AALBORG UNIVERSITY
DENMARK

Using Research-focused PBL to Support Computer Engineering Students' Learning Engagement in A Systemic PBL Environment

Yan Zhao, yanz@cs.aau.dk

Department of Computer Science
Aalborg University

Pedagogical supervisor: Xiangyun Du, xiangyun@plan.aau.dk
Expert supervisor: Christian S. Jensen, csj@cs.aau.dk

December 9, 2022

1 Introduction

Problem-Based Learning (PBL), defined as "an instructional learner-centered 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" [15], is one of the latest innovations in active learning for which a wide range of positive outcomes for students are claimed. Such an innovation facilitates deep learning through better understanding of concepts and the development of skills, as well as fostering student engagement and enthusing classes [3, 6]. In PBL, students tend to use a more in-depth approach of learning and understand the meaning of materials being studied, which increases deep learning and decreases surface learning for students especially in practical courses [6], e.g., computer science and software engineering. In PBL, the teaching goal is to create an interesting environment that is conducive to active, engaged learning study and allows for supervised exploration. The most important learning occurs in situations that are both meaningful and practical, and student-centred teaching promotes purposeful and continuous learning.

In such an environment, the exchange of ideas between teachers and students can collide with some valuable and creative ideas [12, 13]. In addition to playing the role of knowledge disseminator, teachers also play other roles like discipline enforcers, students' friends, and team leaders. University students have a variety of personality characteristics and particularities. They are not as profound as their teachers in terms of specific professional knowledge and knowledge, but they also have their own ideas and dignity. When university teachers get along with students, they must respect the personality and individuality of the students and get along and learn with the students modestly. It is also an important role for teachers to understand who the students (i.e., learners) are, what knowledge and experience they have, and what they want to achieve, so that they can customize the teaching activities meeting students' needs [11, 14]. Accordingly, in a PBL environment, teacher-student relationships play a key role in the teacher-student experience and have been found to be related to learning. Teacher-student communication is an educational process where teachers influence students purposefully according to a predetermined direction [15]. When teachers have an influence on students, students will inevitably influence teachers. The field of literature on PBL in engineering education has reported PBL's effectiveness regarding students' improvement of deep approach to learning [6], learning engagement [13], diverse professional competencies such as problem solving and teamwork [7]. Nevertheless, most of the current literature were embedded in PBL implementation at a course level, while the PBL implementation at a curriculum level is little practiced and researched [3].

Aalborg University (AAU) has been over decades practiced a systemic PBL approach, namely the AAU PBL model, integrating a problem-based and a project-organized teamwork approaches [12]. Within the systemic PBL model, students' learning process is guided by problems as a start of the learning, and students work together in team to solve the problem through a process organized in a format of project, within a timeline of the whole semester (five months) which accounts for half of their semester credits. Within the AAU PBL model, the problems can be developed in various ways ranging from discipline knowledge focused and well-structured problems to ill-defined real-life problems from industry [11]. While students develop their engagement to learning at different levels depending on the ways PBL is implemented [13], there is a need for more research on impact of diverse practices on student engagement within a systemic PBL approach like AAU PBL model [3]. To address such a need, this paper reports a pilot study of designing and implementing a research-focused approach to PBL involving students to work on research in the field as

the 'problem' of their team-based project work.

2 Preliminaries and Problem Statement

2.1 Preliminaries: My Teaching Context

In AAU, a semester project works together with three related courses aiming at providing students with a deep insight into the semester topic [15]. For the student-centered project supervision, the author supervised three BAIT3, one SW5, and one SW9 groups at the 2021 fall semester, two SW8 groups at the 2022 spring semester, and three BAIT3 and one DAT5 at the 2022 fall semester. All groups are required to submit a report at the end of the semester and take an oral exam.

1. **BAIT3 supervision.** The semester topic is "Development of a database system for a specific application", and the author supervised six groups with different topics, i.e., Digitalized Restaurant Ordering System, P3 Meal Planner, Whiskey Traders, Car Rental Management System, On-wheel Meal Ordering System, and Pet Business.

2. **DAT5 supervision.** The semester topic is "Experimental Data Analysis and Modeling or Theory-Driven Data Analysis and Modeling", and the author supervised one group with the topic of Heart Runner AI that applies computer science theories to solve real-world problems.

3. **SW5 supervision.** The semester topic is "Route Planning", and the author supervised one group with the topic of aSTEP Route Planner that analyzes, evaluates, and applies methods and techniques within database systems and machine intelligence.

4. **SW8 supervision.** The semester topic is "Mobility", and the author supervised two groups with different topics, i.e., Route Deviation Detection and Navigation System as well as Meals on Wheels.

5. **SW9 supervision.** Students selected proposals as their master's degree graduation thesis topics and work on the same topic in both 9th and 10th semesters. The group the author supervised chose the topic "Deep Learning for Brain-computer Interface". The students cooperate with researchers from the Department of Health Science and Technology.

For the course-based teaching, the author gave a Data Mining course, with 15 ECTS, at 2022 spring semester. The course targets the computer science (DV6) students at the 6th semester. The course aims to teach the main principles of data mining techniques. At the end of the course, the students are expected to understand a few commonly used techniques for data mining, and how to apply them in different applications. The exams were conducted in a written form.

In the meantime, as a student attending the AAU pedagogical training that aims to help us be a qualified pedagogical employee at AAU by gaining pedagogical and didactic knowledge, skills, and competencies to solve the teaching challenges, the author is supposed to apply PBL to the learning process.

1. **Courses.** During the training, the author took five compulsory courses and three elective courses, from which the author obtained pedagogical theories to support my teaching activities.

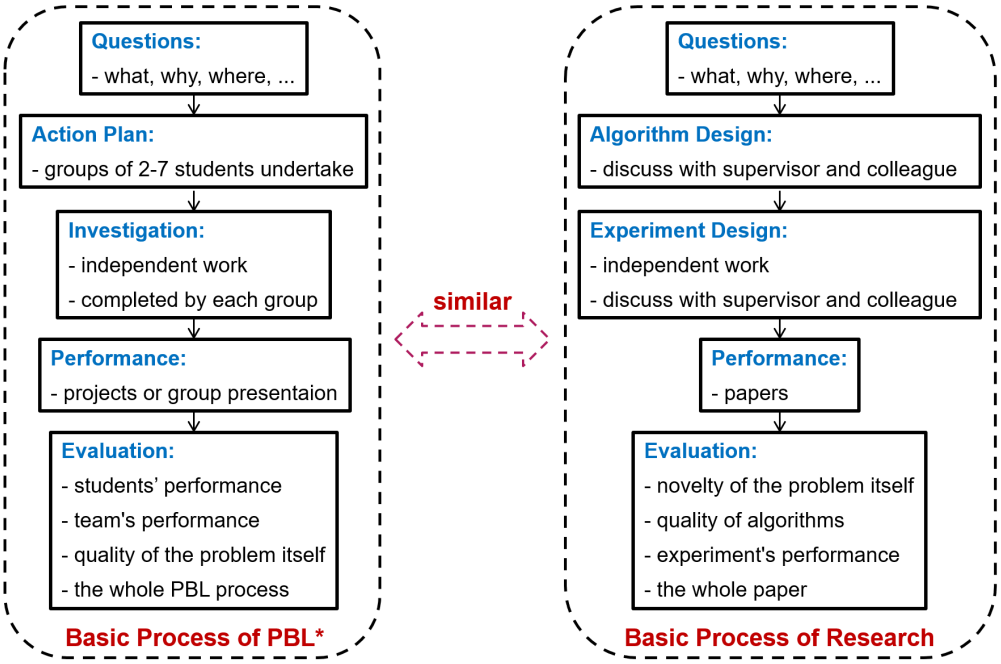

Figure 1: PBL vs. Doing Research

2. **Supervisors.** The author have two supervisors, one pedagogical supervisor Xiangyun Du and one expert supervisor Christian S. Jensen, who observed the author's course teaching and project supervision and provided me with valuable practical suggestions that one can never learn from books. They met regularly, and the supervisors provided feedback through the problem-based project meetings and course-based teaching lectures.

2.2 Problem Statement

The objective of PBL is to improve on the learning experience for all students. Note that it consists of two sub-problems: 1) how to improve on the learning experience for junior students; and 2) how to improve on the learning experience for senior students. Student bias related to age, with younger students preferring younger supervisors and older students preferring older supervisors [16]. Compared with junior students that have a sense of freshness and passion for university environment and the knowledge they learn, senior students are no longer interested in university environment and the knowledge they learn and may just study for exams. Besides, senior students are faced with many different pressures such as academics, employment, and self-development. These pressures suppress these students, causing them to lose interest in studies. If these pressures cannot be transformed into positive motivation, it affects senior students ability to judge and learn. More seriously, it affects the personal development of senior students. Therefore, it is difficult and necessary to motivate senior students. To tackle this issue, this study was guided by the research question: In which ways engineering students may develop learning engagement in a research-focused PBL setting?

The study assumes that involving senior students to conduct research work as the supervisors do in their academic work. Figure 1 illustrates a connection between

a PBL approach to a typical research process. PBL includes raising questions, making action plans and investigation by students, and finally evaluating the performance of students, teams, the proposed problem, and the whole PBL process [14]. The process is similar with that of research-based learning, which also includes raising questions, designing algorithms, conducting experiments, writing papers, and evaluating the novelty of the problem, the quality of algorithms, the experimental performance, and the whole paper. To enhance supervisor-student relation and motivate students' engagement, the study designed a pilot initiative of involving students to work on ongoing academic research as their semester project work. The remaining of the study reports the design, process of implementation as a pilot, and initial evaluation of student feedback.

3 Methodology and Implementation

It is necessary to think critically, analyse problems in full-scale, and make decisions in the face of complex knowledge in the twenty-first century, which leads universities to take research and inquiry as important in students' development [5]. Therefore, the integration of teaching and research aiming at higher education has attracted substantial attention in recent years [1, 8, 9, 10, 17]. A previous study [4] shows that academics are better able to integrate their research and teaching in disciplines (e.g., computer science and software engineering) where knowledge is diffuse and academics work more independently than in disciplines (e.g., political science and history) with a high degree of consensus about curriculum content and lots of research collaboration. Research on the integration of teaching and research has shifted from a teacher-centred approach to one that emphasizes the incorporation of research-derived knowledge into the curriculum, to a focus on developing strategies for teachers/supervisors and students to learn through various forms of research and inquiry [1, 9, 10]. In this section, a framework for research-focused PBL is proposed with three dimensions: research-focused project through research proposal design, enhancing student's learning engagement through research, and co-creation of mutual learning with the project supervisor.

3.1 Research-focused Project through Research Proposal Design

A proposal is a document that creates a plan for a designed project, and a solid proposal acts as a source of truth for students, where supervisors can provide advice and integrate their research and PBL. The most suitable advice means that the supervisor can assist students with what needs to be done. Therefore, a good proposal should clearly focus on the semester topic and explain the problem. However, it is also important to be clear that proposals do not have to exist purely for the benefit of students. It needs to contribute to the work and development of the supervisor. To achieve this, a good solution is to integrate the research of supervisors and PBL into proposals. Besides, a good proposal should meet PBL objectives, e.g., improving the self-directed learning and problem solving of students. A well-written research-focused proposal allows the supervisor to demonstrate the value provided and show that the supervisor is the right person for the project.

The author of the study, who served as the project supervisor of the students proposed an initial design of the research topics. To integrate research, objectives of PBL, and the project of DAT5 students as well as to achieve the semester goal/topic (i.e., Experimental Data Analysis and Modeling or Theory-Driven Data Analysis and Modeling), the author proposed two proposals, i.e., Effective and Efficient Task Assignment in Spatial Crowdsourcing and Unsupervised Time Series

Anomaly Detection. These two proposals are based on the research fields of the author, where the author has published several papers. Students in group DAT-05-03 selected the first proposal and defined a novel problem, namely Heart Runner AI, in spatial crowdsourcing. They explore and develop a new method combining reinforcement learning and genetic evolutionary, achieving the PBL objectives and inspiring the author to find new problems and solutions.

3.2 Enhancing Student's Learning Engagement through Research

Students' research awareness also plays a crucial role in research-teaching integration. Claims that teaching is research-led are not credible if students have negative or no idea about the university as a research environment [2]. Research on student perspectives shows the extent to which students see themselves as part of the research community. Geography students, for example, feel that research is most visible 'in the field' and is done by lecturers and students. However, physics majors indicate that research is visible in the presence of laboratories and machinery, which is believed to be done by lecturers 'over there' [2]. There is evidence showing that many of a university's initiatives in research-led teaching are initially teacher-centred. An interesting aspect of development is the constant awareness that the concept of research-led teaching is not well defined and requires evolving understanding. In practice, a good way to enhance students awareness of research in their project is to encourage students to present their project and results in public (e.g., uploading reports and codes to Github), which is beneficial for them to broadcast the project results. During the supervision for group DAT-05-03, the author suggests students to submit their report and codes to Github and stresses the necessity, e.g., it is helpful to pursue higher education and find a satisfied job. The students show great interest about it, which enhances their awareness of research to a certain extent.

3.3 Co-creation of Mutual Learning with the Project Supervisor

Working on a student's project can be a period of inspiration and learning, but it can also be chronic stress and concern about unfinished reports. The primary task of the supervisor is to help students work through the project and understand what has been learned from the relevant courses. Rather than offering support and advice, supervisors should encourage students to actively organize information. By doing so, supervisors can also learn more about what happens during supervision and how to encourage mutual learning. It is necessary to learn from students, creating an environment where supervisors understand that they do not have a wealth of knowledge in every field. Harnessing the wisdom of students not only helps supervisors grow, but often inspires students to learn further and share their expertise.

During the supervision of DAT-05-03 students, they explore a new problem, Heart Runner AI, which is a three-party task assignment problem including workers (i.e., runners), tasks (i.e., patients), and defibrillators. Besides, they explore the combination between reinforcement learning and genetic evolutionary. While the supervisor (i.e., the author) has broad knowledge in spatial crowdsourcing, the supervisor admits that the knowledge about these techniques is limited. The supervisor often asks students to share their knowledge and expertise, or to help the supervisor when getting stuck. They build relationships that enable them to learn from each other.

4 Data for Piloting

In the 2022 fall semester, the author conducted student evaluations in the DAT5-03 supervision. Six students returned the questionnaire, where the questions are shown below, and Q denotes Question.

Q1. Do you prefer a research-related proposal or a course-related proposal?

Q2. How much benefit by a research-related proposal?

Q3. What do you think of a research-related proposal?

Q4. Do you think it is helpful if the project is related to the research field of your supervisor?

Q5. Do you think a research-related project is helpful for finding a job in industry?

Q6. Do you think a research-related project is helpful for pursuing higher education?

Q7. Do you feel stressful when conducting a research-related project?

Q8. Do you think it enhances your awareness of research by a research-related project?

Q9. Do you think it enhances your interest of research by a research-related project?

Q10. Which way do you think is the best to present and broadcast the project results?

Q11. Do you think it is helpful for knowledge sharing among group member by a research-related project?

Q12. Do you feel better if the teachers (supervisors) can give you feedback on time?

Q13. Do you feel better if the teachers (supervisors) share related publications to you?

Q14. Which way do you prefer to find a suitable solution to your problem in the project?

Q15. Do you believe your project/report can help the supervisors to improve or inspire their research?

5 Analysis and Initial Results

Based on the questionnaire results, the following analysis can be summarized:

1. **Evaluation for research-focused project through research proposal design (Q1-Q3).** Most students (66.67%) prefer a research-based proposal. 50% of the students think they can benefit a lot from a research-based proposal, which is a good way for learning knowledge.

2. **Evaluation for enhancing students learning engagement through research (Q4-Q10).** All students believe it is helpful if the project is related to the research field of the supervisor, and 83.33% believe that a research-based project can help them for pursuing higher education. As expected, only 33.33% of the students think a research-related project is useful

for finding a job in industry. Most students (83.33%) feel stress-free to conduct a research-based project, which means that it is easy for them to deal with it. Half of the students think a research-based project enhances their awareness of research, and 83.33% claim that such a project enhances their research interest, which demonstrates the superiority of a research-based project. In terms of the way to present and broadcast project results, 66.67% of the students tend to use a project report and share their codes by Github. It shows that they promote the dissemination of research results actively.

3. **Evaluation for co-creation of mutual learning with the project supervisor (Q11-Q15).** A majority (66.67%) of the students believe it is helpful for knowledge sharing among group members by a research-based project. All students feel better if supervisors give feedback on time, which means that the feedbacks from supervisors are helpful and valuable. 83.33% of them hope that supervisors could share related publications to them, from which they can explore the solution by themselves. 66.67% of the students believe that their project/report can improve or inspire the research of supervisors.

6 Reflection and Future Work

In AAU, the pedagogical learning goal is to develop teaching skills to engage students in teaching process [11]. In this work, a new problem aiming to integrate research and teaching for improving the enthusiasm of senior students on learning is proposed. To solve it, a theoretical analysis and an empirical study are given. The results show that the proposed methodology can integrate research and teaching, thus enhancing the enthusiasm and interest of senior students on learning to maximize the teaching and supervising effect [12, 15]. The paper reports the initial results of the piloting approach using research-focused PBL to support student learning engagement. The approach shall be further revised, and more data are needed in the future including both qualitative and quantitative sources to provide a comprehensive understanding of students learning. Based on the preliminary results, it can be suggested that future design of such an approach shall focus on some research-driven practical applications that benefit students for finding a job in industry and enhance their awareness of research more effectively.

References

[1] Angela Brew. Teaching and research: new relationships and their implications for inquiry-based teaching and learning in higher education. *Higher education research & development*, 22(1):3–18, 2003.

[2] Angela Brew. Imperatives and challenges in integrating teaching and research. *Higher education research & development*, 29(2):139–150, 2010.

[3] Juebei Chen, Anette Kolmos, and Xiangyun Du. Forms of implementation and challenges of pbl in engineering education: a review of literature. *European Journal of Engineering Education*, 46(1):90–115, 2021.

[4] Carol L Colbeck. Merging in a seamless blend: How faculty integrate teaching and research. *The journal of higher education*, 69(6):647–671, 1998.

[5] Boyer Commission. Re-inventing undergraduate education: a blueprint for america's research universities. In *Stony brook, NY: carnegie foundation for university teaching*, 1988.

[6] Xiangyun Du, Usama Ebead, Saed Sabah, Jianping Ma, and Khalid Kamal Naji. Engineering students' approaches to learning and views on collaboration: How do both evolve in a pbl environment and what are their contributing and constraining factors? *EURASIA Journal of Mathematics, Science and Technology Education*, 15(11):5–15, 2019.

[7] Xiangyun Du, Khalid Kamal Naji, Saed Sabah, and Usama Ebead. Engineering students group-based strategy use, forms of collaboration and perceptions of assessment in team projects–a case study in qatar. *International Journal of Engineering Education*, 36(1):296–308, 2020.

[8] Peter Earley and Vivienne Porritt. Evaluating the impact of professional development: The need for a student-focused approach. *Professional development in education*, 40(1):112–129, 2014.

[9] John Hattie and Herbert W Marsh. The relationship between research and teaching: A meta-analysis. *Review of educational research*, 66(4):507–542, 1996.

[10] Mick Healey and Alan Jenkins. *Developing undergraduate research and inquiry*. Higher education academy york, 2009.

[11] Anette Kolmos. Pbl curriculum strategies: From course based pbl to a systemic pbl approach. In *PBL in engineering education*, pages 1–12. 2017.

[12] Anette Kolmos, Flemming K Fink, and Lone Krogh. The aalborg model-problem-based and project-organized learning. *The Aalborg PBL model-Progress, Diversity and Challenges*, pages 9–18, 2004.

[13] Khalid Kamal Naji, Usama Ebead, Abdulla Khalid Al-Ali, and Xiangyun Du. Comparing models of problem and project-based learning (pbl) courses and student engagement in civil engineering in qatar. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(8):1–16, 2020.

[14] Eric Pawson, Eric Fournier, Martin Haigh, Osvaldo Muniz, Julie Trafford, and Susan Vajoczki. Problem-based learning in geography: Towards a critical assessment of its purposes, benefits and risks. *Journal of geography in higher education*, 30(1):103–116, 2006.

[15] John R Savery. Overview of problem-based learning: Definitions and distinctions. *European Journal of Engineering Education*, 9(2):5–15, 2015.

[16] Julie E Sprinkle. Student perceptions of effectiveness: An examination of the influence of student biases. *College student journal*, 42(2):276–294, 2008.

[17] Ann Stes, David Gijbels, and Peter Van Petegem. Student-focused approaches to teaching in relation to context and teacher characteristics. *Higher education*, 55(3):255–267, 2008.