

# The International Journal of Engineering Education

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#### Design-Centric Engineering Education

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**Kok Kiong Tan—National University of Singapore, Singapore**  
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**Huixing, Zhou—College of Engineering, China Agricultural**  
**University, P.R. China**

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<b>R. Sell and S. Seiler</b>	759–766	Improvements of Multi-disciplinary Engineering Study by Exploiting Design-centric Approach, Supported by Remote and Virtual Labs

In the current paper the design-centric approach for mechatronics and smart product design is presented. The novel aspect of the proposed solution is a comprehensive learning concept and environment which includes remote labs, mobile hardware, methodology, learning material and web environments. The whole concept supports fast and student-oriented learning process for acquiring knowledge and practical skills of integrated systems. The concept is applied into practice in the course of several stages. The most recent case study is described in this paper and the course setup proposed. The feedback from students indicates the time spent by the student on the activity, when the course follows the proposed concept. It is apparent that students spend considerably more time than the curriculum requires. At the same time, workload of the supervisor is lower. However, the quality and learning outcomes are higher than those of previous related courses, but without using novel technologies. In the current paper special attention is paid to remote and virtual labs related to the proposed learning concept.

**Keywords:** distance learning; virtual micro controller; design-centric study; robotics

<b>Pere Ponsa, Cristina Manresa-Yee, Diana Arellano, Johanna Gómez and Alex Pérez</b>	767–777	Human-Centred Design in Engineering Curricula
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This paper describes the inclusion of human-centred design in the curriculum of the Design and Product Development Engineering. The aim is to improve the relationship among experts and to integrate the human factors domain in engineering education. We present case studies of design-centric projects related to home automation systems in the Bachelor and Master of Science programmes. The preliminary results in laboratory conditions with Engineering students and professors show the effectiveness of the integration between engineering and the human factors disciplines. Moreover, it is shown how Engineering students understand the benefits of the Human-centred approach by using holistic models to develop new and innovative products.

**Keywords:** active methodologies; human-centred design; product design education

<b>Andi Sudjana Putra and Tan Kok Kiong</b>	778–781	An Alternative Perspective in Engineering Education: A Parallel to Disruptive Technology
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This paper presents a parallel between the ever-present transformation in engineering education and the disruptive technology. The shared characteristics of these two—among which, on how they affect changes in its own area—provide an opportunity to draw lessons from the manner disruptive technology transforms businesses and to use them to shape a perspective in designing an engineering education that is relevant to the current era and adaptable to fulfil the current societal and human needs. Furthermore, an analysis into how the current trend of design-based education system has acted like a disruptive technology in engineering education is also presented.

**Keywords:** transformation; engineering education; disruptive technology; design-based education

<b>Vanessa Svihla, Anthony J. Petrosino and Kenneth R. Diller</b>	782–798	Learning to Design: Authenticity, Negotiation, and Innovation
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Engineering design is a collaborative and complex process, and our understanding of how to support student teams in learning to design remains limited. By considering in-situ student design teams in a capstone biomedical engineering course, we are afforded the opportunity to contrast two versions of a non-sponsored project, then consider expert perceptions of their later sponsored designs. Data from two cohorts of the course yield compelling contrasts for authentic design learning experiences. We found that a non-sponsored redesign project led students to values customer needs and to use them to define the design problem, whereas in a kit-based version this did not occur. We also found that greater perceived opportunities to negotiate one's understanding within a team predicted more innovative team designs.

**Keywords:** engineering design; innovation; expertise

<b>Willian Z. Bernstein, Devarajan Ramanujan, Fu Zhao, Karthik Ramani and Monica F. Cox</b>	799–810	Teaching Design for Environment through Critique within a Project-Based Product Design Course
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Future environmental regulations are creating new employment requirements within traditional engineering organizations. These organizations require recent graduates to have a strong handle on environmental issues related to new product development. Since mechanical engineering curricula are saturated with courses covering a broad spectrum of engineering fundamentals, there is little room to develop a separate course to teach principles related to sustainable product design. This manuscript presents a novel

method for teaching Design for Environment (DfE) strategies within a mechanical engineering product design course through the use of expert critiques. The results from this study indicate that integration of a critique based module within an existing design project is an effective medium for teaching sustainable product design. Also, receiving feedback in the form of disruptive design critiques breeds innovative design modifications that lower the energy and carbon footprints of the design across multiple lifecycle stages. More importantly, the results indicate that after participating in this teaching module, students are more likely to apply the learned DfE principles within academia and industry.

**Keywords:** design learning; project critique; design for environment; contextual learning

**Chih-Hsiang Ko, Ting-Chia Chang, Yung-Hsun Chen and Li-Han Hua** 811-817 A Design-Centric Approach for Augmented Reality Collaboration

Due to the advances and development in computer technology, it is imperative for teachers to use digital tools to instruct students on subjects that are previously accomplished by traditional media and communication methods. The growth and spread of computer-assisted instructions stimulate design educators to develop pedagogically effective learning environments for traditionally studio-based design education to cope with the demand for interdisciplinary collaboration. The main purpose of this study was to investigate how students interact with augmented reality in interdisciplinary design teams and to evaluate their attitudes toward the system. An augmented reality based design collaboration was proposed to facilitate interdisciplinary design work. The result indicated that design students and engineering students tended to regard the system as more stimulating. However, design students tended to regard the system as unreliable. It is hoped that a design-centric augmented reality collaboration can increase student learning motivation and learning achievements.

**Keywords:** augmented reality; design education; ARToolKit

**Jiyoung Han, Seung-Hyun Yoo and Eunkyeong Kwon** 818-823 The Educational Effects of an Introductory Engineering Design Course based on Creative Projects

The purpose of this study was to verify the educational effects of a mandatory introductory engineering design course wherein the students find their own project items and solve them using creative projects. Case studies, investigation through surveys, and weekly reflective journals have been performed in order to achieve this goal. The results of this research present the details of running the class and the outcomes of the student's projects; the educational effects and difficulties are analyzed. It turned out that brainstorming is very helpful for idea generation and patent searches are useful in the problem solving stage. The finding of real engineering problems regarding the project topics is the most difficult part of the project, however it strongly correlates to the improvement of the students' hard skills and promotes the perception of engineering problems in the sense of engineers, not as users but as suppliers.

**Keywords:** creative project; design education; educational effects of engineering design; engineering creativity

**Huixing Zhou, Peng Sun and Dong Zheng** 824-830 Practice-Oriented Intuitive Approach for Engineering Undergraduates: A Case Study

Although mathematical illustrations are widely used to explain concepts in control engineering education, however it appears somewhat difficult for some students to understand in the initial stage and then results in reducing of their learning enthusiasm. We noticed that students have huge interesting and active attitudes about experiment. In this paper, we introduced the experiment of point-to-point movement, typically in manufacture industry, for the students with no any control knowledge. Based on the principles of traditional rotary motors, students are guided to design a linear motor platform. The linear motor moves from zero position to a desired position. Students are requested to do their best to design a controller based on their intuitions and experiment results. The results and problems occurred will encourage students to study control knowledge and back to solve the problems. This practice-oriented intuitive approach (POIA) offers an alternative to learning control theory from concrete experience, so students can grasp knowledge and relate control concepts to simple events. A case study is provided, which involves a team of five undergraduates with a project named linear motor driven inverted pendulum and controller design sponsored through the Undergraduate Research Program (URP) by China Agricultural University. The results confirm the effectiveness of the proposed method.

**Keywords:** engineering education research; experiments; intuitions; group work; case study

**Jin-Suo Lu, Yan-Ping Ding, Alexander Swift and Ting-Lin Huang** 831-844 Towards Design-Centric Engineering Education: Capstone Course Reform in a Chinese University

The need for creative engineering to address the multi-faceted problems facing the world today has never been so great. The challenge for educators everywhere is to nurture world-class solution developers, despite local constraints in available resources or organization, by leveraging native strength and opportunities. At the Xi'an University of Architecture and Technology (XAUAT) in China, proposed reforms towards a design-centric learning environment featuring multi-disciplinary student teams for open-ended design projects from current public needs draw upon the existing academic specialties of this institution, and apply new ways of approaching education to enhance the existing Chinese undergraduate engineering curriculum. A design process is proposed that approaches those in professional firms, adjusted to maximize student acquisition of interpersonal (teamwork, conflict management, and negotiation), communication (written, oral, and graphical), and project management and design skills. The example institution's academic strength and industry connections suggest a number of possible projects, of which a wastewater treatment plant (WWTP) is chosen as a representative example allowing the detailed working out of a schedule of student deliverables (in this case, a feasibility study and a preliminary design) and a description of the learning process, starting with initial lectures and field trips, continuing through the discipline-by-discipline development of the project design, and culminating in reports and drawings evaluated on ability to satisfy the needs of the client by both faculty and experts from industry.

**Keywords:** engineering education; design-centric education, capstone design; inter-disciplinary design; waste water plant design

**Sanja Loncar-Vickovic, Zlata Dolacek-Alduk, Vladimir Sigmund and Dina Stober** 845-851 Student Workshops in Engineering Education: Case Studies at the Faculty of Civil Engineering in Osijek, Croatia

This paper presents an application of the design-centric education through five interdisciplinary student workshops conducted between 2000 and 2010 at the Faculty of Civil Engineering Osijek, Croatia. The main workshop aims, namely the incorporation of contemporary educational tendencies and techniques into curricula and the socially responsible interaction between the Faculty and its environment, are described. Furthermore, a case study workshop entitled 'Where is the Railway?' is presented detailing performed activities, results and the evaluation. Positive and negative aspects of design-centric approach to teaching/learning are discussed from the students' and the teachers' viewpoint. The balance of project preparation and management with the freedom in creating project's contents and results is stressed. Finally, the role of universities is accentuated through choice of locations, buildings and institutions involved in the workshops.

**Keywords:** design-centric education; project based learning; interdisciplinary engineering education; student workshops

**Fernando Martini Catalano, Álvaro Martins Abdalla and Fulvio Luiz Delicato Filho** 852-858 What is Missing for Traditional Design-Centric Engineering Education to Better Prepare Newly Graduated Engineers for the Global Era?

This paper presents an analysis of the capacity of design centric methodologies to prepare engineering students to succeed in the market. Gaps are brainstormed and analyzed with reference to their importance. Reasons that may lead the newly graduated engineers not to succeed right from the beginning of their professional lives have also been evaluated. A comparison among the

two subjects above was prepared, reviewed and analyzed. The influence of multidisciplinary, multicultural and complex environmental influences created in the current global business era is taken into account. The industry requirements in terms of what they expect to 'receive' from their engineers are evaluated and compared to the remaining of the study above. An innovative approach to current engineering education that utilizes traditional design-centric methodologies is then proposed, aggregating new disciplines to supplement the traditional engineering education. The solution encompasses the inclusion of disciplines from Human Sciences and Emotional Intelligence fields willing to better prepare the engineer of tomorrow to work in a multidisciplinary, globalized, complex and team working environment. A pilot implementation of such an approach is reviewed and conclusions are drawn from this educational project.

**Keywords:** team working in engineering; human relations; leadership; aerospace design-centric

**André Luiz Aquere, Diana Mesquita,** 859-870 Coordination of Student Teams Focused on Project Management Processes  
**Rui M. Lima, Simone B. S. Monteiro**  
and **Marcia Zindel**

Engineering learning processes are expected to develop technical and transversal competencies on students that are demanded by the engineering professional bodies. The need for the development of competencies raised an incremental interest in applying innovative approaches in Engineering Education. One of the methodologies used in this context is Project-Based Learning (PBL). At the University of Brasilia, a course degree in Production Engineering was created having as a main reference the Project-Based Learning (PBL) approach. The use of PBL implies a change of behavior of teachers who play a main role of facilitators of competencies development, and of the students, who learn in a collaborative way, working with others in teams. Students' working in team and developing a project during a semester will require effective coordination models. The objective of this paper is to propose a model of coordination among students' teams based on project management knowledge. Furthermore, a qualitative approach is applied to evaluate the application of this model during one semester. The results show that a coordination model for student teams developing projects is important to support their learning process, which is not solely dependent on students, as teachers/tutors have an important role before, during and at the end of the project. The tutor is especially important, as he/she is responsible for supporting the teams in several project management dimensions. This is an essential support for students to know how to manage the team, communicate, define goals, carry out the activities on time, plan the milestones and understand the impact of their decisions. These competencies are also part of student learning and are an important part of engineering education.

**Keywords:** design centric education; project based learning; project management in education; coordination of student teams

**Jitesh H. Panchal, Olusola Adesope** 871-879 Designing Undergraduate Design Experiences—A Framework based on  
and **Richard Malak** the Expectancy-Value Theory

Although the need for infusing design experiences throughout the undergraduate engineering curricula is widely recognized, designing a good design experience is a challenge for the instructors. A well-constructed design project may excite the students and enhance their motivation and learning experience significantly. At the same time, a poorly constructed design project may in fact reduce student motivation. Despite the importance of design experiences, there currently is a lack of systematic frameworks to help instructors in core engineering courses. This paper addresses this gap by presenting a conceptual framework based on the expectancy value theory of achievement motivation. The expectancy value theory is based on two important factors that affect students' task-related motivation: expectancy, which is an individual's belief about how well he/she will do on upcoming tasks, and values, which are the reasons/incentives for completing a task. The framework is illustrated using a Systems Dynamics course taught at Washington State University. An assessment tool for the course based on the expectancy value theory is presented in the form of a survey. Statistical analysis of the outcomes of the survey for one semester is presented. The assessment tool presented in the paper can be used for evaluating the effectiveness of the design project and identifying avenues for improvement.

**Keywords:** undergraduate education; design projects; expectancy-value theory

**Jorge Villalobos and Oscar González** 880-891 A Curricula Model for Supporting a Design-Centric Computing  
Engineering Education

The constant evolution present in the information and communication technologies (ICT) as a result of the changing environment is a big challenge for computing engineering (CE) professionals that face a demand for solving increasingly new and complex technological problems. This technological evolution imposes, among others, a process evolution within the organizations, the information multiplication to be integrated and processed, an increase in competitions to respond faster to global needs, and an increasing demand for systems integration. As a result, CE programs have an undeniable and constant necessity to evolve their curricula to keep up to date. We have defined, put into production, and validated a curricula design model based on competences to facilitate the design and implementation of CE programs. The frame for competence definition is stable, allowing a fast adaptation to the continuous change. The curricula design model turns around a set of competences defined in terms of the life cycle of problem resolutions, which is structured around projects. We illustrate how to design project-based CE programs that aim students to incrementally develop competences for understanding complex problems and for designing solutions around them.

**Keywords:** curricula design model; project-based; design-centric education; assessment method

**Teresa G. Wojcik, Garrett M. Clayton,** 892-903 The Value of Impromptu Design Exercises as an Approach in  
**Aleksandra Radlińska and Noelle Comolli** Design-Centric Engineering Education

To address the significant gap in engineering curricula regarding the teaching and learning of design, accrediting agencies and industry leaders have called for the integration of design experiences throughout engineering coursework. This paper shares the results of a study which examined the process of implementing impromptu design exercises in engineering science classes as one means of infusing design instruction throughout the curriculum. The paper shares both the challenges and benefits cited by instructors and students in using impromptu design activities to teach design. The authors conclude that impromptu design exercises hold considerable potential as an approach in design-centric curriculum, a potential not fully realized by their current use as icebreaker or team-building activities.

**Keywords:** impromptu design; design education; hands-on pedagogy

**Kwanmyung Kim, Namhun Kim, Seonhee** 904-919 A Radically Assembled Design-Engineering Education Program with a  
**Jung, Duck-Young Kim, Youngshin Kwak** Selection and Combination of Multiple Disciplines  
and **Gyoyhyung Kyung**

A radically assembled design-engineering program in the school of Design and Human Engineering (DHE) at Ulsan National Institute of Science and Technology (UNIST), newly founded in 2009, is presented. The most distinctive feature in DHE is that all students are required to select two disciplines for their major among three major disciplines, which are; (i) Integrated Industrial Design, (ii) Affective and Human Factors Engineering, and (iii) Engineering and Systems Design. The DHE's major system of the new design-engineering program was developed to foster the next generation designers and engineers, having talent in not only creative ideation but also systematic realization. In this paper, we first describe the founding background, educational rationale and curriculum structure. The curriculum includes students' selective curriculum paths based on their talent and aptitude; collaborative education structure as well as multidisciplinary team-based project courses taught by groups of instructors from different disciplines. Then, the new design-engineering education program is assessed in both quantitative and qualitative ways. The first step of the research is to assess the students' core competencies required in design-engineering combined program by using K-CESA (Korea Colligate Essential Skill Assessment) with 32 students enrolled in DHE. A phenomenological study is also conducted to

understand the problems in the current program via in-depth interviews with representative students in DHE. Also, a creative trans-disciplinary short course for students from other universities with various majors (e.g., engineering and design) was offered and tested to evaluate the combined educational system. Finally, we propose the direction for curriculum improvement and follow-up assessment plans, including assessments for students and faculty.

**Keywords:** combined design and engineering education; interdisciplinary education; education curriculum

## Section II

# Contributions in: Electronic Portfolios, Motivation, Problem-Based Learning, Design Competition, Collaborative Design, Learning Outcomes, Industry Sponsorship

**Stuart Nettleton**

920-931 The Power of Pull in Engineering Student Learning

Biggs' Study Process Questionnaire is used to measure the constructive alignment of student choice with deep and shallow approaches to learning in established undergraduate and postgraduate engineering subjects designed for pull-learning, in contrast to push-teaching. Dividend output factors of increased student marks are established for a deep approach to learning and the inverse of a Shallow Approach to learning. Empirical Bayesian analysis comprising Exploratory Factor Analysis and Bayesian Confirmatory Strategies is used to deeply mine and draw inferences from relatively small sample sizes. This research confirms Biggs' suggestion that the tendency of education to erode towards Shallow Learning may be addressed through curriculum design that constructively aligns student choices with deep engagement. Students in subjects designed for pull-learning do appreciate the constructive alignment of their choices with deep engagement. Furthermore, there is a dividend payoff in marks for both deep engagement and the opposite of shallow engagement. The findings provide considerable optimism for the development of pull-learning techniques to increase the generic work-ready skills of graduate engineering students.

**Keywords:** Biggs Study Process Questionnaire; Empirical Bayes; Bayesian Confirmatory Factor Analysis; electronic portfolio; eportfolio

**Timothy T. Yuen, Can Saygin, Heather Shipley, Hung-da wan and David Akopian**

932-938 Factors that Influence Students to Major in Engineering

In order to improve recruitment in engineering at the undergraduate level, it is important to examine how current engineering students perceive the engineering field and the factors that influence major selection. This qualitative study explores why students choose their engineering majors and how they perceive their field. The results show that students perceive engineering as problem solving, improving society, innovation, and an applied science. Additionally, students major in engineering due to personal interests, perceived aptitude, career options, and to improve society. The findings further show that students' interests in engineering can be predicted by certain classroom environments in current and previous engineering courses.

**Keywords:** engineering education, motivation, undergraduate education, major selection

**Benoît Galand, Mariane Frenay and Benoît Raucant**

939-947 Effectiveness of Problem-Based Learning In Engineering Education: A Comparative Study on Three Levels of Knowledge Structure

The effectiveness of problem-based learning is still a matter of debate in higher education. A previous meta-analysis introduced a distinction between three levels of knowledge structure to be assessed (understanding of concepts, understanding of principles, and application of these concepts and principles) and showed that, in medical education, problem-based learning only significantly outperformed conventional learning on the 'understanding of principles' component. The purpose of this study is to compare the understanding of concepts, understanding of principles, and application of knowledge among engineering students before and after the introduction of a problem- and project-based curriculum (PBL). To achieve this, four cohorts of students (total N = 385), two of which had followed a lecture-based curriculum and two a PBL curriculum, completed a criterion-referenced test assessing the three levels of knowledge structure. It was found that students from the PBL curriculum outperformed students from the conventional curriculum, particularly on the application of knowledge. In conclusion, these results indicate that PBL can be effective in engineering education, but bring into question the generalizability of findings from medical education to other curricula in higher education (especially when a project-based learning component is added).

**Keywords:** achievement; skills; learning; curriculum; innovation

**Antonio P. Volpentesta, Salvatore Ammirato and Francesco Sofo**

948-958 Collaborative Design Learning and Thinking Style Awareness

This paper reports on a concerted attempt to develop the design ability and creativity of students from different engineering disciplines through a Project-Based Learning (PBL) approach in a collaborative educational environment. A heavy reliance was placed on teaching the students six styles of thinking, especially in the beginning and final phases of project design. Different collaborative learning experiences in product design were conducted, which required students to practise six styles of thinking. Using a thinking style inventory, pre- and post-survey, data were collected and successively analysed through ANOVA techniques. Statistically significant results showed that students successfully developed empathy and an openness to multiple perspectives. Furthermore, data analysis confirmed that the proposed collaborative learning experience positively contributed to increased awareness in students' thinking styles.

**Keywords:** collaborative design learning; thinking style; project-based learning; preferential thinking

**Mohamed Al-Marzouqi and Muftah H. El-Naas**

959-965 The Role of Environmental Design Competitions in Engineering Education

Engineering design is an essential and integral part of engineering education. It must always be carried out within certain constraints that may include technical, economic, environmental and societal concerns. Environmental design competitions represent an effective tool in enhancing the role of design in dealing with real engineering challenges. This paper presents a case study of the Environmental Design Competition (EDC) at the UAE University. The organizational procedure, the structure as well as the students' perspectives are presented. The education outcomes of the competition are also presented and compared with ABET (Accreditation Board of Engineering and Technology) criteria.

**Keywords:** capstone courses; design competitions; environmental design; engineering education; group work; ABET

**Alcion Benedict Popp, David C. Levy**      966–981      Rationalizing Relationships between the Various Sets of Learning Outcomes as a Data Driven Mapping Strategy  
and **Simon Barrie**

The paper begins by introducing a Generic Graduate Level Statement of Learning Outcomes (GGLSOLO), developed at The University of Sydney EIE (Electrical and Information Engineering) department, which has been derived from other commonly used sets, such as the CDIO set of learning outcomes and the revised Engineers Australia NGCS Stage 1 set of learning outcomes. The SORP (Scope Overlap Reduction Process) rationalizing technique will be demonstrated with this degree level set of learning outcomes and in concert with the curricular learning outcomes from the faculty of engineering. Subsequently, the method will be demonstrated for any set of learning outcomes and any set of curriculum learning outcomes.

**Keywords:** automation; graduate level set of learning outcomes; statements of outcomes; rationalization; validation

**Fakhteh Soltani, David Twigg**      982–988      Industry Input into the Education of Undergraduate Engineering Students  
and **John Dickens**      through Sponsorship

There is a lack of high quality engineers entering industry. In addition to this, the rate of producing new generations of engineers is failing to cope with the changing demands of employment. Further development of the relationship between higher education institutions and industry is needed to avoid crucial impacts on the productivity and creativity of businesses. Sponsoring students and degree programmes is a successful example of university-industry collaboration which can be an effective way of ensuring that sufficient graduates with the right knowledge and skills enter industry. It enables employers to maintain a close relationship with students and university departments as they will be involved in the education and initial training of engineers. The results and methodology of a research project being undertaken to determine the influence of industrial sponsorship on students, academia and employers is presented. The results of a series of students, academics, and employers' surveys are also presented. Conclusions are drawn on the outcomes of sponsorship for academics, employers and students.

**Keywords:** industrial sponsorship; employers-students links; engineering education; professional skills