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Guest Editorial

Project- or Problem-Based Learning (PBL) in Engineering Education: Variations and Prospects

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Project- and/or problem-based learning (PBL) has been incorporated into diverse educational contexts worldwide. It is aimed at supporting learner-centredness and providing students with 21st-century skills and professional competencies [1]. Researchers have defined PBL in many different ways. For Savery, it is "an instructional learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" [2]. Emphasizing the role of project work in learning in their systematic review, Helle, Tynjälä, and Olkinuora [3] describe how learning can be organized through projects, providing solutions to problems according to a set of objectives. Within such an approach, a timeline, end products such as reports and designs, and teamwork are key factors. Over the past 40 years, the Aalborg PBL model has integrated problems, projects, and teamwork as part of a holistic approach to learning and teaching. It continues to evolve, developing new forms of practice and addressing contemporary challenges [4–5].

The past decades have witnessed the widespread implementation of PBL in engineering education across the world. While it is agreed that PBL is a useful instructional methodology for meeting the learning outcomes accreditation demands [6–7] and providing the competencies needed for the sustainable development of education [8], there is a general assumption that this also applies to the field of engineering. Although scholars have tried to distinguish PBL by types and models [1, 9–10], there has been little discussion of the use of projects [11], an essential component of engineering PBL. A recent research review of engineering education [12] indicates that, although there seems to be a growing tendency to use PBL at a system level, it is mostly applied at course level, where the nine PBL categories suggested by Savin-Baden are often combined [1]. The application of pedagogical ideas concerning student-centredness and problems will vary depending on educational histories, present policy and regulations, institutional profiles, disciplinary regimes, and interactions with the wider society. Variation within a curriculum may also be related to degrees of implication (at course, programme, or institutional level); types and modes of problems and projects (e.g., length of duration, and scope in terms of course credit); teamwork (e.g., team size, formation, composition, and types of collaboration); facilitation; assessment methods; and the design and use of digital learning facilities. Multi-faceted PBL practices may be attributed to diverse context-bound factors concerning teaching and learning, institutional and sociocultural aspects, and inclusiveness. Therefore, diverse PBL practices must be compared in relation to their given contexts and student learning.

Problem-based learning does not in itself solve issues of student motivation, nor does it automatically lead to the achievement of relevant competencies. If students have the same kinds of educational experiences, there is a risk that these will become routine and fail to promote deeper reflection. Therefore, students must be exposed to a variety of learning methodologies that are documented using diverse research methods. Intensive efforts have been made to report PBL practices that focus on course design and processes via published conference proceedings. In addition, a large number of studies have presented the results of students' feedback regarding attitude, motivation, and performance in the context of PBL. However, the effectiveness of PBL in engineering education has still not been proven [12–13]; at the same time, engineering education research in general has been criticized because it lacks sound conceptual foundations [14–15]. Therefore, further empirical and theoretical research is needed.

This special issue of International Journal of Engineering Education includes articles on the state of the art and future of PBL. The eight studies employ a diverse range of research approaches and discuss critical issues relating to courses, curriculums, problem types, assessment methods, culture, and gender. The majority of the authors are practitioners who have researched, designed, and implemented their own PBL programmes, thereby demonstrating their commitment to the field.

The issue begins with a systematic review of the literature by Andreja Drobnič Vidic. Current research trends in PBL methodology include problem-, project-, and inquiry-based learning in mathematics, science, technology, and engineering (STEM). By comparing the three student-centred approaches, Drobnič Vidic highlights the increasing diversity of research design, participants, disciplines, and PBL practices. In PBL, theoretical subjects such as maths can be closely integrated not only with science but also with engineering and technology. The author shows how implementing different PBL strategies and connecting STEM opens up avenues for future research.

Four of the contributions discuss PBL in the digital era. Lisa Bosman, Aasakiran Madamanchi, Scott Bartholomew, and Vetria Byrd describe how PBL has been used in a US university to develop students' understanding of artificial intelligence (AI) using adaptive comparative judgment (ACJ) as the method of assessment. The authors found that the students' engagement level in associated PBL activities improved their learning outcomes. The study extends current knowledge of the effectiveness of diverse PBL practices in the context of an AI-supported environment.

Vicente López-Chao, Jose Luis Saorín, Jorge De La Torre-Cantero, and Dámari Melián-Díaz also focus on PBL implementation, this time in a Spanish university, where they have used a collaborative graphic simulation method. They measured students' spatial and mental rotation skills before and after the course and assessed their process satisfaction, result satisfaction, motivation, and level of communication. The results suggest a positive relationship between the students' experience of PBL and an improvement in spatial skills.

Juebei Chen, Jiabin Zhu, and Tianyi Zheng use phenomenography to explore the diversity of Chinese female engineering students' team (task, social, and individual) roles in PBL. Their findings reveal the importance of increasing diversity in engineering education. The authors argue that greater attention should be given to building a female-friendly learning and teamwork environment to avoid marginalization and to improve female engineering students' learning experience and outcomes.

Using the Aalborg University PBL model, Bettina Dahl and Annette Grunwald examine variations in the types of problems students are given in a systematic PBL environment in Denmark. They identified five specific types of contrast problems by analysing 21 theses from a selection of engineering, science, and mathematics study programmes. The problems ranged from well-structured to poorly structured and simple to complex. The authors illustrate how exposing students to a variety of problem types helps them become competent problem-solvers.

Instructors Carolina Rojas, Moira Negrete, Ariel Areyuna, Mariela Tapia, María Flores, and Ariel Salazar discuss their perceptions of the PBL-related challenges faced by students in settings characterized by extreme social inequality – in this case, Latin America – and their corresponding instruction strategies. The authors present comparative data on the differences between the self-confidence and social skills of students from public and private universities. Their study provides a valuable insight on how to implement PBL in a diverse environment.

Niels E. R. Lyngdorf, Youjin Ruan, Juebei Chen, Xiangyun Du, and Anette Kolmos investigate how three Chinese university engineering teachers' developed their professional knowledge and role identities in a six-month intercultural PBL programme in Denmark. Four dimensions were applied to assess the participants' learning outcomes and changes in role identity: ontological and epistemological beliefs; purpose and goals; self-perceptions and definitions; and perceived possibilities for action. Their findings offer evidence that the inquiry-, team-, and real-world nature of PBL can support the professional development of engineering education staff from diverse backgrounds.

Last but not least, Wei Liu, Runhua Tan, Zibiao Li, Han Li, and Bojun Yang explain how a PBL-based TRIZ training approach can improve professional engineers' inventiveness. Experience in patent applications and working on new products were shown to have a positive influence on the effectiveness of PBL. This study will inspire discussions on how PBL can be used in the workplace as well as in educational institutions.

This special issue presents a wide variety of PBL implementations, from courses to curricula and from the perspective of students, educational staff, and professional engineers. We hope that the articles herein will inspire our readers' own PBL designs for engineering programmes and foster positive changes in future practice

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