

The International Journal of Engineering Education

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Contributions in: Life-Long Learning, Assessment, Remote Laboratories, Graduate Education, Ethics, Learning Outcomes, Outreach, PBL, Project Management, Calculus, Engineering Dynamics, Automation, Structural Engineering, Electronics, CAD, Computer Animation, Dosing Systems, Factory Practicum, Solar Energy

- Ahmad Ibrahim** 1061–1062 Editorial
- John C. Chen, Susan M. Lord and Karen J. McGaughey** 1063–1071 Assessing Engineering Students as Lifelong Learners

Higher education aims to instill in students the need for and the practice of lifelong learning. Given its importance, there are surprisingly few instruments to assess this outcome. Two recently developed instruments purport to measure various facets of this outcome in college students. We used the Lifelong Learning Scale (LLS) and the Autonomous Learner Scale (ALS) with engineering students ($n = 356$) at a large, public university in the western U.S. Analysis of variance was used to assess for differences between subgroups of students. The results from the LLS revealed that Asians self-reported as weaker lifelong learners in comparison to Whites. The results from the ALS showed Asian students self-reporting significantly weaker scores on “independence of learning” and “study habits” in comparison to Whites and Hispanics. Finally, male students held a higher self-belief in “independence of learning” compared with female students. Perhaps most important was the lack of any significant changes in either the LLS or the ALS with the year of study in the engineering curriculum. Inter-instrument comparisons showed good correlations between the factors of each instrument, indicating that the two are largely measuring similar facets of lifelong learning. Given the brevity of these two instruments, we recommend using both together to provide a deeper examination of students’ lifelong learning habits.

Keywords: lifelong learner; autonomous learner

- Sally Sue Richmond, Joanna F. DeFranco and Kathryn Jablokow** 1072–1082 A Set of Guidelines for the Consistent Assessment of Concept Maps

Concept maps are used to structure and communicate information, as well as to assess one’s depth of understanding of a topic. In our research, in which we used concept maps as a form of assessment, we determined that the existing techniques available in the literature to evaluate concept maps can lead to inconsistencies in the assessment results. In this paper, we will present data that illustrate these inconsistencies, as well as the concept map assessment guidelines we developed to improve assessment consistency; we tested these guidelines on 131 concept maps. This process was influenced by the many concept map assessment techniques published in the literature and will provide educators with the necessary guidance to meaningfully, consistently, and accurately evaluate student concept maps.

Keywords: concept maps; student assessment methods; concept map analysis; concept map metrics

- Auhood Alfaries, Maha Al-Yahya, Henda Chorfi and Remya P. George** 1083–1094 CURONTO: A Semantic Model of the Curriculum for Program Assessment and Improvement

The Continuous Improvement Process (CIP) of an academic program in higher education is a tedious and time consuming task. Updating any part in the curriculum requires a thorough review of all the related and subsequent courses. Since 2008 the B.Sc. program of Information Technology (BSIT) in King Saud University (KSU), has initiated a CIP based on outcomes of both course and program levels in response to ABET accreditation requirements. To ensure the program delivers its educational objectives and student outcomes through a well-designed curriculum, we propose, in this paper, a semantic representation to model a complete curriculum using OWL ontology. Using such representation permits a global view of the internal relations and dependencies within elements of a curriculum and hence enables the CIP to be carried out easily.

Keywords: ontology; curriculum development; program outcomes; continuous improvement

- S. Mugisha, E. F. Doungmo Goufo and L. D. Mogari** 1095–1109 Analysis of the Performance of First Year Students in Calculus

Assessment scores of students in mathematics in an Open Distant Learning setting have not always been impressive. In this paper an exploratory study into the assessment of students’ performance in the first year Calculus module is being conducted using past examination scripts between 2006 and 2009. The study, done at the University of South Africa (UNISA), re-assesses the work done in the end-of-year examination, by both looking at the distribution of marks awarded and assigning new scores based on an assessment rubric adapted for the problem at hand. By using the rubric scores, further assessment of students of qualitative dimensions is possible which can serve as feedback for the module lecturer. They include assessing the relative importance of students’ understanding of a problem, recognizing what was wanted, as well as formulating a solution strategy; implementing the strategy, hesitating, and displaying ingenuity in the solution of Calculus problems. In the process, we use the techniques of splitting the measuring instrument to estimate a reliability coefficient (Conbach’s alpha coefficient, Rulon’s split half reliability coefficient and Spearman-Brown split half reliability coefficient) on the basis of two halves and we provide a mean score showing a perfect understanding and proved that it is possible to standardize it by normalizing to 25, so as to facilitate comparisons with earlier averages.

Keywords: assessment rubric; calculus; qualitative dimension; score normalization

Conceptual understanding plays an important role in science and engineering education. The present study focuses on an investigation of students' perceptions of difficult concepts in a high-enrolment, high-impact, foundational engineering dynamics course. A total of 88 undergraduate students who recently took an engineering dynamics course participated in the present study. At the end of the semester, students were asked to identify, from a list of 50 concepts in seven categories, those concepts that were difficult for them to understand or difficult to apply in problem solving. The results show that more than 20% of the surveyed students identified 11 most difficult concepts. The top three difficult concepts include the Principle of Angular Impulse and Momentum for a rigid body, the Conservation of Angular Momentum for a rigid body (or a system of rigid bodies), and the angular impulse of a rigid body. In general, the concepts that students perceived as most difficult were often associated with rotational motion, rigid bodies, impulse and momentum, and laws and principles in engineering dynamics. Students indicated that a concept would be more difficult for them to understand if it involved other concepts, especially rotational-related or angular-related concepts. The research findings of the present study imply that in education practices, such as classroom lectures and homework assignments, the instructor should pay more attention to concepts such as rotational motion, rigid bodies, impulse and momentum, and laws and principles in engineering dynamics.

Keywords: concepts; engineering dynamics; questionnaire surveys; students' perceptions

Peter Gibbings

1120–1129 Qualitatively Different Ways Students Experience Remote Access Laboratories

This paper reports variations in students' experience of using remote access laboratories (RAL). Outcomes describe what students are actually attending to when engaged in RAL activities. The research was informed by the well-accepted and documented qualitative research method of phenomenography. Four qualitatively different conceptions are described, each revealing characteristics of increasingly complex student experiences. These conceptions reveal increasing awareness of certain aspects of RAL, the most notable of which is how the realness of the activity affects student engagement from simple experimentation to an appreciation that linking theory with practice provides a rich learning experience and can prepare them for professional work. The research outcomes inform pedagogy by providing a platform for improving RAL development and facilitation practices and thereby improving student learning outcomes.

Keywords: remote access laboratories; RAL; phenomenography; online learning

Radhi Mhiri, Maarouf Saad, Moustapha Dodo Amadou and Vahé Nerguizian

1130–1135 Potential of ICTs and Pedagogical Approaches to Improve Remote Laboratory

The online laboratory or Lab At Distance (LAD) is an interesting tool in training systems and can also provide enrichment for the conventional laboratory. The literature shows that in LAD development projects, the biggest concern is centred on the technological prowess and technical solutions developed. In general, learning improvement achieved through these activities is not considered. In this paper, we discuss the experience of developing enriched LAD by emphasizing the pedagogical approach. Visiting a Web site for an industrial application related to laboratory work allows contextualization of this work and gives more meaning to the work to be completed. The student is then led to discover a problem derived from an industrial reality described by images and videos from a virtual tour. Additional video and image resources are also used to explore the laboratory equipment used and provide additional valuable learning. We also present the experience of developing a set of LAD according to our pedagogical approach. LAD are developed by the school of engineering, École de Technologie Supérieure (ÉTS), in Montreal and three colleges (CEGEP) in Quebec. From this experience, the paper highlights both the technical and pedagogical strengths. The different choices adopted for LAD are discussed and a preliminary assessment of the operation of this set of LAD is also presented. Our experience shows the feasibility of sharing LAD between the four institutions. This solution provides an interesting way for optimising the operation of equipment and reducing investment, thus promoting the acquisition of new equipment to be up to date with changes in technology. The operation of these LADs shows that the use of ICT gives extra depth to the LAD by associating it with authentic applications and presenting the work required as a real problem to be dealt with. Our experience shows that this pedagogical approach makes more sense for work, promotes student motivation, provides access to the industrial reality and brings the learning process beyond the limits of conventional laboratory work.

Keywords: Lab At Distance; remote lab; pedagogical approach; information and communication technology; problem based learning; contextualization; sharing equipment; virtual tour; motivation

Bushra Tawfiq Chowdhury and Aditya Johri

1136–1144 U.S. Graduate Engineering Students' Perceptions of and Strategies towards Acquiring External Funding for their Education

Each year a large number of graduate engineering students apply for external funding, primarily from the U.S. National Science Foundation (NSF), either directly as fellowships or indirectly as graduate research assistantships. Although pursuing an opportunity at NSF is a challenging and rewarding experience and a much needed skill, we know little about how graduate engineering students approach this process and what leads to success. In this paper we use an interview-based qualitative study to specifically examine formal versus informal support available to students to apply for funding and the process of application subsequent to students' decision to pursue a funding opportunity. Our study shows that the pursuit for grants is primarily encouraged by faculty members and applicants utilize this opportunity to scope one's research ideas, get a higher stipend, and reduce their dependence on teaching or research assistantships. Moreover, figuring out specific details of the application procedure, writing in a way that is satisfactory to the funding agency, and knowing where and when to apply are among the few of the challenges engineering graduate students face during the grant application.

Keywords: graduate education; engineering students; external funding; interview study

Larry L. Howell, Carl D. Sorensen and Matthew R. Jones

1145–1165 Are Undergraduate GPA and General GRE Percentiles Valid Predictors of Student Performance in an Engineering Graduate Program?

While both subjective measures and quantitative metrics play an important role in admissions decisions, quantitative metrics are amenable to critical analysis using the tools of academic analytics. The hypotheses that motivated this study are: 1. Can an applicant's undergraduate grade point average (UGPA) and scores on the Graduate Records Examinations (GRE) be used to accurately predict the performance of the applicant in a graduate mechanical engineering program? 2. Is a single construct based on these quantitative predictive metrics a valuable tool in efficiently making admissions decisions? This study analyzed the relationship between quantitative predictive metrics, available at the time of application to a mechanical engineering graduate program, and quantitative performance assessments measured at the thesis defense. The sample includes 92 students graduating with MS degrees in mechanical engineering from a private university in the United States. The input variables include UGPA, and percentiles for the verbal, quantitative, and written sections of the GRE. The performance metrics were obtained at the thesis defense. They are graduate grade point average, months to graduation, peer-review publication rating, and advisor determined performance rating. Each variable was normalized and the relationship between the predictive metrics and the performance metrics was analyzed statistically. Regression models were created for each performance metric and for a weighted sum of all the performance metrics. The dominant predictors are the UGPA and the score on the quantitative section of the GRE. A quantitative application rating is

found to be 5 times the normalized UGPA plus four times the normalized score on the quantitative section of the GRE. Quantitative metrics account for one fifth of the variance in the performance metrics. The Quantitative Application Rating—a single construct based on the quantitative predictive metrics studied—aids in making admissions decisions.

Keywords: graduate admissions; admissions validation study; academic analytics

Chung-Fah Huang 1166–1175 Associations among Civil Engineer's Ethical Education Experiences, Ethical Beliefs, Ethical Perceptions and Ethical Behaviour

This study is to discover the current situation of the professional ethics education of engineers in Taiwan's construction industry and also to discover which types of ethical education experiences can really shape suitable ethical attitudes and behaviours for construction practitioners. These engineers can be categorized into three types according to their ethical education experiences. This study included 526 civil engineers, and it showed that only 13% of the engineers studied ethics at school. Factor analysis and reliability analysis were employed in this study to explore the factors of ethical beliefs, perceptions and behaviour of construction industry engineers. According to the three t-tests on the three types of engineers with different ethical education experiences and those without any ethical education experiences, it was found that ethical education experiences from on-the-job training and the strict regulations of organizations have a significantly more positive effect on ethical attitude development. It was also found that civil engineers' ethical behaviour is subject to the influences of their ethical beliefs and ethical perceptions, particularly their ethical perceptions of interpersonal relationships. Therefore, it is suggested that construction organizations and employers should emphasize teamwork and respect between employees so as to achieve more effective results in boosting engineers' ethical behaviour.

Keywords: ethics education experience; ethical belief, ethical perception; hierarchical regression; civil engineer

Susan McCahan and Lisa Romkey 1176–1189 Beyond Bloom's: A Taxonomy for Teaching Engineering Practice

Engineering practice, which is the ongoing application of engineering knowledge and skills in the professional context, is an important part of engineering education. Undergraduate students should demonstrate potential for using professional engineering skills and knowledge in their work after graduation. However, there is no tool to help instructors describe or measure the learning associated with engineering practice. This paper reviews the literature in the field of professional practice and suggests a new taxonomy of learning outcomes for this area, inspired by Miller's Pyramid from the medical education literature, supporting the use of learning outcomes for engineering practice in undergraduate education. The professional knowledge literature was reviewed to help describe engineering practice, and delineate it from other cognitive skills in engineering. The literature on learning taxonomies provides an understanding of existing tools, and demonstrates a gap in describing the learning associated with engineering practice. Finally, the proposed taxonomy was applied to two engineering courses, to better describe the taxonomy in context. Future research will specifically consider how the practice taxonomy can inform teaching and assessment practices. The engineering curriculum should be designed to provide the student with increasingly authentic experiences in which to practice these skills.

Keywords: engineering practice; learning taxonomy; professional skills; learning outcomes

Aharon Gero and Efrat Zach 1190–1199 High School Programme in Electro-Optics: A Case Study on Interdisciplinary Learning and Systems Thinking

An interdisciplinary electro-optics programme was recently established at a leading high school in Israel. This unique programme combines physics with electronics and spans over a three-year period. The programme was meant to increase students' interest in physics and engineering, and develop their systems thinking skills. A central part of the programme is the final project done over the last school year (12th grade), in which the students design and implement an electro-optical system. The study described in this paper characterized by qualitative tools the change that had occurred during the academic year in the attitudes of fourteen 12th grade students toward the programme, and the change in their systems thinking skills. The results of this study indicate that beyond the students' increasing interest in the programme, they thought of it as leading to a deeper study of the disciplinary components. Further it was discovered that over the year there was an improvement in the students' systems thinking skills.

Keywords: electro-optics; electrical engineering education; high school; interdisciplinary curriculum; systems thinking

K. J. Chua 1200–1212 Performance Differences between First-time Students Undergoing Hybrid and Pure Project-based Learning

This study compares and evaluates the learning ability and performance differences between two classes of students undergoing Project-based-learning (PBL). One class ($n = 30$) was subjected to a pure PBL curriculum while the other ($n = 30$) was facilitated via a hybrid PBL-lecture curriculum. More specifically, it examines if there are significant differences in knowledge score, problem-solving ability, and eventual project-deliverable outcomes between the two sets of students. Confirmatory factor analysis (CFA) was conducted and Cronbach's alpha parameters were computed to investigate the validity and reliability of the research tools employed. Based on the project continuous assessments, key findings have indicated that students undergoing the hybrid PBL curriculum realized deeper fundamental formative knowledge, enhanced their problem-solving abilities, and produced better performing artifacts with regards to the set of design skills between these two classes. This study further highlighted that first-time PBL students performed better under a hybrid PBL-lecture mode as they may lack the problem-solving and interpersonal skills needed to participate in full-fledge PBL sessions. The present study provides new insights into the intrinsic link between students' learning experiences, learning strategies, and their abilities to perform in projects under a PBL environment.

Keywords: hybrid project-based learning-lecture; problem-solving; engineering design project; engineering education

Arturo Gonzalez, David Jennings and Loreto Manriquez 1213–1224 Multi-Faceted Impact of a Team Game Tournament on the Ability of the Learners to Engage and Develop their Own Critical Skill Set

The purpose of the work presented in this paper is helping students to improve and accelerate their learning through a form of cooperative learning known as Team Game Tournament (TGT). The principle behind TGT is that the success of a team lies on the success of the individuals composing the team. TGT enhances learning via the establishment of a tournament where the class is divided into small academically balanced teams that play against each other. Facilitator's notes from visual monitoring, data from student questionnaire and exam results are collected for two structures-related modules of civil engineering stages 3 and 4 with and without TGT. Students show to be focused and participative, to develop their critical thinking and social skills and no less importantly, to enjoy the new learning format. These perceptions are confirmed by student feedback and a significant improvement in their performance at the exam. Student's learning is considerably strengthened by being held individually accountable for formulating and answering questions that contribute to the team score in a TGT style. Team mates help each other and study more than individually because they care for them and for the team.

Keywords: cooperative learning; teaching methods; student attitudes

Jorge Maturana, Gonzalo Tampier, Guillaume Serandour and Richard Luco 1225–1233 Developing Teamwork Skills in First and Second Year Engineering Students

This paper reports and analyzes a multidisciplinary experience carried out with Informatics and Naval engineering students. Mixed teams were formed to build a self-balancing ship model, mixing naval building techniques and microcontroller programming. The objective was threefold: 1) to develop multidisciplinary skills, 2) to introduce students to professional-style projects and 3) to integrate knowledge from core courses. In order to develop a wider awareness about how they are seen in their environment, an

automated peer assessment system focused in feedback was applied. A hundred students of both disciplines took part in this activity over 6 weeks. The activity was generally well received by students. Mutual dependence from peer's work raised awareness about the importance of responsibility, while leadership was perceived through a different perspective. Skills such as conflict resolution, planning and enthusiasm were identified as key issues to boost teamwork. In conclusion, the professional-like environment allowed students to see how their future activity will be, while access to technology and industrial environments were important drivers to motivate them. Improvement opportunities are identified and are being addressed for similar activities in the future.

Keywords: engineering education; multidisciplinary work; project-based learning

N. Barka, I. Benhayoune, A. El Ouafi, J. Brousseau and A. Menou 1234–1241 Increasing Student Performance by Integrating Project Management into CAD Undergraduate Course

This paper presents a new pedagogical experiment based on skills in computer design courses. The evaluation of competencies is principally carried out during design projects that involve new products issued according to client need. The 11 students are introduced to CAD software through a theoretical course that gives them the requisite background and appropriate tools. The evaluation is essentially conducted during the design process, which includes the use of the CAD software package and integrates project management procedures to increase the engineering students' performance. Considering the project's complexity and the short time period the achieved results are very promising and demonstrate high deliverable quality. These results promise an excellent potential to be reused to enhance the teaching level during future years.

Keywords: engineering education; skills; CAD; project management

Fernando Alba-Elías, Ana González-Marcos and Joaquín Ordieres-Meré 1242–1253 An Active Project Management Framework for Professional Skills Development

The objective of this paper is to present a framework that is intended to enhance the learning experience of Project Management engineering students. There were more than 150 participants from five engineering disciplines at universities in various locations. They attended project management courses at their own universities, but with a shared virtual experience in executing and managing their projects. Different aspects have been investigated, such as the feasibility of using an integrated and technological framework to help the integrated learning process, the use of Educational Data Mining (EDM) techniques to provide additional feedback of students' performances and forecasting students' successes at an early stage, based on the collected data. In addition, a survey was conducted to assess the students' level of satisfaction and their learning. We concluded that the integrated framework has demonstrated its usefulness in promoting the project management learning process among geographically-dispersed students, even when they come from different engineering disciplines and environmental sciences. Further, an increasing amount of student feedback was received. This impacted the teacher's effort unexpectedly. Finally, specific behaviors were found to be closely related to the student's final score. The main finding is that practical application of immersive frameworks increases student motivation and the outcomes of the course, thereby closing the usual gap between theory and practice.

Keywords: project management; project-based learning; blended learning; educational data mining

Arantzazu Burgos, Isabel Sarachaga, Maria Luz Alvarez, Elisabet Estévez and Marga Marcos 1254–1270 Training Proposal based on MeiA to face Automation Challenges

The new challenges in process control require strengthening the development of design skills and the use of real-world experiences throughout the engineering curricula. So this paper presents a training proposal that aims to incrementally develop competences for implementing the control software of industrial automation systems within engineering curricula. The METHodology for Industrial Automation systems (MeiA) guides students through the development process from the analysis, through the design, implementation and operation phases. The student competences are developed through three incremental and integrated levels: (1) initial procedure; (2) introduction of design principles and (3) development of methodological skills. This methodological proposal implicitly introduces fundamental concepts of software engineering. This ensures that students are able to develop complex control systems following structured programming concepts. In addition, they generate different type of documentation about the design, reducing the effort from design to implementation and operation. Furthermore, the training proposal focuses on motivating the students through real-world problems, introducing analysis and design issues incrementally through the three levels. At the same time, multi-disciplinary skills are also introduced by integrating the whole development process from the very beginning. The experience after the implementation of the training proposal shows a significant increase in student interest in this engineering field in recent academic years.

Keywords: engineering education; industrial automation; control software; MeiA methodology

Fábio Lima, Álvaro Camargo Prado, Alexandre Augusto Massote and Fabrizio Leonardi 1271–1279 Automation Course for Industrial Engineers: An Approach Based on Petri Nets, Software Tools and Laboratory Experiments

This paper proposes a methodology for teaching industrial automation to Brazilian industrial engineering undergraduate students, based on analysing a computational solution associated with an integrated manufacturing laboratory. As a first approach an analytical analysis of the automated process is carried out. Then the manufacturing laboratory is combined with software tools, to provide the industrial engineering student with a powerful analysis for using these kinds of systems to improve product quality and production performance. For the computational analysis, we have inserted Petri Nets to evaluate the production system performance with a good acceptance from the students. This is the highlight of this work since using Petri Nets for Industrial Engineering undergraduate students is not a common approach. Finally, an assessment proved that such a strategy has been producing excellent learning results.

Keywords: automation; simulation; discrete event systems; flexible manufacturing systems

Cenk Alhan and Hatice Gazi 1280–1294 Bringing Probabilistic Analysis Perspective into Structural Engineering Education: Use of Monte Carlo Simulations

In structural engineering education, particularly at the undergraduate level, it is customary to teach analysis of structures with a deterministic approach where applied loads are assumed to be constant. The possibility of variability in these loads is typically taken into account by using load amplification factors at the design stage. Unfortunately, these load factors are accepted by students without questioning what they really are. Besides other complex methods, use of Monte Carlo Simulation Method has the potential to teach students probabilistic structural analysis without expecting a solid background in the theory of probability. As a final outcome, it is expected that structural engineering students will gain a new perspective aside from their traditional deterministic perception of structural analysis. In this article, use of Monte Carlo Simulation Method in teaching probabilistic structural analysis is demonstrated via examples with different complexity levels including a simple beam under gravity loading and a frame under combined gravity and earthquake loads. Proposed subject was taught at different classes of different levels varying from Sophomore to Graduate level students and a very positive feedback was obtained. It is concluded that Monte Carlo Simulation can be used to bring a probabilistic analysis perspective to structural engineering education.

Keywords: Monte Carlo Simulation; probabilistic structural analysis; engineering education

An animation based learning unit on the subject of the bipolar junction transistor was recently developed for electronics students in a two-year college in Israel. A previous research had indicated a significant gap between the achievements of students in a basic course studying the electronic device through animation and those of students studying it through static diagrams drawn on the board. The longitudinal study described in this paper examined whether animation based learning of the bipolar junction transistor has a long term effect on students' achievements and whether this gap is maintained in advanced courses covering analog electronics. Findings indicate that even a year after the completion of the basic course, the achievements of students who have studied the transistor through animation continue to be significantly higher than their peers', and that animation based learning promotes retention and transfer.

Keywords: computer animation; electronic devices; electrical engineering education; retention; transfer

**Shi-Jer Lou, Wei-Yuan Dzan,
Chun-Yi Lee and Chih-Chao Chung**

1303–1312 Learning Effectiveness of Applying TRIZ-Integrated BOPPPS

This study aims to explore the teaching effect of a TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch), an integrated factory practicum in a BOPPPS (Bridge-In, Objective, Pre-Assessment, Participatory Learning, Post-Assessment, and Summary) model in a university in Taiwan. The subjects in this study were undergraduate interns in a factory at the university. They were divided into an experimental group and a control group. The teaching strategies of 'BOPPPS and TRIZ' were tested. The outcomes from the data analysis show that the 'BOPPPS and TRIZ' strategies are extraordinarily effective for developing students' creativity and synergizing learning. Accordingly, training teachers to use 'BOPPPS and TRIZ' can make the factory practicum a more meaningful internship program.

Keywords: BOPPPS; TRIZ; factory practicum; university students

**Dragan Dragicevic, Gordana Ostojic,
Branislav Tejic, Srdjan Tegeltija and
Stevan Stankovski**

1313–1323 Development of Didactic Dosing System for Raw Materials in the Form of Granules

Dosing process can be applied in various industries. In order to better prepare students for the requirements, conditions and equipment that exists in the industry, a dosing system for raw material has been developed at the Faculty of Technical Sciences, Novi Sad. The main objective was to enable students to work with flexible system in terms of raw material types. Other important objectives were to allow students to become acquainted with different types of actuators and sensors, Field bus systems, Supervisory Control and Data Acquisition (SCADA) systems, material handling, intelligent control systems, and to learn methods of dosing system design and implementation. In this paper, a detailed description of the developed didactic dosing system for raw materials is presented. This dosing system supports in-class hands-on activities in material handling tasks, allowing them to learn about the structure of the dosing system and its components. Through this learning process students are able to evaluate the use of different methods of dosing system design. One of the most important learning benefits is that of understanding dosing system implementation and limitations, by working through different scenarios that simulate industrial tasks and conditions.

Keywords: dosing system; granules

**Auguste Ndtoungou, Abdelhamid Hamadi,
Salem Rahmani and Kamal Al-Haddad**

1324–1336 Standalone Solar Photovoltaic Energy System Analysis and Design

The complete design and calculation of Solar Panel (SP) system feeding isolated homes represents a challenge for future engineers to apply knowledge acquired during their training. In this paper, a method of sizing and control of solar energy generator is proposed based on modeling of physical system components by mathematical equations that will help to understand the system components and their interactions. It provides a perspective view on how to efficiently use the knowledge acquired by the student during the engineering curriculum, and test their ability on how to validate complex theoretical concepts. The work presents a photovoltaic system feeding a three-phase standalone load. Mathematical development of the control along with steps required for the choice of SP and battery are made with ease to better understand complex engineering concepts. A new control for the dc-ac power electronics converter is derived from the mathematical model which allows maintaining the ac side voltage at the desired values as dictated by the constraints imposed on the DC bus voltage. The choice of the battery storage system (BSS) is based on 48 hours load energy autonomy. Simulation using Matlab Simpower Systems, and experimental results using real time simulator of OPAL-RT applied to a laboratory prototype 1.5 kVA are presented for validation purposes.

Keywords: solar panel; battery; MPPT; curriculum design; inverter; boost converter; micro inverter; power quality; engineering education; capstone project