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Problem Based Learning

Michael Wald	655	Editorial
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Erik de Graaf and Anette Kolmos	657–662	Characteristics of Problem-Based Learning

Problem-based learning (PBL) is widely regarded as a successful and innovative method for engineering education. Since the development of the PBL model at McMaster University in Canada in the late 1960s, many different varieties have emerged. This paper highlights the Dutch approach of directing the learning process through problem analysis and the Danish model of project-organised learning. Various definitions of the concept PBL identify characteristics at the levels of theoretical learning principles, educational models and educational practices. The McMaster–Maastricht PBL model and the Aalborg model of project work share characteristic features such as the theoretical principle of the problem analysis at the basis of the learning process, integration of knowledge and practice, collaboration and group work. Notable differences were found with respect to the type of assignments, assessment methods and organisation of the group work. In comparison to traditional engineering curricula, the PBL models appear to inspire a higher degree of involvement in study activities and, consequently, a higher level of complex comprehension. A possible drawback is the risk of gaps in specific knowledge areas. Therefore, it is crucial that the students in a PBL curriculum become lifelong learners who have learned to take responsibility for their own learning process.

Renate Fruchter and Sarah Lewis	663–671	Mentoring Models in Support of P ⁵ BL in Architecture/Engineering/Construction Global Teamwork
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Understanding the goals and constraints of other disciplines is key to working well in cross-disciplinary projects. Education programs rarely offer learners the opportunity to participate in authentic project-based cross-disciplinary collaborations in a global teamwork e-Learning environment. Problem-, Project-, Product-, Process-, People-Based Learning™ (P5BL) is an approach that has been developed to address this issue. This paper presents mentoring models in cross-disciplinary teamwork learning experiences developed in Stanford University's P5BL program. It addresses the Architecture/Engineering/Construction (A/E/C) industry's need to broaden the competence of engineering students to utilize the acquired theoretical knowledge and understand the role of discipline-specific knowledge in a multi-disciplinary A/E/C P5BL learning environment. Mentoring opportunities are presented within a situated and constructivist perspective on learning, to explore the theoretical constructs and practical implications of developing communities of practice that reach beyond the university walls.

Madeleine Abrant Dahlgren	672–681	PBL through the Looking-Glass: Comparing Applications in Computer Engineering, Psychology and Physiotherapy
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The present investigation aims to describe and analyse aspects of students' experiences of PBL within three different academic contexts: computer engineering, psychology and physiotherapy, respectively. A sociocultural perspective was outlined as a theoretical point of departure. Altogether 58 students participated in the study. Semi-structured interviews were used as the method of data collection. Data were analysed qualitatively. The results showed differences between how problem-based learning is realised and understood by the students in the three programmes. These differences are discussed in relation to the perspectives of knowledge and learning embedded in the programmes, as reflected through the students' experiences.

David Hansen, William Cavers and Glyn H. George	682–695	Use of a Physical Linear Cascade to Teach Systems Modelling
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Entire undergraduate programs have been known to adopt PBL. This might be considered a 'macro-application' of this pedagogical approach. Sometimes micro-scale applications can be useful, i.e. introduction of a single challenging and rather open-ended problem. The problem selected should be generic in nature and rather difficult because to promote learning by the mere mimicking of specific examples is poor pedagogy. Micro-to-meso-scale PBL initiatives have a number of advantages: they familiarise faculty with the PBL approach, they have lower cost and risk, the tutors start at an appropriate position on the PBL learning curve, and they are administratively simple. A comparison between the activities of Engineering Design and Process Modelling is presented. The PBL exercise described herein was developed around a set of linear reservoirs that were specially constructed to provide the students with a hands-on verifiable experience with mathematical modelling. This physical cascade system is unique in that an exact analytical solution exists for the nth reservoir. The degree of success with this modelling exercise is discussed.

Lars Peter Jensen, Jan Helbo, Morten Knudsen and Ole Rokkær	696–700	Project-Organized Problem-Based Learning in Distance Education
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Project-organized problem-based learning is a concept that has been successfully utilised for on-campus engineering education at Aalborg University. Recently, this 'Aalborg concept' has been used in networked distance education as well. This paper describes the experiences of two years of Internet-mediated project work in a new Master's degree in Information Technology. The main conclusions are that the project works as a strong learning motivator and enhances peer collaboration, for off-campus students as well. However, the concept cannot be directly transferred to off-campus learning. In this paper, the main problems experienced with group-organized project work in distance education are described, and some possible solutions are listed.

William Cockayne, John M. Feland III and Larry Leifer	701–705	Using the Contextual Skills Matrix for PBL Assessment
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This paper presents a tool for assessment of engineering skills and knowledge, based on a model of taxonomic classification. The tool methodology is built on previously published research and usage in the area of human performance measurement. The paper presents the development of the classification and its application in a comprehensive problem-based learning program in the School of Engineering at Stanford University. Examples are given to illustrate how the tool can be used to communicate the skills, create a common language and foster the creation of trust in teams within the PBL environment. The paper goes on to describe additional usage by faculty, students and industry practitioners in education and career planning.

This paper describes an approach to a more systematic and goal-directed way of handling knowledge in educational engineering design projects. A knowledge management concept consisting of an IT-based knowledge management platform and a knowledge management training as an integrated part of the training of other fundamental trans-disciplinary competencies is introduced. This contribution is based on experiences in problem-based teaching in engineering design projects at the Technical University of Berlin as well as in experiences in implementing knowledge management into industry.

This paper commences by briefly introducing the Systems Engineering degree programme at Loughborough University, explaining why it was designed with problem-based learning (PBL) as its integrating theme. The paper focuses on a final-year module which requires finalists to act as tutors to second- and first-year students undertaking PBL-based group project work. It explains the rationale for this approach and discusses some of the lessons that have been learned from the process. The paper concludes by discussing the benefits to the students of this form of facilitating and mentoring PBL.

The unit operations laboratory is designed to engage students' interest, as it requires them to tackle practical assignments connected to prior knowledge. The course is organized around ill-defined open-ended problems. Students have to identify the problem, formulate hypotheses, search for information, conduct experiments, extract conclusions, and determine the best set of operating parameters to fulfil the objectives. The course requires extensive use of social skills (teamwork, decision-making, task management and oral and written communication). The 'stop and go' method of organization was found to be very helpful in re-directing experimental work and as a source of continuous feedback.

Because of the ambiguous nature of the capstone design course between the perfect setting for problem-based learning (PBL) and the unique challenges of the design process and its outcome, the third component of the PBL triad 'problem/student/teacher' gains additional importance, i.e. the teacher. This paper explores the role of the teacher in a capstone design course as a 'pan-mentor'. 'Pan-mentoring' is defined here as establishing a close relationship with teams of students during the capstone design project, in order to foster the students' learning and to ensure a satisfying project outcome. Thus, 'pan-mentoring' addresses challenges of capstone design (the chasm between theory and practice, vagueness and open-endedness, and performance anxiety) by drawing on the advantages of PBL (such as, self-regulated learning, enhanced critical thinking, and increased creativity).

Stakeholders in engineering education should change the learning paradigm from a teacher-centred to a student-centred approach. Experience gained in teaching automatic control, mechanical engineering orientation, machine language, engineering orientation and technical drawing has given the author confidence that changing the approach, enhances the quality of learning as well as rewards the instructor with greater professional fulfilment. Unfortunately changes made so far 'here and there' in the educational programs are not enough to secure full conformity with present requirements of the real engineering practice. Suggestions are made to improve the curricula as a whole in industrial engineering, mechanical engineering and control system engineering with the hope that we will be soon witness more administrators encouraging changes in teaching approach.

Traditionally, mechanical and manufacturing engineering degree courses have tended to place too much emphasis on theory, with too little application to the integration of real engineering problems. Further, students have tended to work on their own in tackling problems encountered, thus neglecting the important skill of working in a group and interpersonal communication skills. The authors present a model for a problem-based project, which aims at providing an opportunity for the students to work in groups on a real manufacturing problem and to simulate a situation as if they were employed in industry. A by-product of the project is that students have the opportunity to practise their oral and written communication skills. The problem-based learning aspect of the project is implemented through a design project that involves a typical consumer product. Assessment is an essential part of this integrated problem-based learning approach and this includes four important criteria: individual member assessment, group assessment, leader assessment and tutor assessment. The implementation results indicate that students find the approach more interesting and that it is an effective way of learning.

The paper concentrates on the integration of the pedagogical theory and the Problem-based Learning (PBL) practice. This is illustrated on an engineering module example, Microelectronics, which follows a vocational teaching and learning strategy. Assessment methods in relation to PBL, facilitating and mentoring roles of teachers in PBL, transferable skills and learners' motivation are also aspects discussed by the paper and demonstrated on the basis of the Microelectronics module case study. Conclusions on the use of the PBL method in modern engineering education are drawn.

This paper describes how problem-based learning can be used to teach physics to first-year engineering students. The problem-based learning pedagogical approach promotes the development of key skills such as problem-solving and group skills. A model of problem-based learning is then suggested for use with first-year students and the implications of its use are detailed. The evaluation of this PBL course is outlined. This paper should be of particular interest to anyone who is not in a position to convert a complete course from traditional teaching methodologies to problem-based learning but would like to introduce it into one part of a course.

The usual way of learning technical knowledge about a microcontroller (MCU) is by reading relevant handbooks and textbooks. This method requires students to memorize many technical terms and usually ignores its actual application of the data. In this paper, a new approach is proposed using the problem-based learning technique to convey such engineering knowledge. A creative group project was designed for the class whereby students were required to develop their own way of designing a calculator using MCU. Throughout the project, they acquired self-learning techniques to tackle new problems. Moreover, problem-based learning provided students with a cooperative learning environment to enhance their learning capabilities.

Fernando Ramos and Enrique Espinosa	754–758	A Self-Learning Environment based on the PBL Approach: An Application to the Learning Process in the Field of Robotics and Manufacturing Systems
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This paper deals with a PBL approach used to bridge a teacher-centered learning to a student-centered learning. It has been applied in undergraduate and graduate courses of robotics and manufacturing systems with successful results. A cognitive analysis of the relationships between abilities and the steps to solve problems has been carried-out to follow the actual behavior of the students during the evolution of the course, as compared to the assumed one. Our goal was to maintain a permanent challenge among the students that allows them to discover the relevant aspects related to understanding, stating, representing and solving real world problems.

Martin B. Mgangira	759–761	Integrating the Development of Employability Skills into a Civil Engineering Core Subject through a Problem-Based Learning Approach
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Institutions of higher learning are expected to design their programmes to meet the needs of industry to ensure that students acquire the skills, both technical and non-technical, that will be used in future employment. Thus academic institutions have to develop teaching strategies to meet these demands. This paper presents a strategy in teaching, utilising the problem-based learning approach, which allows for the development of non-technical skills in a civil engineering core subject. The teaching strategy is based on the assumption that, by using the active knowledge base in a particular subject with specific application strategies, both technical and non-technical applicable skills can be developed in an integrated manner. An example is provided to illustrate the teaching strategy, and student perceptions of the strategy are also presented.

Alejandro Alvarado-Lassman, Victor de la Cueva and Rafael de Gasperín	762–765	Implementing and Assessing the ABC ² Constructivist Model in Chemistry for Engineering Undergraduate Classes
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This paper shows the results of testing the effectiveness of a constructivist model called ABC² in a chemistry class for engineering majors. Its success was measured using qualitative and quantitative techniques (e.g. observation, interviews, tests and final projects). The results were then compared with a traditional teacher-learning model employed by a separate university, which employed experimentation and control groups to test students' ability to solve problems.