesco Braghin, Simone Cinquemani and **Ferruccio Resta** — 1000–1007 — An Experimental Way to Teach System Modal Description

The dynamics of a mechanical system is often described by using the equations of motion expressed in terms of modal coordinates. However, the approach in modal coordinates is not appreciated by students, mainly because of their difficulties in finding the physical meaning of this representation. During a Mechanical Engineering study course, a laboratory experience has thus been developed to view the modal shapes of a mechanical system experimentally and to understand their physical meaning. This approach allows students to better understand this topic and to increase their critical thinking.

Keywords: modal coordinates; modal description; mechanical system; system dynamics

Society demands the adaptation of engineering degrees to the needs of the labor market. This study was designed to investigate the level of expertise in the various competencies acquired by graduates of Agricultural Engineering in the course of their studies and the level required of them in their jobs. Online questionnaires aimed at graduates and employers were developed to assess both professional and technical competencies, and then piloted on graduates at the University of León (Spain). Graduates indicated that they perceived a deficit in professional competencies. A significant agreement was observed between perceptions of graduates and employers about which professional competencies are most important in the labor market. The results indicated a deficit in training in some technical competencies and excessive emphasis in others. Most of the core subjects which form the basis of an engineer's education, especially Mathematics and Statistics, were rated by graduates as very important for work. The highest training deficits detected in this study were related to communication, practical engineering, and engineering business skills. The methodology described in this paper proved useful for obtaining information on the most important competencies for the labor market, deficits and over-emphasis in training, and those competencies that should be incorporated into the curriculum.

Keywords: competencies; engineering education; Agricultural Engineering; surveys

This paper aims to investigate the opinion of agricultural engineers about their education, identify EHEA-based educational needs for a successful future, and depict the current situation of the labor market for graduate agricultural engineers as well as the professional prospects for undergraduate students. The chosen sample of Agricultural Engineers are those in the region of Galicia (NW of Spain). It is consisted of graduate students of the Higher Polytechnic School at the University of Santiago de Compostela since 1987 and members of the Galician Association of Agricultural Engineers (Colegio Oficial de Ingenieros Agrónomos de Galicia—COIAG). The results show the dynamism of the profession in Galicia and reveal the importance of both traditional and new areas of activity. In addition, the results show high expectations among the participants regarding the new curriculum. Agricultural engineers acknowledge and support all the competencies included in the curricula and demand more competencies related to the new fields of activity of the profession to be included.

Keywords: Agricultural Engineering; Higher Education; Galicia; Spain

This study uses an experimental approach to explore the relationship between individuals' disciplinary backgrounds in engineering and how they draw objects that are common to different disciplines within nanoscience and nanotechnology. We recruited graduate students ($n = 16$) from three engineering disciplines at the University of Washington. We report responses to a design task where subjects were asked to draw diagrammatic representations that captured their interpretation of disciplinary prompts from three areas of engineering—Biological Engineering, Chemical Engineering, and Electrical Engineering. Findings highlight two important elements of modern academic scholarship and teaching in engineering: (i) baseline visual communication competency appears to be higher than anticipated; (ii) interdisciplinary boundary-crossing appears to be on the rise, because while there are disciplinary biases it appears that there are much fewer than expected. We discuss implications of these findings for teaching in areas such as nanoscience and nanotechnology and suggest future avenues that might elaborate on related questions pertaining to disciplinary boundary-crossing, nanotechnology and visual design.

Keywords: nanotechnology education; science and engineering visuals; visual communication; interdisciplinary education; boundary-crossing, multidisciplinary education; graduate science education

Today technological improvements provide several alternatives and opportunities for improving traditional educational systems. However, integrating these technologies in an appropriate and successful way into the curriculum of traditional systems is a challenge. This work presents the enhancements added to an undergraduate course on Digital Communications which is an introductory course offered to senior undergraduates or first year graduate students. The Digital Communications course covers some essential stages in a typical digital communication system, namely, signal formatting such as analog to digital conversion, baseband modulation and bandpass modulation by concentrating on demodulation and detection at the receiver end. The enhancements include computer simulations, web-based simulation tools and remote laboratory experiments along with several out of class activities. The enhancements have improved the course significantly by supporting constructivist and blended learning methods. The improvement to the course was demonstrated over two years, from the student progress assessed from the collated results of the student evaluation forms and a questionnaire on the course learning outcomes, and a comparison of their performance in the written exams. The results show that there is a significant improvement both in the progress and satisfaction of the students on the enhanced course curriculum. This study shows how different technologies have been successfully integrated to the curriculum of Digital Communications course in a higher education organization and concludes its success factors.

Keywords: Electrical Engineering education; digital communications; virtual and remote laboratories; constructivist education; blended learning environment