

The International Journal of Engineering Education

Contributions in: Active Learning, PBL, Flipped Classroom, Educational Games, STEM, Assessment, Creativity, Student Enterprise, Virtual Internship, Distributed Practice, Multidisciplinary Education, Diversity, Motivation, Engineering Curriculum, Project Management, Mechanics, Engineering Architecture, Advanced Manufacturing, Electrical Engineering, Hardware Design, Physics, Mobile Learning, Modelling, Hydraulic Systems, Engineering Laboratories

Ahmad Ibrahim

1711 Editorial

Prateek Shekhar and Maura Borrego

1712–1725

Examining Instructional Change: An Observational Study of Engineering Instructors' Use of Active Learning

Research has shown the positive impact of instructional change efforts on the use of active learning. However, most of the research on adoption of these practices is based on self-report. Instructor self-report of pedagogical practices may differ significantly from actual practice and often limits examination of factors influencing the change. This study presents an observational examination of instructional change rather than commonly used self-report approaches. We conducted a case study examining instructional change with two engineering instructors using active learning. Using classroom observations as our primary data source, we refined our explanations and triangulated our findings with instructor interviews and student focus groups. Although overall positive student response was received for the two courses, variations in student engagement were observed between and within the implemented active learning types. We provide evidence on the influence of instructors' beliefs on active learning use, its resulting impact on student engagement and present implications for instructional change efforts and research.

Keywords: active learning; instructional change; instructor beliefs; student engagement

Mario Solis and Antonio Romero

1726–1736

PBL from Real Projects and Students Initiative: A Case Study

The benefits of Project Based Learning (PBL) to acquire technological knowledge as well as transversal skills by students are well known. However, the implementation of PBL requires additional efforts from teachers and students, as well as additional teaching resources when compared to traditional teaching. This paper presents a case study of a singular PBL experience developed within a subject entitled Experimental Structural Analysis. This subject had PBL already implemented. However, the paper describes a new PBL experience that was suggested by some students that were part of the Formula Student (FS) team from the University of Seville. 24 students and 2 teachers took part in this new experience. The proposed PBL introduced some new challenges in the subject. The paper describes how the subject was organized in terms of theoretical and practical lessons, tutorials and assessment (including the introduction of a novel Self Assessment Factor). The paper analyzes the results from an academic point of view and describes the benefits, difficulties, advantages and opportunities arising from a PBL approach in which students play a new role as real promoters of a real project. Results from academic scores, surveys from students and teachers' perceptions are analyzed. The percentage of students who ask the teachers of the subject to supervise their final degree project is used as a new satisfaction indicator from students. The paper shows that this PBL methodology is enriching and suitable for the learning process of most the students. However, new challenges arise such as encouraging all the students to be actually involved in the cooperative work and ensuring that the main theoretical concepts are learned. The FS competition is proven to be a good opportunity for implementing PBL based on a real project.

Keywords: PBL; formula student; real project; self-assessment

Matej Mihčić and Ivica Završki

1737–1750

Professors' and Students' Perception of the Advantages and Disadvantages of Project Based Learning

Requirements of the job market have substantially changed in the recent years while the teaching methods have remained largely the same. Employers find the graduates lacking in teamwork, communication and other soft skills as well as in engineering thinking, engineering intuition and higher order thinking and problem solving skills. Project based learning (PBL) appears to provide an alternative teaching process capable of addressing these employers' needs. The problem arises with implementation of PBL into existing engineering curricula, which are not flexible and easily changeable. Therefore, if full scale implementation of PBL courses is difficult, most significant advantages and barriers to implementation should be sought out. Goal of the paper was to discover the most significant advantages and disadvantages of PBL from the students' and professors' point of view. To that end, both students and professors were questioned on their perception of PBL from their own personal experience on a complex interdisciplinary student project. Taking into account the difference in sample sizes of the two groups, the students' opinions were collected through an online survey and the professors' through semi-structured interviews and an ABC method questionnaire. Research findings from this paper may be used to determine which aspects of PBL are most suited for engineering education and conversely, which should be focused on the most. On the other hand, it is useful to know which disadvantages and barriers to implementation are the most significant and which need to be overcome first to enable PBL implementation.

Keywords: project based learning; engineering education; advantages; disadvantages and implementation barriers; student perception; faculty perception

Urban Burnik and Marko Meža

1751–1762

Open-Source Impedance Measurement Instrument Development Project Enhances Engineering Students' Technical and Organizational Skills

The need to bridge the academic skills of students involved in tertiary education and improve their readiness for employment in the industry is being widely addressed. This paper presents a novel approach supported by a national programme that can run in parallel with conventional study-based activities and encourages direct interaction within the triangle: student—university—

industry. Through an autonomous participation in a small-scale industrial project, ten students were given an opportunity to gain technical and professional engineering skills without sacrificing the time needed for a company-based internship. Self-evaluation reports and feedback from the industrial partner demonstrate that the participating students developed a varied list of technical and organisational skills and competences and got experience in public presentation of their results.

Keywords: problem-based learning; industry-based learning; practical student experience; engineering skills; Red Pitaya

Shi-Jer Lou, Cheng-Pei Liang and Chih-Chao Chung 1763–1775 Effectiveness of Combining STEM Activities and PBL: A Case Study of the Design of Fuel-Efficient Vehicles

This study aims to explore students' learning effectiveness in energy education that integrates STEM (science, technology, engineering, and mathematics) activities and PBL (project-based learning). The subjects of experimental teaching were 32 junior engineering students enrolled in a project-based course in a Taiwanese university, and this study held a 9-week activity—"STEM & PBL Activities for the Innovative Design of Fuel-efficient Vehicles". In the activity, the integrated thinking emphasized by STEM plays a dominant role when combined with project-based learning strategies. The students took the main role in the course, while the teacher provided guidance to the students in learning and monitored their learning progress. Both qualitative and quantitative analyses were adopted in this study: the qualitative analysis focused on students' projects, and interviews were conducted to understand students' opinions on the teaching activities; the quantitative results were analyzed and discussed. The STEM & PBL energy course covers various disciplines, such as science, technology, engineering, and mathematics, yielding a significant positive effect on learning effectiveness in the field of energy education. The teaching mode of the course includes four aspects: the students discuss real energy problems to deepen their integrated STEM knowledge and abilities; the students work on actual fuel-efficient projects, with focus on integrated STEM learning; the students implement the project based on the STEM knowledge they learn from the energy education course; and the teacher promotes the learning portfolio of STEM and energy education. Based on the above conclusions, this study offers suggestions for teaching and future studies.

Keywords: STEM; PBL; fuel-efficient; education on energy

Gudmundur V. Oddsson and Runar Unnthorsson 1776–1785 Flipped Classroom Improves the Student's Exam Performance in a First Year Engineering Course

This paper presents results from an ongoing study into what is needed in order to improve student's understanding of the material taught and trained in a first year's engineering course. Presented are results of comparing two reverse teaching approaches to a conventional teaching approach based on student's performance in a final written exam and the student's satisfaction with the course. In this study, the authors tested two reverse teaching approaches—one carried out in 2015 and the other in 2016—and compared the results to a baseline set in a previous study where a conventional teaching approach was studied over a 10 year period. For the reverse teaching, the lectures were recorded using a screen video recording software which recorded both the lecturer's voice and the activities on the screen. This allowed the students to watch the lectures at their convenience. The lectures were given by the same lecturer as in the previous study and the material and the textbook were the same. In 2015 the lectures were fully removed but the lecturer showed up to answer questions regarding the recorded lectures. In 2016, the lectures were used to cover selected topics from the week's material and to allow the students to practice their skills by hand. The results reveal that there is a positive relation between flipped classroom and exam grade average and a strong indication that doing exercises as part of lecturer—student meetings will improve exam grade.

Keywords: grades; student ratings; reversed teaching; flipped classroom

Enrique Abad, Julia Gil and Pilar Suárez 1786–1797 A Game-Based Educational Method Relying on Student-Generated Questions

Student-generated multiple-choice questions (MCQs) revised by the instructor were used to design an educational game and to set part of the final exam of an elementary course in Photonics. The exam results of students who had been asked to author MCQs (experimental group) were compared to those of a control group subject to traditional teaching. The results of the experimental group in the MCQ test of the exam were significantly better, whereas the results in the problem solving-part were comparable, resulting in a better overall performance of the experimental group. An anonymous survey revealed that the students were satisfied with the method. The students also acknowledged that the method had helped them to attain a better command of the course contents at a theoretical and practical level.

Keywords: student-generated questions; participatory learning; educational games; knowledge-assessment tools

Omar Cheidde Chaim and Edson Walmir Cazarini 1798–1802 Peer and Self-grading: Comparisons between Analytical and Holistic Rubrics in an Engineering Classroom

Incorporating a variety of assessment practices can help improve the engineering education practices. However, many tasks that add value to the process can be too time consuming and have their usage limited if used frequently and in large classes. One of the tools to facilitate professors and assessors practice is that of peer and self-assessments paired with rubrics. This work analyses and compares the implementation of two different rubrics' types, analytical and holistic, in a six-month course on decision making in industrial engineering. The rubrics were designed to assess format, research bibliography, text quality and content. As results, we found significant differences between both type of rubrics in achieving consensus, bad practices issues, average grades and feedback influence. While easier to achieve consensus and less time consuming to design, holistic rubrics are easier to tamper with and consistently present higher grades. Analytical rubrics heavily influence written feedbacks exchanged between students. Overall, we believe that through responsible use, analytical rubrics can have a positive impact in the development of engineering education.

Keywords: engineering education; peer-assessment; self-assessment; rubrics

Chao Mou, Qing Zhou and Xiaoling Zou 1803–1814 Understanding and Predicting Poor Performance of Computer Science Students from Short Time Series Test Results

Predicting student performance (PSP) is an important application not only for students but also for instructors and staff in educational institutions. Many educational institutions would test and record student performance at regular interval (e.g., every semester or every year), thus producing a short time series, i.e., a sequence of several data points arranged in temporal order. Since short time series may not be effectively manipulated with data mining (DM) algorithm, a technique adopted in most PSP applications, this paper proposes the use of Discrete-time Markov Chain (DMC) and Hidden Markov Model (HMM) for the analysis and prediction of student performance in short time series. This study investigated test results of 167 university students with the intention of earning a degree in computer science in the first five semesters since their enrollment. Analyses showed that HMM can reveal more details than DMC about how student performance changes over time. Moreover, HMM performs better than DMC and the three commonly used DM techniques in predicting students' performance in the fifth semester from their past test results. HMM was also integrated with clustering technique to determine the risk levels of poor performance students.

Keywords: computer science students; predicting student performance; educational data mining; short time series; comparisons between prediction models; hidden markov model

Petre Ogrutan, Ana-Maria Cazan and Lia-Elena Aciu 1815–1823 Difficulties of Evolution from Imitation to Creativity in Engineering Education

This paper presents a study regarding an attempt at developing electrical and electronic engineering students' creativity through elective homework (non-mandatory assignments) and thematic contests. The small number of students participating in these activities showed the difficulties of transition from imitation-based learning to creativity-based learning. In order to evaluate the causes of these difficulties, an adequate questionnaire has been devised. The questionnaire was filled out by 110 students both at the beginning as well as after completing some of the authors' taught courses. The questionnaires were intended mainly to measure motivation, attitude towards taught courses and the organized extracurricular activities. The study allowed a hierarchization of the first 5 reasons invoked by the students who completed their assignment as well as the same number of reasons stated by those who didn't. The students' responses have ascertained that their attitude towards creativity arises from earlier educational experience and should be encouraged during childhood, otherwise only a few would be willing to perform additional activities and to show openness towards innovative tasks. Several possible curricular upgrades were identified, aiming at a gradual increase of creativity and better student motivation.

Keywords: engineering education; motivation; creativity; self-control; homework

Milovan Lazarevic, Djordje Vukelic, Stevan Stankovski, Nemanja Sremcevic and Gordana Ostojic 1824–1833 Enhancing Student Competence through Novel Student Enterprise Concept

The purpose of this paper is to explore how students, organized in the proposed form of Student Enterprise, can most efficiently enhance their operating knowledge and competence about sustainability during their free-choice learning time. The Student Enterprise concept differs from other kinds of practical learning at other universities. It represents a student organization whose activities are not a standard part of any curriculum, in which students efficiently acquire various action competences during their free-choice learning time. This concept was first theoretically designed based on the previous experience in teaching and extensive literature review. Students-volunteers were then organized in specialized teams within the Student Enterprise, with the common goal to design and manufacture one novel product each academic year. Total number of student that have participated in Student Enterprise in academic years 2012/13 to 2015/16 was more than 170. Acquiring of knowledge and skills during free-choice learning time proved far more efficient than the conventional studying during semesters. The findings suggest that the Student Enterprise concept can be implemented within different study programs. Students are motivated to participate in activities in various Student Enterprise teams. Also, the coached team environment allowed students to acquire operative knowledge about sustainability principles even if they had no previous experience with sustainability.

Keywords: student enterprise; higher education; free-choice learning; action competence; enterprise function

Matthew R Markovetz, Sean Sullivan, Renee M Clark, Zachari Swiecki, Golnaz Arastoopour Irgens, David W. Shaffer, Naomi C. Chesler and Cheryl A Bodnar 1834–1841 A Grounded Qualitative Analysis of the Effect of a Focus Group on Design Process in a Virtual Internship

A key component associated with the development of an entrepreneurial mindset is the ability to understand customer needs and consider this when developing a product. This study sought to understand whether the inclusion of a customer focus group as part of a virtual internship created any differences in the design processes of sophomore engineering students (114 students). The Nephrotex virtual internship requires that students design a dialysis membrane by optimizing a selection of four components: membrane polymer, polymerization process, processing surfactant, and carbon nanotube percentage. We found that sophomores who engaged in a focus group during the virtual internship Nephrotex showed (statistically) equal focus on cost versus technical measures of design performance during the focus group. Despite this, design cost was lower in the section that participated in a focus group, with no decrease in product quality. This indicates that customer voice may be an important factor in decreasing product cost. We also found that sophomore students prioritized their interviewing of customers within the focus group towards end users, such as the patient and nephrologist. Qualitative analysis of sophomore responses demonstrated that they found utility in the focus group (30% of participants) but did not necessarily believe that the customers had useful knowledge of the relevant design attributes (17% of participants). Such realizations may have contributed to the equivalent quality and decreased costs associated with the designs of sophomores who participated in a focus group.

Keywords: virtual internships; customer voice; customer needs; design process

M. D. Thouless 1842–1855 Slow and Steady: The Effects of Teaching a One-Semester Introductory Mechanics Class Over a Year

From the time of the earliest work in educational psychology, there has been evidence that expanding the time for study leads to enhanced retention of knowledge. Yet, the current format of tertiary education in the US tends to package material into compressed units. The goal of this study was to explore whether increasing the time over which students are exposed to material results in a deeper knowledge of the material, with better problem-solving skills. An introductory mechanics class usually taught over one semester was taught over two semesters, with no change in total content, work-load, delivery, or assessment. A control was established with the usual form of the class being taught by the same instructor in the second semester. At the end of the two classes, a common final exam was given to both sections and graded together. The performance on the homeworks and the first mid-term appeared to reflect the academic performance of each section prior to enrollment in the class. The performance of the experimental section in the second midterm improved slightly relative to the control section. However, the performance of the experimental section in the final exam was significantly better than the performance of the control section. Extending the time over which students are exposed to new material may lead to a deeper understanding and better problem solving skills.

Keywords: mechanics education; distributed practice; problem solving

Naseem Daher, Farook Hamzeh and Sara I. Khaddaj 1856–1867 Breaking Down the Walls—An Introductory Course in Engineering and Architecture

Engineers and architects employ their technical abilities, innovative approaches, and problem solving skills to devise products and services that support human needs and contribute to the progress of civilizations. Designing and building in the real world require the collaborative input of several specialists from different disciplines; however, engineering and architecture curricula do not necessarily emphasize multidisciplinary education. To mirror the needs of the job market, university education should focus on training students to work in a multidisciplinary environment and develop a holistic view of engineering practices that their future jobs would demand. This study presents a new course aimed at engaging first year engineering and architecture students in a multidisciplinary environment, which inspires students' creativity in problem solving and engineering design. This paper presents different teaching methods for achieving various learning objectives, analyzing students' satisfaction, and highlighting lessons learned from delivering a novel course to engineering and architecture students. Results showed that students were attracted to learning about other disciplines, appreciated the multidisciplinary aspect of engineering, and were interested in acquiring professional engineering skills. Thus, the course was successful in creating a smooth transition between high school and university in helping students lay out the tracks for further development of their engineering skills.

Keywords: multi-disciplinary education; introduction to engineering and architecture; innovation in education; pedagogy

Mahmoud Dinar, Roby Lynn, Evan Barnett, Andrés García, Gregory Kurfess, Thomas Tucker and Thomas Kurfess 1868–1877 Easy Sculpting: A Pilot Study in Teaching CNC Machining to Students From Disparate Backgrounds Without Learning G-Code

Engineers and architects employ their technical abilities, innovative approaches, and problem solving skills to devise products and services that support human needs and contribute to the progress of civilizations. Designing and building in the real world require the collaborative input of several specialists from different disciplines; however, engineering and architecture curricula do not necessarily emphasize multidisciplinary education. To mirror the needs of the job market, university education should focus on training students to work in a multidisciplinary environment and develop a holistic view of engineering practices that their future jobs would demand. This study presents a new course aimed at engaging first year engineering and architecture students in a multidisciplinary environment, which inspires students' creativity in problem solving and engineering design. This paper presents different teaching methods for achieving various learning objectives, analyzing students' satisfaction, and highlighting lessons learned from delivering a novel course to engineering and architecture students. Results showed that students were attracted to learning about other disciplines, appreciated the multidisciplinary aspect of engineering, and were interested in acquiring professional engineering skills. Thus, the course was successful in creating a smooth transition between high school and university in helping students lay out the tracks for further development of their engineering skills.

Keywords: multi-disciplinary education; introduction to engineering and architecture; innovation in education; pedagogy

Allison Godwin, Adam Kirn and Jacqueline A. Rohde 1878–1891 Awareness Without Action: Student Attitudes Toward Team Diversity after Engineering Teaming Experiences

In an increasingly global economy, engineering educators must develop engineers able to work in diverse teams. Much of the research on diversity has focused on cognitive aspects of diversity education. In addition, research on teaming focuses on developing student effectiveness for working in teams. Our study examines 2576 first-year engineering students' attitudes about working in diverse teams and perceptions of diversity at two institutions. We found that students' awareness of diversity increased; however, students' unwillingness to take action to support diverse groups also increased. We also found that students' attitudes towards teaming are 'sticky' and difficult to shift over a single-semester experience even when teaming effectiveness and diversity are explicitly taught in the classroom. Our findings indicate the teaming experiences and discussions of diversity need to be deliberate and distributed throughout the engineering curriculum. This work opens the conversation about how we teach and train engineers to work in diverse teams in first-year programs and beyond.

Keywords: diversity; teamwork; student perceptions

Shai Mano-Israeli and Aharon Gero 1892–1899 What Drives Teachers to Teach Electronics at a Two-Year Technical College? A Self-Determination Theory Perspective

Two-year technical colleges are post-secondary educational institutions that provide practical training in diverse fields of engineering. Given the central role of teachers in the learning process, the study described in the paper characterized the factors driving in-service teachers to teach electronics at a leading two-year college in Israel. The study, which made use of quantitative and qualitative tools, found that the teachers are primarily motivated by their interest in teaching (intrinsic motivation) and by the recognition of its inherent value (identified regulation). According to self-determination theory, these findings could be explained by the fulfillment of the three basic needs (the needs for autonomy, competence, and relatedness) in most of the teachers. Comparison of the results to the distribution of motivational factors in electronics students studying at the same college reveals a significant gap between the intrinsic motivation of the two groups. This gap, in favor of the teachers, indicates a relatively low level of perceived autonomy among the students.

Keywords: electrical engineering education; two-year colleges; in-service teacher motivation, self-determination theory

Jacek Uziak, M. Tunde Oladiran, Marian Gizejowski and Kurt Becker 1900–1911 Incorporating General Education Components into an Engineering Curriculum

Engineering curricula should provide a graduate not only with specialized knowledge in a particular engineering subject but should also infuse general skills and abilities in preparation for life of work. The General Education part of a curriculum can be the source of such transferable intellectual skills as critical thinking, written and oral communication, problem solving and teamwork. The paper presents an assessment of an attempt to introduce General Education into curricula at the University of Botswana, with special emphasis on engineering students. It shows general education courses enrolment realities over a period of 12 academic years. It contrasts the results with the previous study covering a shorter period of time. The paper concludes that the attempt of the broadening the perspective of students by the introduction of the general education courses was not successful. The engineering students were not getting the broad education that general education courses were designed for. The same applied to students with limited elements of science and technology in their university curriculum as general education courses from Science and Technology area attracted almost no students from other faculties. The paper proposes a different model for incorporation of general education into the curriculum.

Keywords: complementary studies; general education; engineering curriculum; accreditation

Luis Ballesteros-Sánchez, Isabel Ortíz-Marcos, Rocío Rodríguez-Rivero and Jesús Juan-Ruiz 1912–1926 Project Management Training: An Integrative Approach for Strengthening the Soft Skills of Engineering Students

The need to rethink project management practices and review how different competences of project managers can be reinforced remains a crucial challenge. This study is intended to explore how soft skills can be measured and strengthened in project management training of engineering students. The purpose is to define and test a valid framework that will help to better design, assess and improve project management training programs. This research has been carried out with 67 engineering students in the role of project managers who lead 456 team members. The main results of this study include the definition of a Soft Skills Index for measurement of soft skills in project management, the assessment of improvements perceived by the students on completion of the training experience and an analysis of the correlation between hard and soft skills.

Keywords: project management; engineering students; competences; soft skills

K. Kloboves, J. Mihelić, P. Bulić and T. Dobravec 1927–1939 FPGA-Based SIC/XE Processor and Supporting Toolchain

SIC/XE is a well-known educational computer architecture designed and widely used for teaching system-software concepts and programming. In this paper, we present a design and implementation of SIC/XE computer, which we implemented using a field-programmable gate-array development board. The system consists of a processor, device controllers, and other auxiliary components. Additionally, we developed a suite of system software utilities (a simple toolchain) for use with our system. The suite includes assembler, linker, and simulator utilities, used to develop and run SIC/XE programs. Programs can be transferred from a personal computer to the board over a serial connection using a provided software tool. The presented hardware and software components have proven to be a convenient tool for teaching both, System-Software and Hardware design course on the undergraduate level.

Keywords: teaching concepts; system software; hardware design; FPGA implementation; software toolchain; SIC/XE educational computer

Víctor Robledo-Rella, Luis Neri, Julieta Noguez and Andrés González-Nucamendi 1940–1952 The Use of Mobile Learning Resources to Enhance Physics Learning for Engineering Students: A Six Year Study

The use of mobile devices for learning purposes has increased in recent years, but there has been little effort to measure its impact on student outcomes. The goals of this work are: to quantify the impact of using mobile learning resources on academic performance and to know the student perception about these resources. Our hypothesis is that mobile learning resources have a positive effect on the learning processes. We evaluate the effectiveness of two mobile learning resources for engineering students regarding free body diagram and conservation of linear momentum. We gave pre and post-tests to experimental and control groups during a 6-year time span and analyzed the differences in the learning gains for both groups. We also gave perception questionnaires to our students about the use of mobile learning resources. With a sample of $N = 645$ students, we found that the experimental group obtained learning gains 7–10 points higher (on a 0–100 scale) than the control group. We found robust evidence regarding the effectiveness of our mobile learning resources through linear regressions ($p = 0.001$ – 0.053) and *t*-Student tests ($p = 0.002$ – 0.045). However, the observed effect size was only $ES = 0.28$. The student perception questionnaires indicate that students found the implementation of mobile learning resources to be very useful. Our results are indicative of a positive impact of the use of mobile learning resources to enhance student concept comprehension and problem-solving skills in undergraduate Physics courses.

Keywords: mobile learning; learning gains; student perception; physics; blended learning

Marjan Golob and Božidar Bratina 1953–1970 Modelling, Simulation and Control of Hydraulic Systems for Educational Purposes

A different modelling approach for modelling of hydraulic systems is presented in this paper. The modelling approach deals with how to obtain adequate mathematical models of the most common hydraulic elements, which are often used in process industries. Partial models should be suitable for behaviour simulation of the complete hydraulic system, for simulation of hydraulic process control applications, for supervision of hydraulic processes, and for educational purposes. All partial models, model of the pump, model of the pipeline, model of the tank, and model of the control valve, are connected logically and properly connected in a MATLAB/Simulink environment and form the mathematical model of the desired hydraulic system. The difference between the classical and presented approach is explained where non-linear and linearized models of all hydraulic elements tanks are derived. Two hydraulic processes are simulated and results show the potential of the presented modelling approach. The proposed hydraulic modelling approach was used in Bachelor and Master Study Programmes in the scope of students' individual work as seminar or project work. The model and real process measurements gave students a proper insight of modelling problems, design and selection issues of equipment and examples of good engineering practice. Positive students' feedback was towards understanding the underlying physics of the developed theoretic models in connection to real process behaviour and measurements, which is mostly missing when dealing with classic modelling and simulation courses.

Keywords: water supply systems; dynamic model; centrifugal pump; pump-valve system

Mostafa A-B Ebrahim, Hani Shafeek, Youssef Mobarak, Mohamed F. Soliman, M. H. Abdel-Aziz, Ahmed Abouelfadl, M. Bassyouni, Mohammed Aman and Asif uz Zaman 1971–1981 Factors Affecting Design, Construction and Renovation of Engineering Laboratories

Well-equipped and organized laboratories are necessary components of any technical institute, especially of engineering colleges, and are earnestly required to impart quality education. Established laboratories will not only help in providing the users—researchers, faculty members and students—with the necessary tools to conduct research and academic experiments but also attract industries to collaborate with the institute. This study is undertaken to suggest appropriate actions and effective approaches in constructing and developing a quality laboratory facility for an engineering faculty, not on the details of laboratory construction per se. Many parameters on which customized engineering laboratories design, construction and renovation pertinent to the needs and requirements of the end users and lab administrators are thoroughly assessed and analyzed before proposing an action plan for development. Among the various issues of importance, three issues—human issues, process issues, and technical issues—are considered common to most types of laboratory facilities. Many of these elements, despite appearing to be common sense, bear great importance to the proper management of any establishment process and hence need due consideration. This study serves as a road map for the scientific community, lab administrators and researchers interested in establishing engineering laboratories according to their requirements but can be extended to be followed elsewhere.

Keywords: engineering laboratory; construction; renovation; human issues; process issues; technical issues; health and safety

Ane Sarasola, Marta Huebra, Jose Luis Zubimendi and Ana Okariz 1982–1990 Importance of the Formulation of Hypothesis and Design of Experiments in Introductory Laboratories

The scientific method is a basic and widely-used tool in many high-school and university laboratories. However, contrary to popular thought, what appears to be a simple and well-known methodology reveals its complexity when the students try to carry out an open or 'non-guided' lab-activity. Practical laboratory sessions are often limited by the teaching context or the uniformity of the experiments that the small lab-groups of students must carry out in each practical session. As a consequence of this, the first steps of the scientific method, i.e., hypothesis proposal and the subsequent design of the experiment are not usually defined by the students. Under these limiting conditions these two concepts—hypothesis and design—are usually presented to the students in a theoretical way instead of using an empirical approach. This work shows that putting into practice these first steps of the research work requires understanding many subtle aspects and acquiring mastery over a period of one or more academic years. We show that the theoretical teaching of these concepts involves misconceptions and we propose an introductory practical session that improves students' understanding.

Keywords: engineering grade; open ended laboratory; physics; scientific method; hypotheses; design of experiments; laboratory teaching