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Editorial

Twenty-first Issue of the Journal of Problem Based Learning in Higher Education

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Bettina Dahl Søndergaard | Aalborg University, Denmark
John Vergel | Universidad del Rosario, Colombia

Welcome to the first issue of the thirteenth volume of the Journal of Problem Based Learning in Higher Education (JPBLHE). This is our annual issue and contains eleven research papers, three case studies, and one *Invited Author* paper, making the issue one of the largest to this date. We have witnessed a growth in submissions this past year, and that is also showing in the actual number of publications. We are grateful for this tendency and are working hard at raising awareness of the journal and increasing its impact in the global research field of problem-based learning in higher education.

This year we publish this one issue, the annual issue. It is, as stated, considerably larger than previous years. We interpret this noticeable growth in submissions to our journal mostly as a sign that PBL in higher education is becoming more widespread. This is also reflected in the spread of countries from which the authors come (listed alphabetically): Australia, Brazil, Denmark, Hungary, Indonesia, Malaysia, Nigeria, South Africa, Sweden, the United Kingdom, and the United States of America. It truly reflects an international journal. In addition, we suspect that since JPBLHE is a "Diamond Open Access" journal, which means that publishing is free for both authors and readers, this makes the opportunity for publishing with us attractive to more authors, since publication is not dependent on the authors' financial support and funds. Publishing thus remains open to authors who find the very high Article Processing Charges (APC's) of other journals too expensive, they have a

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research grant where open access publishing is mandatory, or out of principle they want to publish open access. We are most glad to be able to keep this opportunity open and provide our publication channel for free. The reason why we can publish Diamond Open Access is that JPBLHE is part of the AAU Open Journals of Aalborg University. The journal's content is archived at the AAU Library server. Many thanks to AAU for providing, and funding, this platform for JPBLHE and many other journals (list: https://journals.aau.dk/).

In line with our wish to be an open and international journal, we initiated a Spanish Section for our annual issue to publish papers and cases in Spanish and with abstracts in both English and Spanish. Among other reasons, a plurality of languages in the same journal gives insight into areas of research and researchers that may not otherwise know of each other. The editor of our Spanish Section is Professor John Vergel from Universidad del Rosario in Bogota, Colombia. We are off to a good start since we already have papers in Spanish submitted and currently under review. We look very much forward to also see this initiative grow into a sustainable and constructive section in the journal. We encourage our readers to spread the news of the Spanish Section to their colleagues in the Spanish speaking world.

Our invited author this year is Professor Julie Borup Jensen, Aalborg University. Last year (Vol 12, Issue 1) we published the first paper in our new series *Invited Author*. This series of papers is meant to give prominent researchers in the field of PBL a chance to write something from the heart. Professor Julie Borup Jensen is, as stated, the second Invited Author, with Professor John Mitchell, University College London as the first. Professor Jensen does research within capacity building in the areas of organizational and professional learning, creativity and aesthetic knowing in social processes, organizational aesthetics, and practice in subject matter. Her paper addresses the issue of 'finding the problem', when students work with PBL projects. She draws on a theoretical landscape of John Dewey and experimental learning, exploring a concept of critical creativity through two empirical cases. It is an exciting paper, which we hope will gain the attention it deserves.

Finally, we would like to thank all the reviewers who have donated their time and wisdom to help to improve the papers and case studies in this issue:

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Creativity in Higher Education

Finding the Problem in Problem-Based Learning

Julie Borup Jensen * | Aalborg University, Denmark

Abstract

This article explores *problem finding* as a lens to highlight creativity in problem-based learning (PBL) in higher education. By discussing two empirical examples from two social science and humanities educational programs at Aalborg University, Denmark, a Deweyan, experiential learning approach is put into play with socio-cultural and socio-material learning perspectives to explore how materials may support students' critical-creative problem inquiry.

The empirical analyses point to new insights for creativity in PBL as requiring students to build a certain basis of critical judgment to *find problems*, that is, competences to explore and question social and societal conventions, norms, and taken-for-granted worldviews, including those independent of the predefined objectives of their educational quests. The article points to the potentials of integrating materials and metaphors in PBL-project and group work to explore PBL and critical creativity as interconnected and, in some respects, mutual prerequisites for PBL in higher education.

Keywords: Problem-based learning; problem finding; creativity; critical thinking; imagination; materiality in education

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Introduction: from reproduction to production of knowledge

Since the 1960s, problem-based learning (PBL) has been widely acknowledged as a student-centered pedagogical approach in higher education that supports active learning, critical thinking, and the application of disciplinary knowledge in authentic contexts (Hmelo-Silver, 2004; Savery, 2006). PBL was a paradigmatic shift from teaching methods focused on the reproduction of existing knowledge through memorization and tests, toward forms of learning that emphasize active engagement, inquiry, and problem solving. In other words, the production of knowledge through learning (Savery, 2006). In its original form, PBL challenged the norm of students sitting in the classroom as passive recipients of disciplinary or theoretical content (Thomassen & Stentoft, 2020). Instead, students were encouraged to engage in authentic, open-ended exploration, simultaneously developing a personal and contextual relationship to knowledge. A task such as "How can we reduce plastic waste at our university?" situates disciplinary understanding within a well-known context for the students, while prompting them to explore theories and concepts through engagement with a real-world phenomenon.

This engagement is not solely disciplinary or conceptual, but also experiential. It requires students to explore and specify what constitutes *a problem* in the first place, and how disciplinary, theoretical perspectives shape what can be seen and acted upon. Engineering students, for example, may define plastic waste as a technical challenge focusing on materials and systems, while students from sociology, psychology, or philosophy may frame it as a question of cultural practice, organizational structure, or behavior change (Kolmos, 2017; Telléus, 2019). The PBL process thus becomes a question of both disciplinary and personal *judgment* for the students. Moreover, it is unpredictable, and it is creative, as we shall see in the following.

However, in the current educational culture of competition, performance, and time pressure, students are increasingly socialized into understanding learning as a competency to adapt to pre-formulated learning goals and curricular logics of fulfillment and mastery of canonic content (Jensen et al., 2022). The learning process is expected to be smooth, swift, and provide a clear basis for comparison with other students (Mackenzie & Olsson, 2023; Papageorgiou & Kokshagina, 2022). This educational culture places pressure on PBL to adapt to a goal oriented pedagogical approach that may obstruct some of its explorative foundations.

Problem finding: an overlooked and creative learning resource?

Creative production of new knowledge is emphasized as central value when working with PBL in a higher education context (e.g. Hansen & Bertel, 2024; Jensen, 2019). However, PBL is mainly framed as a means of fostering students' abilities to *solve* complex, real-world problems through collaborative project group work involving inquiry and (theoretical) reflection (Engen et el., 2018; Telléus, 2019). The extensive body of research documenting the pedagogical benefits of PBL tends to overlook, to some degree, the process of problem *finding* (exceptions are, e.g., Jensen & Lund, 2016; Thomassen & Stentoft, 2019; Wakefield, 2003). According to Jensen and Lund (2016), this may be a consequence of the adaptive educational thinking mentioned in the introduction, because problem finding concerns how students explore, conceptualize, frame, define, and redefine the problems that are the centerpiece of the whole collaborative problem-solving process. The ability to identify and construct meaningful problems and solve them is, however, not necessarily a smooth process, but rather one that forms the basis for learning that builds the judgment and competences necessary to think critically (Beghetto & Kaufmann, 2014; Jensen & Lund, 2016; Thorndahl & Stentoft, 2020). The capacity to identify and formulate problems also reflects students' level of disciplinary understanding and the transformative potential of working with disciplinary knowledge to process the problem identified (Scholkmann et al., 2023). If students' problem-finding process is cultivated, they are supported in producing new knowledge rather than reproducing already existing knowledge, in other words in *being creative* through PBL (Beghetto & Karwowski, 2019; Runco, 2019; Sternberg, 2018).

Research question

If it is in the problem-finding process that students engage in critical reflection within and between disciplines, it is a vital educational task to support creativity in PBL. This requires us to embrace the ambiguity and emergence that are some of the consequences of open, student-led inquiry processes. PBL's ambition of teaching students to apply disciplinary content and concepts to solve problems should therefore be accompanied by teaching them how to find, identify, and formulate disciplinary and societal problems worth both exploring, examining, and solving. Based on this, this article therefore addresses the following question:

> *How might creativity be a fruitful lens through which the processes of problem finding and problem solving may be framed in teaching in HE?*

To answer this question, I start with two empirical examples from my teaching practice at two different educational programs within the Faculty of Social Sciences and Humanities at Aalborg University. The examples are put into play with an experiential learning perspective as a foundational basis for my understanding of PBL involving creativity (e.g., Dewey, 1980, 1988), supplemented by theoretical concepts from socio-material pedagogy (e.g., Fawns, 2020) and socio-cultural learning theory (e.g., Bruner, 1996).

Theoretical framework: experiencing through problem finding and problem solving

Many of the approaches to PBL discussed above were developed within the field of psychology or sociology of learning rather than within pedagogy. They have provided valuable insights into how learning is linked to individual and social thinking processes and to teaching. In the following, however, I suggest a deeper exploration of pragmatistic takes on creativity. Although pragmatist thinkers, first and foremost John Dewey, have been the basis for much of the original development of PBL as a pedagogical approach, creativity as related to PBL has not gained as much attention as learning. As Petersen (2024) argues, "in contemporary discourse, PBL is predominantly tied to what Dewey argued against, namely extraneous aims" (p. 1). I am inspired by Petersen's critique of contemporary PBL research as taking Dewey's ideas into account for a rather instrumentalist, problem-solving take on PBL as my basis for taking up his ideas today. In this article, I concentrate on Dewey's ideas about finding problems through critical inquiry before solving them as a way to re-think the creative powers of PBL in contemporary higher education and work toward what Petersen attributes to Dewey as thinking education as a value in itself: "PBL as a form of education 'worthwhile in its own immediate having' (p. 109)" (Petersen, 2024, p. 1, citing Dewey's *Democracy and Education*).

Dewey and creativity

John Dewey was one of the first philosophers of learning to talk about creativity in the same breath as learning processes (Dewey, 1979, 1980, 1988). In his 1930 Milton Judson Davies Memorial Lecture, *Construction and Criticism*, at the Institute of Arts and Sciences, Columbia University, Dewey (1930/1988) presented creativity as being closely - in fact, inseparably, linked to learning and learning processes in education. He did not view creativity as the result of learning processes, but rather as an integral part of the experiential learning processes of both children and adults. He saw creativity in light of his fundamental idea that learning processes are closely connected to the identification and solving of both practical and conceptual *problems* (Jensen, 2015, pp. 150–151).

According to Dewey, a problem arises when the student experiences a discrepancy between what she has previously understood, encountered, and been familiar with, and what she experiences in the current situation (Dewey, 1979). This situation poses a problem that encourages her to find out what this discrepancy is about – in other words, to understand the nature of the problem. This process relates to the student's efforts to explore and to discern components of the problem, and this exploration of the problem (problem finding) forms the basis for arriving at a meaningful problem formulation, which in turn is a prerequisite for ultimately changing and learning. In this explorative process, creativity plays a crucial role in how the student creates new understandings of something previously familiar or experiences something entirely new and forms a new insight, a "problem solution" (Dewey, 1979).

Creativity, problem finding, and PBL

What is particularly interesting in relating Dewey's concept of creativity to PBL in higher education is that he did not view problem exploration solely as a mental process, but as a concrete investigation of the surrounding world through the body, senses, and experimental actions in interaction with the physical, material, social, organizational, and educational environment (Dewey, 1988; Dewey & Bentley, 1991). Creativity thus serves as much more than a motor to thinking; it is a vital way to activate students' experiential processes, both by relating to previous experience and learning, and by being involved in finding the problem around which the PBL process evolves. This is in line with several educational researchers within the field of PBL, who focus on the explorative, creative, and critical aspects of PBL in higher education (Jensen & Lund, 2016; Thorndal & Stentoft, 2020). How creativity creates a bridge between theory and practice may also be one way to look at creativity in a problem-based approach to education. Creativity in Dewey's understanding entails a way of teaching and learning that involves *the practical* in the form of some kind of empirical material, along with *the conceptual* in the form of theory and/or philosophy (Scholkmann et al., 2023).

Dewey, criticism, and constructivism

One might, however, still ask whether the most fundamental parts of Dewey's understanding of creativity are encompassed by the concept of PBL in a modern Western university setting—namely, *critical inquiry* (Dewey, 1988). I raise this question because Dewey's normative and ultimate errand in emphasizing creativity in learning processes is the very reflexivity, independent judgment, and discernment that students may develop in creative processes. As mentioned, when creativity becomes a vital component of student learning processes, their capacities for *critical exploration and thinking* are brought into play and nourished, in interaction with *constructive imagination*, where creativity plays a role in imagining a better way to act or understand the world. However, critical thinking and constructive imagination may be "dangerous" in an educational approach where students are expected to comply with more or less predefined competence goals and perform in accordance with absolutist grading systems. These dangers relate to the fact that creativity has two dimensions – the problem finding and the problem-solving processes. Both may challenge different states of status quo:

1. Problem finding and critical thinking. The development of students' independent judgment depends on whether the educational environment offers students opportunities to think critically. Critical thinking is not just about "wondering"—it is about acquiring competences to question what is culturally given and taken for granted, such as power structures, conventions, and norms, both in society and in university disciplines (Dewey, 1979, 1988). These critical aspects are deeply involved in the explorative process that leads to "finding" the problem to be solved in a PBL process.

2. Problem solving and constructive imagination. If critical thinking is made possible, students' independent judgment forms the basis for them to constructively imagine new actions and new ways of perceiving the world as solutions to the problem found in the first place. Constructive imagination is also in play when students solve problems by creating new possibilities for acting, negotiating, and thinking democratically in community with others and the environment (Dewey, 1988). Like problem finding, this process may be critical toward cultural conventions and norms, because a solution might pose a challenge to existing logics, both in society and in university disciplines.

Applying disciplinary content into critical inquiry to find the problem to solve may be the first role of creativity, and then applying disciplinary content to imagine new practices and worldviews to solve the problem found may be the second (cf. Tanggaard, 2019). In short, critical-creative exploration and constructive imagination are vital steps in this problem-finding/solving process in PBL in higher education. In Dewey's sense, putting this understanding of creativity in learning into play in the problem-finding/solving process makes the process inherently explorative (Dewey, 1979). In these explorative PBL processes, students' experience is brought into play in new ways and connected to the theories and disciplines they study (Jensen et al., 2022).

Context, method, and empirical background

To an increasing degree, I have integrated the considerations outlined above into my own teaching since my employment as a PhD student at Aalborg University in 2009. I teach in both the ordinary masters' programs and continuing education for professionals as well as at the PhD level. My specialized disciplinary content is also connected to creative approaches to learning, problem solving, leadership of innovative change processes, and competences to create transformation within organizations. This article's two empirical examples derive from my teaching in the continuing master's program *Innovation and Creative Learning Design* (60 ECTS) and the full master's program *Learning and Innovative Change* (120 ECTS).

Context: Aalborg University

It should be mentioned that PBL is the pedagogical model used at Aalborg University for all educational programs. At Aalborg University, this involves two distinct and fundamental pedagogical principles, namely that (a) students produce disciplinary and interdisciplinary problem-based projects as the core of a module (Engen et al., 2018; Telléus, 2019), and (b) the project work is predominantly carried out in collaborative groups of 2–6 students, often collaborating with local businesses, institutions, and organizations in the region of Northern Denmark (Zhou & Krogh, 2019). Within these two fundamental principles lies a pedagogical PBL approach in which students formulate a problem to explore within their disciplinary field, both through the empirical reality that constitutes the problem and their conceptual understanding of same. These fundamental principles are a prerequisite for understanding the two empirical examples below, where I focus on problem-based *project work* in the first example and *collaborative group processes* in the second. Before presenting the two examples, I briefly outline how I have generated empirical material from my own teaching practice and how I have composed the examples by combining empirical material and theory.

Methodology: my teaching portfolio

My teaching portfolio forms the raw material for researching my teaching practice. It consists of a professional learning diary that includes content such as descriptions, PowerPoint slides, student exercises and assignments, photos and videos from teaching situations, and a logbook with reflections. Methodologically, diary- and log-keeping is a widely acknowledged tool for professional development. Log-keeping both describes and documents activities carried out and methods developed, keeping track of my own professional development and learning (Dysthe & Engelsen, 2011; Youniss, 2011). The log itself, however, is not sufficient for theory development. Aiming to theorize my experience toward broader insights, I have developed a methodology of rigorous selection of empirical documentation and theoretical reflection on empirical practice. This method is inspired by Donald Schön's (1995) reflective practitioner and leans on his categories of knowing-in-action, reflection-in-action, and reflection on action (pp. 22–31). To emphasize the knowledge-generating aspect of using my own descriptions and reflections as empirical material, I draw on Edwards's (2017, p. 8) further development of the reflective practitioner-approach, the concept of *reflection-beyond-action*, which underscores the wider potential of reflection and reflexivity for knowledge production. The concept acknowledges the theorizing potential beyond the concrete, empirical situation by formulating condensed learning examples that can be recognized in other, similar contexts and future situations as conceptual development. and potential theory development.

Thereby, my logs function as any other qualitative empirical material such as interviews, field notes, or observations. To process the empirical material, I have developed a simple analysis tool or matrix that includes Schön's three levels of reflection (Columns 1 and 2) and Edwards's addition (Column 3) to process empirical material (Schön, 1995; also previously described in Jensen, 2016, 2019):

Knowing-in-action and reflection-in-action: Description	Reflection on action: retrospective reflection	Reflection beyond action: Practice development and theorizing

Figure 1. Analytical tool for research in own practice.
Source: Schön (1897), Edwards (2017), and Jensen (2016, 2019).

The column to the left contains "raw data" – that is, my own unedited classroom observations, descriptions, and photos, among others (knowledge-in-action), along with my immediate thoughts in the situation (reflection-in-action). The column in the middle is for (a) interpreting data, (b) condensing meaning, and/or (c) developing themes and categories (reflection on action). The column to the right relates to the two first columns by suggesting theoretical perspectives and concepts that would shed new light on the empirical material and the processing of it beyond the concrete context (reflection-beyond-action).

Empirical material

By means of this analytical tool, my situated observations, descriptions, and photos (among other data) are brought into play with a broader theoretical framework, in this case, a creative-pragmatic learning perspective, as outlined above. In this interplay between raw empirical material and theoretical concepts, my own material on teaching activities, my impression of the students' responses to the activities, and the material and conceptual outcomes of the teaching activities lead to the development of the narrative case examples presented below. The practical and theoretical insights created thereby can contribute to developing knowledge in a broader pedagogical sense, corresponding with Schön's (1995) and Edwards's (2017) understanding of the development of knowledge from practice.

To a wide extent, the use of my own pedagogical considerations, actions, and descriptions as empirical material aligns with an autoethnographic approach (Adams et al., 2015; Rowe, 2017). By emphasizing the context, atmospheres, and actions, the descriptions aim to communicate beyond the concrete context (cf. Edwards, 2017) and create imaginative resonance for other educators working with PBL (Adams et al., 2015). Because students are directly and indirectly described, and their creative learning products are depicted in the article, ethical considerations have been crucial. The descriptions are therefore not only anonymized according to the ethical principles and code of conduct within research developed by the British Educational Research Association (BERA, 2024), but also written with the deepest respect possible toward the students' agency, creativity, and trust in the process (cf. post-qualitative research, e.g. Ahmed, 2006). I have obtained their consent to communicate my observations from the classrooms, and I present my photos of the students' productions resulting from the creative problem-finding and problem-solving processes with their permission.

In the following, I present two examples of how I have used materiality to provoke critical thinking and creative imagination in students. The first example describes how a problem-finding process in relation to project work is initiated with the creation of a project avatar, and the second describes how problem finding may be dealt with in group processes in project work through collaborative reflection with LEGO bricks.

Project work with avatars: problem finding in project work

Below, I describe how I work with a material and metaphorical approach to initiating project work (with reference to my teaching portfolio).

Figure 2. Project avatars made from recycled material and trash.
(April 18, 2024, author's photo, with permission)

The photo (Figure 2) derives from a teaching session (April 2024) in the continuing master's program Innovation and Creative Learning Design; this session occurs at the very beginning of the students' work on their final master's thesis. Their theses are reports on a problem-based project completed in collaboration with a real-world organization. In the last 2 years, I have introduced the *project avatar*, a metaphor aimed at engaging the students creatively in exploring their initial problem formulations. According to the Merriam-Webster dictionary, the word *avatar* has a fourfold meaning: First, in *Sanskrit*, an avatar denotes a divine being or force that descends to earth and takes on a bodily form through which the divine power may be executed to accomplish a mission – in other words, the earthly body in flesh and bone is bestowed with divine powers. Second, in a virtual reality context, an avatar refers to a *virtual* body and the powers that this virtual body possesses, for instance, when a human player takes on the body of a superhero in a computer game, which is almost the reverse function as its original, Sanskrit meaning. Third, an avatar can also be an idea, a concept, or ideology that is embodied in human form, and finally, fourth, it can refer to a variant phase or version of a continuing basic entity (e.g. "the late avatar of educational policy"; Merriam-Webster, 2025). What unites these metaphorical, associative meanings, however, is the avatar as possessing transformative (super)powers.

The avatar metaphor with its association with both *flesh and blood* and *superpowers* inspired me to invite the students to reflect critically on how they used disciplinary knowledge from the field of learning as a superpower to inquire, find, and formulate a problem for their project in the earthly sphere (empirical field) as well as their assumptions about the problem and its solution (theoretical field). I told them that the avatar should embody all their ambitions for the project: the positive change their project should generate in the organizations they worked with, the superpowers (in the form of creative learning design theories) the avatar would use, and what super-tools creativity would provide for the avatar to imagine new solutions, among other aspects. Finally, the avatar should be a physical "being."

The students started out by exploring two tables with "trash" materials such as used textiles and shoes, empty packaging material, plastic lids, old CDs, shells, and other materials from nature. I asked the students to choose materials that appealed to them and would help them to embody their initial project idea in the shape of an avatar, and that would "bestow" on the avatar all their conceptual and methodological ideas for their project (superpowers). I therefore asked them to have the problem they wanted to work with in mind so that the "superpowers" would be directed toward exploring, formulating, and clarifying the problem. Finally, their avatars should reflect what the students ultimately wished to accomplish in real life organizations with their superpowers.

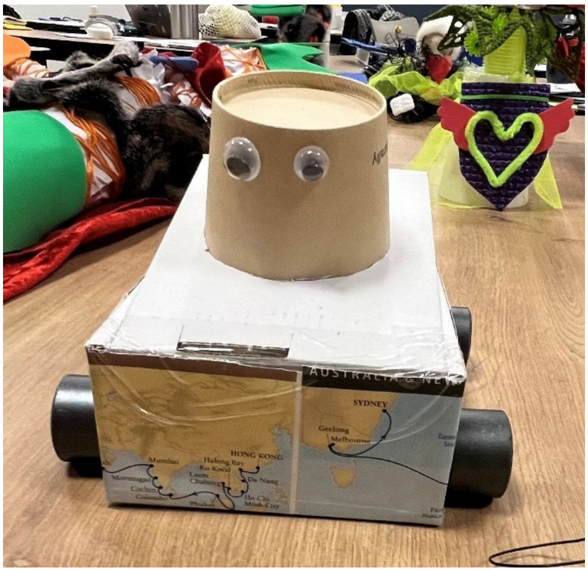

Figure 3. One student's avatar with conceptual superpowers.
(April 18, 2024, author's photo, with permission)

An example of an avatar and its superpowers is shown in Figure 3. This student worked as vocational education and training (VET) teacher. His project was about researching and developing a new way of teaching vulnerable students in his VET-school. The avatar's mission was to create an inclusive learning environment, and its superpowers were flexibility (the wheels), knowing the landscape of the organizational context for teaching (the map), the VET students' learning processes and trajectories of learning (the map), awareness of the dynamics in the classroom (the eyes), and having an overview of how to act in situations while teaching (the elevated position of the eyes). The student thus reflected on the complexity of inclusive learning environments and how his learning theories might help him find and formulate the problem that would be used to guide his project work.

Metaphors and materials

In the reflective evaluation in plenum after the session, the students emphasized their experience of immersing themselves in a process of creativity-based inquiry. The metaphorical and material creative process of devising "beings" with transformative superpowers "forced" the students to ask basic questions of their preliminary problem formulations and their projects' ambitions, but also to ask if their avatars' conceptual superpowers were in fact directed toward the most relevant problem within the context of their projects. They acknowledged that they were "disturbed" in terms of their expectations of a "normal" thesis introduction (Jensen et al., 2022). The avatar metaphor not only pushed them toward reflecting on the problem within their project, but the superpower metaphor also led them to reflect on how much knowledge about learning and change processes that they had built up throughout their education. By being further disturbed with materials, they started to think about their disciplinary concepts as embodied superpowers that they would be able to use in empirical problem-finding situations, so they would be more equipped to look beyond conventions and taken-for-granted worldviews in practice (Dewey, 1988). Thus, they were given an opportunity to use their creative imagination to determine how they could apply conceptual superpowers when exploring their field of inquiry (finding the problem) – in this case, learning in an organization. Summing up, the material process created two spaces for learning for the students: (a) they had the opportunity to think in greater depth about how their understanding of learning (disciplinary content) was connected to the problem they planned investigating in their projects, and (b) how knowledge of learning could help them investigate, formulate, and solve the problem and create value in the organizations they worked with in their projects.

The students also expressed that the materials initiated new thoughts about their projects' problem fields, as well as the ideas and practices that were taken for granted in the empirical context. For instance, the student creating the avatar with the superpower of "wheels" said that the sensory feeling of the round metal studs in his hands made him realize that his problem field of *inclusive learning environments* was complex, because his student group acted in unpredictable ways. The "wheels" made him acknowledge that it would be important for him to frame the *processual* aspects of organizational change in his problem formulation, not only the end goal of an implementation process (Runco, 2019; Tanggaard, 2019). Generally, the students said that the very encounter with the materials and the task of using them to express the avatar's superpowers made them imagine how their acquired conceptual knowledge ("superpowers") would function as tools for inquiry in their projects. As mentioned, this example with avatars addressed the problem-finding process related to the PBL project work at Aalborg University. The following example centers on the characteristic pedagogical approach of group work in the Aalborg University PBL model, in which students work together in collaborative projects.

Group work and problem finding

When students collaborate in groups as they carry out problem-based project work, a rather common challenge is establishing a collective understanding of the problem that guides the study that forms the core of the project in PBL at Aalborg University (Thomassen & Stentoft, 2020). The challenge often occurs when students have different interpretations of the theories or concepts in their field of study, as well as how to understand them in relation to a real-world problem. Challenges also arise when the students are unaware of the time it takes to explore these differences to ensure that the problem formulation is well researched (Jensen & Lund, 2016). The example below shows how creativity may be integrated into the problem-finding process, again by means of a material "disturbance"—here in the form of LEGO bricks.

The example originates from a teaching session that I facilitated within the master's program Learning and Innovative Change (September 10, 2019). The session was inspired by LEGO Serious Play (see Hansen et al., 2009), described in detail below. Using LEGO bricks is my way to direct students' attention to the collaborative aspects of problem finding in the problem-based project work. The LEGO materiality relates the students' content understanding to problem inquiry, because the LEGO bricks function as tactile tools for thinking and support the student in articulating and reflecting on the words, phrases, and actions that they associate with the concepts of the discipline, going into deeper layers of their present conceptual assumptions. This conceptual clarification process is especially important to allow PBL to play out in project group work, because it is precisely the lack of a common understanding of the concepts used in the project's problem-finding phase and formulation of the problem that can be an obstacle for the collaborative dynamics that ideally drive the process (Alt & Raichel, 2022). To clarify how the materiality of the LEGO bricks may enable this deeper, collective understanding, I briefly describe the steps as they played out in a concrete process with seven project groups, with three to five members in each (I asked the students to move the tables from rows to group tables, onto which I put boxes with the LEGO bricks).

Individual problem finding

Figure 4. An individual student's understanding of the concept of "Learning".
(September 10, 2019, author's photo, with permission)

The process started with each student building an individual LEGO figure intended to express their present understanding of the concept of learning (which was the disciplinary content of the lesson). In 1-minute turns (which I carefully monitored), they presented their figures to the group with an explanation of the meaning of its different characteristics. These presentation rounds were made in the groups. The photo (Figure 4) is an example of one student's individual interpretation of the concept of learning, as reflected and visualized through the elements of the figure (e.g., key, helmet, the abyss, watering pot). The student's narrative explaining the figure contained metaphorical words and expressions like "key to understanding," "throwing yourself into the abyss," and "watering and nourishing a plant," which showed the student's individual and immediate understanding of the concept of "learning" from reading the course literature. The figure was also a starting point for a small narrative from the student's own previous experience of learning, where she had experienced that learning is both a painful (helmet) and rewarding (watering pot) process. I had asked the other group members to remain silent while each student presented their figure to the group, not commenting or asking questions, which allowed the presenting student to use the full extension of time to present their thoughts. After each presentation, the other students in the group had the opportunity to ask questions or comment in a 2-minute round.

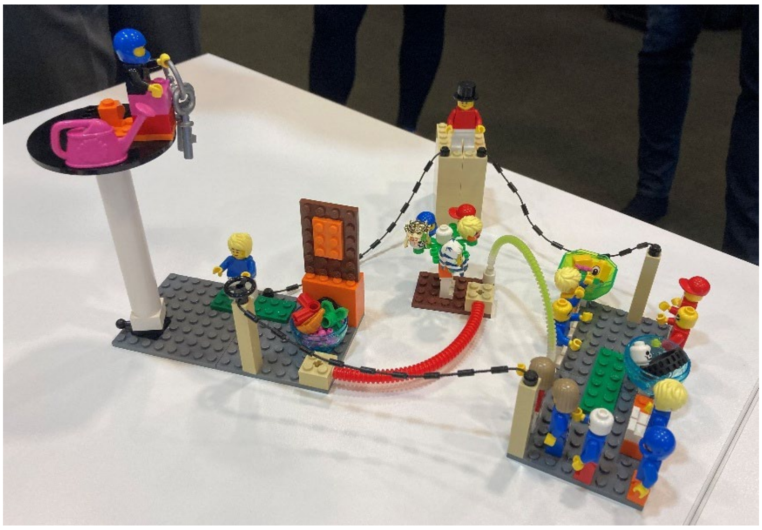

Figure 5, The individual figures built together.
(September 10, 2019, author's photo, with permission)

Collective problem finding

In the next task, the students had to combine their individual figures into a collective figure that could show how the students' perceptions and interpretations of "learning" overlapped and coincided and how they differed (Figure 5). Because the groups had already started to work on their PBL projects, this exercise gave the students an overview of the complexity of their collective project and the eventual collaborative challenges that derived from their different – and, to some extent, unacknowledged – taken-for-granted understandings of the concept of "learning" and the implications of these understandings for understanding, exploring, finding, and formulating the shared problem guiding their projects (cf. Alt & Raichel, 2022; Jensen & Lund, 2016).

In the students' reflective evaluation of the LEGO process (as covered in my teaching portfolio), their reactions to the first part of the process (where they had to listen for one minute to a co-student's presentation of their figure) was that it was difficult to stay silent and just listen to each other's narratives. They further reflected on the fact that they would normally strive to get to a quick consensus on how to understand concepts, how to establish the problem in which they would inquire, and how to formulate the problem that would lead them to proceed in the group work. However now, in being prevented from this "result-oriented" approach, they were able to see each other's figures and hear each other's narratives with more patience. They experienced this as being rewarding in the sense that they widened both their understanding of the concept of learning and their understanding of their co-students' thoughts and ideas concerning how the concept of learning would guide their problem inquiry and the problem-finding process (see also Clapp & Hanchett-Hansen, 2019). By seeing each other's figures and listening to each other's narratives – and afterwards building the individual figures together – they understood how their collective assumptions of the problem and the concept of learning would enable them as a group to pose more critical questions to the problem field. This understanding made them more inclined to acknowledge the differences and respect each other's taken-for-granted perceptions and conceptualizations of learning.

Discussion: metaphors and materials in creative problem-finding processes

If I put the above processes with materials and metaphors in play with Dewey's (1980, 1988) thoughts on critical inquiry and problem finding as well as creative imagination, we see that both the production of avatars and the building of LEGO figures function as an articulation of the students' own experiences with learning combined with disciplinary knowledge that has been introduced in the educational activities as well as in the curricular literature. With Dewey (1979), I also regard the avatar and LEGO production tasks as examples of how knowledge creation and learning are intertwined with processes of creative inquiry. This means that students are supported in asking – and, indeed, allowed to ask – critical questions about conventions and taken-for-granted worldviews, including within the very disciplines that they study, in this case, learning. The examples illustrate how critical inquiry and problem finding are both a precondition for learning to occur and something that is created within the process of learning itself as *emerging knowledge*. Both are expressions of how students build judgment and develop critical creativity (Dewey, 1980, 1988).

In the next section, I widen the Deweyan understanding of experience by focusing specifically on the metaphorical-material perspectives that the empirical examples call for. These perspectives are both a socio-cultural and socio-material understanding of problem finding.

Socio-cultural problem finding and creativity

Socio-cultural learning theory is relevant when understanding the empirical examples as showing *cultural production* activities (Bruner, 1996). Both processes took a creative symbolic form when students created avatars and LEGO figures.

According to Bruner, working with materials occasions the students to *externalize* experience, knowledge, and understanding. Externalization refers to the process in which students make "inner" thoughts, world understandings, and ideas tangible in material form by "creating works" (like artwork). Bruner uses the term "oeuvre" with reference to Ignaze Meyerson (the French cultural psychologist) to emphasize that it is not enough to create a product; the oeuvre is an object to which the students have attributed meaning, almost as if it is "bestowed with a life of its own" (Bruner, 1996, p. 76). The concepts of the oeuvre and externalization thereby cast light on the processes of building mutual understanding in the student group in the *externalizing* LEGO process and of bestowing the avatars with the individual student's externalized understanding of their project, its problem formulation, and its conceptual superpowers. If understood as oeuvres, the avatars and LEGO figures facilitated a creative process through which the students could externalize, explore, and "own" their own and each other's perceptions of the same disciplinary words, phrases, concepts, and problem understandings. This supported the students in negotiating collective meaning by means of the avatar and LEGO oeuvres (Hansen et al., 2009) and, very importantly, the *narrative*, *symbolic*, and *metaphorical* language that creates, in socio-cultural understanding, *intersubjectivity* (Bruner, 1996).

These theoretical considerations emphasize how a Deweyan understanding of creativity may relate to a socio-cultural perspective (cf. Bruner, 1996), but also how critical inquiry and problem finding may be understood as a performative and emergent phenomenon, arising within a network of relations that are entangled across processes, relational movements, materials, and spaces. This calls for a socio-material perspective on the kind of problem finding and problem solving embedded in the empirical examples.

Socio-material problem finding and creativity

A socio-material perspective on the examples allows me to analyze the interrelations between human and social processes within a situated context in which materials and metaphors play a role for how the processes of critical inquiry emerge (Smith, 2016). In the examples above, the trash materials and LEGO bricks enable certain formations of experience. These experiences through materials become linked to participation, the creation of social communities, the development of conceptual insight, and the performance of experimental, investigative, critical inquiry into the students' problem fields. In a socio-material perspective, this is connected to the concept of entanglement.
Holmes (2024) describes *entanglement* as a tangle of connections between technology/materiality, methods, contexts, values, and purposes, and, in higher education, I would add disciplinary content as a relational node in the processes

of critical inquiry and problem finding. Applying the new materialist perspective on the examples above captures the interplay between the value-based dimensions of problem finding and problem solving and the learning processes through which insights, creativity, and new practices emerge. The socio-material perspective on creative PBL practices in the classroom allows me to illuminate and bridge the *affective* and *material* dimensions of knowledge creation and learning, while also incorporating *body*, *relationships*, and *materiality* as meaningful components of the collective and shared learning process (Fawns, 2022; Holmes, 2024).

From a socio-material point of view, learning as such is seen as shared knowledge production, generated through students' embodied practices and material engagements in, for example, aesthetic representations and visualizations, in this case, avatars and LEGO figures. The socio-material perspective points to the fact that the materials in the two examples are open to interpretation and therefore invite negotiation of meaning among the students. The materialities thus enable the students' explorations, processing, and application of content knowledge in critical inquiry and problem finding (Fawns, 2022). The students' critical inquiry and problem finding is thus *inscribed* in materialities such as avatars and LEGO figures. Through materiality, the acquired understanding of the problem can also be stabilized and used again in future critical inquiry – in other words, it can be *reified* (Jørgensen et al., 2023; Chemi & Jensen, 2026). This reified understanding of the problem may be awakened in new ways in changing socio-material contexts and occasion new learning processes, such as when students present their avatars and LEGO figures to other students (Sørensen, 2009). In a material, problem-based process of critical inquiry, the different forms of reified understanding are ultimately reified anew when students write their project report. Here, their problem-based inquiry is converted into the form of a problem formulation, an empirical study, or a report (among other forms), thus reflecting the creative process with its material, embodied, and affective aspects.

Creativity and critical socio-cultural and socio-material inquiry in PBL

We can sum up by looking at the two empirical examples within both the socio-cultural and socio-material perspectives, and in doing so, we can see that the students' existing ideas, their critical inquiries, and experiences with the discipline content of learning are all socially re-created in a new material context and new metaphorical narratives, mediated by the avatar creation and LEGO building processes (Fawns, 2022). The inquiry-oriented aspects of PBL are thus rethought and emphasized in novel ways that visualize the students' reflections, problem finding, and imaginative knowledge-creation processes

(Dewey, 1988). In doing so, problem finding and imaginative knowledge creation may thus become socially relatable as well as critical and creative.
In other words, the students' oeuvres may materialize a PBL process, which can be reactivated in new ways across changing socio-material contexts, for example, in the interplay between the classroom (together with peers and educators) on the one hand and their project organizations on the other (Fawns, 2022; Jørgensen et al., 2023). The conceptual understanding of the empirical examples points to the fact that the explorative and creative process of problem finding includes aspects that are more easily nuanced and expressed in multifaceted ways in material-metaphorical form, rather than through words or unambiguous language.

Concluding remarks and implications for practice

Looking at creativity in experiential, socio-cultural, and socio-material perspectives might be a fruitful lens through which the equally vital processes of problem finding and problem solving may be framed in teaching in higher education to pave the way for students' experience of being able to imagine and create change in their future lives. A focus on creativity makes it possible to bring forward potentials of critical inquiry and constructive imagination. A focus on creativity may enable pedagogical reflections on several of PBL's characteristic traits: problem formulation, problem processing, project work, and collaboration in group work, all of which are needed to build judgment and create change. The inclusion of creative activities as an opportunity for collective, inquiry-based reflection on discipline-related problem finding (critical inquiry) and problem solving (imagining new ways to apply disciplinary knowledge and concepts) might therefore benefit PBL project work in groups. As we saw in the examples, creativity in the form of metaphorical and material processes invites students to engage in these collective explorations that challenge conventions and habits (critique), play with reality by means of theory and concepts, and stimulate imagination as a creative effort to develop meaningful new understandings of disciplinary content, as well as new understandings of the world. However, this article also points to the need for educators in higher education to consider how to create opportunities for students to engage in material and metaphorical activities as an opportunity to ask critical questions about what we take for granted in the contexts we inhabit.

Future ambitions for PBL

Based on the above discussions of my empirical examples, I feel impelled to discuss PBL in a slightly wider perspective. As mentioned along the analytical parts and the discussion, the idea of drawing in materials and products in teaching PBL has the aim of paving the way for creativity in relation to problem finding and solving. However, as I understand it, creativity is not a way to merely fulfill the goals of the study program; to me, creativity has a much deeper, radical educational purpose, as touched upon in the introduction. In a world characterized by comprehensive and deep crises, creativity in PBL is more important than ever as an approach in higher education where students are subject to educational policies that encourage them to reproduce knowledge and adapt their thinking to absolutistic educational goals. These goals risk carrying with them a taken-for-granted white, Western, and paternalistic approach to the world that has proven harmful to our earth and its living creatures. I see a different path, where creativity – with its explorative, critical, and constructive ways of asking questions for these taken-for-granted beliefs and systems – could guide our educational ideas. This path potentially leads toward a creative educational environment that could be curious, critical, imaginative, and empowering for the students, while also encouraging them to be part of the changes needed in the future in our societies. To achieve this end, we should build educational policies, systems, and environments that encourage students to develop critical-creative judgment and enable them to create change in society. Based on my own research and experience in classrooms in higher education, this environment is developed by offering students a wide variety of possibilities to engage with disciplinary content. My research suggests that materiality and products in PBL processes support and embrace critical questions and playful processes involving metaphors, poetics, and above all, building students' judgment and experiences of critical-constructive application of knowledge for future change.

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Problem- and Project-Based Learning in Diverse Settings

Reflections on 23 Years of Application

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Abstract

This article presents an autoethnographic account of 23 years of teaching experience using problem- and project-based learning (ProbBL and ProjBL) in higher education, across face-to-face, blended, distance learning, and massive open online course (MOOC) formats. Drawing on 20 peer-reviewed journal articles and personal teaching notes, I systematically analyse how PBL approaches were developed, adapted, and implemented in diverse institutional and cultural contexts. These published works, based on both quantitative and qualitative research, serve as reflective artifacts through which I revisit and reinterpret my teaching practice. Using content mapping and thematic coding, I identify recurring tensions and enabling conditions in the application of PBL over time. Key findings highlight the importance of institutional support, student autonomy, emotional engagement, and community partnerships in sustaining active learning practices. Conversely, structural challenges such as

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faculty precarity, bureaucratic rigidity, and cultural resistance to pedagogical change often undermine these efforts. This article contributes to the literature by foregrounding the often-invisible institutional and emotional labor involved in sustaining transformative teaching practices. It also offers practical recommendations for educators and academic leaders seeking to advance PBL in complex and evolving educational environments.

Keywords: Autoethnography; project-based learning; MOOCs; institutional culture; reflective practice

Introduction

Over the past 23 years, I have implemented problem- and project-based learning (ProbBL and ProjBL) across a wide range of higher education contexts, including MBA programs, undergraduate and graduate courses, interdisciplinary initiatives, and massive open online courses (MOOCs). These experiences took place in diverse instructional formats—face-to-face, blended, distance, multi-campus and MOOCs—and within contrasting institutional cultures, ranging from private business schools to public universities.

In this article, I adopt an analytic autoethnographic approach (Ellis, Adams, & Bochner, 2011; Adams et al., 2015) to examine how these teaching experiences were shaped by, and in turn shaped, broader institutional and cultural dynamics. My goal is not only to reflect on pedagogical strategies and outcomes, but to investigate the conditions under which active learning pedagogies succeed or fail—including the effects of institutional structures, job precarity, student profiles, and educational modalities.

The analysis is grounded in a set of 20 peer-reviewed journal articles authored or co-authored by me, along with personal teaching notes. These materials serve as reflective artifacts, documenting both the implementation of PBL and the challenges encountered in different educational environments. Rather than offering a chronological summary of past work, I engage in a critical and thematic re-reading of these experiences, identifying patterns and tensions that reveal how educational innovation intersects with institutional constraints and sociocultural contexts.

This study seeks to answer the following guiding questions:

- What institutional and cultural dynamics support or hinder the use of ProbBL and ProjBL in higher education?
- How do conditions such as job stability, student autonomy, or community engagement shape the outcomes of these pedagogies?

- What broader lessons about teaching, learning, and innovation emerge when reflecting on two decades of practice?

By addressing these questions, I aim to contribute to ongoing scholarly discussions on the transformative potential of active learning, the invisible labor involved in sustaining it, and the structural barriers that educators often face. This article may be of interest to scholars, teachers, and academic leaders committed to advancing meaningful, context-aware pedagogy in higher education.

Structure of the article

This article is structured around six key teaching experiences drawn from a 23-year trajectory of applying problem- and project-based learning (ProbBL and ProjBL) in higher education. These six experiences were selected not simply for their chronological order, but for their analytical richness—they represent moments when pedagogical innovation intersected with specific institutional, cultural, and structural challenges. Each section draws on peer-reviewed publications and teaching notes that document the experience, while also serving as reflective artifacts for critical reinterpretation. Rather than offering isolated case studies, the article engages each teaching context as a lens through which to analyze recurring tensions: faculty precarity, bureaucratic resistance, emotional labor, community engagement, and student autonomy. This layered structure allows the article to trace patterns across time, connect personal experience with systemic realities, and contribute to broader debates about active learning, institutional change, and the sustainability of transformative teaching practices in higher education.

Theoretical review

Project-based learning (hereafter referred to as ProjBL) is a student-centered, inquiry-driven teaching strategy (Larmer, Mergendoller, & Boss, 2015). Students work collaboratively in teams on long-term projects designed to address real-life challenges. This approach emphasizes learning by doing, fostering collaboration and critical thinking. It often incorporates multidisciplinary learning, with courses structured around a central project that includes clearly defined deliverables and milestones.

Academic literature widely agrees that this learning-by-doing approach offers significant benefits (Zhang & Ma, 2023). It is well established that students learn more effectively when they apply theory in practice, work collaboratively in teams, and share knowledge and expertise (Kumi-Yeboah & James, 2024). Additionally, this approach helps students develop various essential skills, such as communication, project management, and critical thinking (Moustafa & Al-Rashaida, 2024). Researchers emphasize the advantages of engaging students in real-life projects (Romão et al., 2024), particularly in contributing to solutions for community challenges (Rooks & Dorsey Holliman, 2018). Contributing to social projects can be highly motivating, inspiring students to give their best effort to the task (Jacoby, 2014).

Problem-based learning (hereafter referred to as ProbBL) shares similar characteristics with ProjBL; however, its focus is on solving real-world problems. The scope is generally narrower, with the outcome being either a solution or a deeper understanding of a specific problem. Like ProjBL, it is inquiry-driven; however, its emphasis lies more on critical thinking than on creating a tangible product (Bender, 2012). ProbBL involves presenting students with ill-defined problems—challenges that can have multiple solutions—thereby fostering creativity and enhancing problem-solving skills (Dias & Brantley-Dias, 2017).

However, we also recognize that both ProBL and ProjBL come with challenges. The teacher's workload can be significantly higher compared to a traditional teacher-centered course (Warr & West, 2020). Additionally, course management can be more time-intensive, and the outcomes may be unpredictable (Summami, 2015). Furthermore, managing multiple projects and problems across various student teams can pose challenges. Students may experience stress and face conflicts within their teams (Lee et al., 2015).

In this article, I reflect on six different experiences of applying problem- and project-based learning in higher education:

1. Using ProjBL in face-to-face MBA courses,
2. Using ProjBL in undergraduate courses at the Federal University of São Paulo, Osasco Campus,
3. Using ProjBL in pilot courses at the Federal University of São Paulo, Osasco Campus,
4. Using ProjBL in graduate courses at the Faculty of Education, University of São Paulo,
5. Using ProjBL in blended courses at the Rectorate Campus, Program of Technology and Educational Design, and
6. Using project and problem-based learning in MOOCs.

In the courses I teach, I consistently implement Kolb's experiential learning cycle (Kolb, 2014) as a framework for continuous pedagogical improvement. Kolb's model is built on four stages—concrete experience, reflective observation, abstract conceptualization, and active experimentation—which form a dynamic and iterative process of learning. I apply this cycle by carefully planning each course (abstract conceptualization), delivering it while encouraging hands-on engagement (concrete experience), gathering student feedback at both the midpoint and the conclusion (reflective observation), and using this data to make evidence-based adjustments for future offerings (active experimentation). This process not only helps refine my teaching strategies but also promotes a learner-centered environment. For each of these course iterations, I reference peer-reviewed articles I have authored, which document these applications in greater depth, enabling interested readers to explore the practices and results in more detail.

The context

Using ProjBL in face-to-face MBA Courses

From 2001 to 2014, I taught a course titled *Project Simulation* to MBA students at the Polytechnic School of Engineering at the University of São Paulo. This program is fee-based, with the majority of students covering the cost themselves, while a few were sponsored by their employers.

The course was conducted in a traditional face-to-face format, and most students were seasoned professionals with at least five years of work experience. *Project Simulation* served as the capstone course of a two-year Project Management MBA program. In prior courses, students learned the theoretical aspects of planning, executing, and controlling projects, following the guidelines set by the PMI (Project Management Institute, 2021). The goal of the final course was to give students the opportunity to apply this knowledge in practice by collaborating on real-life projects in teams.

As the instructor, my objective extended beyond teaching project management. I aimed to broaden students' perspectives, encouraging them to become more socially conscious and aware citizens by exposing them to issues they may not have previously encountered, such as collaborating with institutions that provide assistance to people in need.

Over the years, I built a robust network of community partners (Arantes do Amaral & Matsusaki, 2016). Initially, this involved visiting community centers and inviting organizations to collaborate with the university. As the impact of our projects became evident, word-of-mouth led more institutions to seek our assistance, further expanding the network.

The majority of these organizations were NGOs that served underprivileged communities, including orphanages, elderly homes, shelters for homeless individuals, and centers for children with cancer or those who had suffered abuse. We also partnered with K-12 public schools, hospitals, and municipal institutions that supported people with mental disabilities.

All these institutions shared a common need: support to improve their ongoing efforts. Some required medicines, others needed food and clothing, while some sought appliances and furniture. Others required software systems or upgrades to their facilities. I referred to these needs as "project themes."

The students, working in teams, were tasked with designing and developing a project that addressed the specific needs of a community partner, putting project management theory into practice. On average, each class consisted of 30 students divided into six groups of five members each. For each course, we created a virtual learning environment (Arantes do Amaral & Gonçalves, 2015), which included a website featuring video lectures, readings, the course syllabus, and a master project schedule.

From 2002 to 2014, this course was offered 47 times. Over that period, 1,400 students successfully completed 204 projects on behalf of 34 institutions. Most projects involved fundraising, prompting students to develop creative strategies, such as organizing raffles, soliciting donations from private corporations, hosting fundraising events, leveraging social networks for donations, and even initiating crowdfunding campaigns (Arantes do Amaral et al., 2016).

Students had voice and choice: they selected the community partner, the project theme, and their teammates. They also defined team roles and responsibilities. However, they were required to adhere to a master schedule I provided, which included clearly defined deadlines and deliverables. Each week, students submitted deliverables such as planning documents (e.g., work breakdown structures), prototypes, or project status presentations. Additionally, they documented their weekly progress on a project website, reflecting on the work completed, challenges faced, and solutions implemented. This practice encouraged deep reflection on their learning process.

Students were also encouraged to follow the progress of other teams' projects by visiting their websites, enabling cross-team learning from both successes and setbacks. Throughout the course, we held multiple project walkthroughs, where each team presented their progress to others, receiving peer suggestions and feedback from me. The students' efforts resulted in the creation of complex products and services, including building restorations, goods acquisition, software development, and the provision of essential items such as food and medicines.

Some projects gained national recognition and were featured in newspaper articles (Dimenstein, 2007, 2008a, 2008b, 2008c, 2009a, 2009b) radio programs and a documentary (Engels, 2013). During my time at the University of São Paulo, I received strong support from MBA program coordinators, who recognized the value of my approach. They saw that the projects not only benefited students and community partners but also enhanced the MBA program’s reputation. Word-of-mouth recommendations from alumni and community partners, along with occasional media coverage, helped attract more students.

During this period, I developed and refined a course methodology (Arantes do Amaral, 2018). On the first day of the course, representatives from community partner organizations introduced the project themes to the students, offering a glimpse into diverse social realities and pressing challenges. These presentations played a pivotal role in igniting the students' motivation, inspiring them to fully engage with their projects. Many students were deeply moved as they learned about the impactful and meaningful work the community partners were doing to support people in need, creating a strong emotional connection to the projects.

Over the next two weeks, students formed teams, engaged with community partner representatives, visited their facilities, and interacted with the beneficiaries to fully understand the project requirements. Subsequently, students devised fundraising strategies and created project management plans. They executed these plans in the following weeks, culminating in a final presentation of their achievements to community partners and other stakeholders, such as city council representatives, community members, MBA coordinators, and faculty. These presentations were both an opportunity for feedback and a celebration of their accomplishments.

The MBA program fostered a modern, competitive culture. Courses were student-centered, aligned with contemporary project management methodologies, and encouraged the use of active learning methods. Mid-course and end-of-course evaluations by students provided valuable feedback, enabling continuous improvement.

The program also benefited from its location in a safe neighborhood with accessible public transportation, including nearby bus and subway stations, which facilitated participation for both students and community partners. The modern classrooms, equipped with proper heat and noise insulation, created an optimal learning environment.

However, my position as a professor was unstable. I was hired as an independent consultant, teaching courses on a contract basis. There were no opportunities for professional growth or engagement in research activities, outreach projects, or international collaborations. After many years in this role, I aspired to apply what I had learned in a broader context. I sought a stable position at a public university, where I could teach more students, develop outreach programs, enhance my teaching skills, and establish international partnerships.

In 2014, I participated in a competitive selection process for a faculty position teaching *Project Elaboration and Management* at the Federal University of São Paulo, Osasco campus (Unifesp Osasco). I secured first place in the selection process. Since 2014, I have been working as a professor at Unifesp.

Using ProjBL in undergraduate courses at the Federal University of São Paulo, Osasco Campus

The *Project Elaboration and Management* course shared similarities with the course I taught in the MBA program. This twelve-week course aimed to introduce students to the fundamental concepts of project management while challenging them to apply these concepts in real-life projects. However, the student profile was notably different: instead of professionals with years of work experience, these were young undergraduate students, most of whom had no work experience or prior knowledge of project management. They came from the fields of Economics, Accounting Sciences, and International Relations. Regarding the classroom environment, several issues stood out. The classrooms lacked adequate heat and noise insulation, making the environment uncomfortably hot in the summer, cold in the winter, and noisy year-round. Additionally, there was inadequate public transportation nearby, and the campus was in a high-crime neighbourhood. These challenges negatively impacted both student attendance and the participation of community partners in classroom activities.

I decided to adapt and use the same methodology I developed for the MBA courses. Students were tasked with learning project management theory and applying it to projects developed for the same network of community partners established over previous years. To support the course, I also authored a book (Arantes do Amaral, 2020), comprising 12 chapters, each corresponding to the content of one week of the course.

Given the students' lack of experience, the project themes proposed by the community partners were less complex than those designed for MBA students. Nonetheless, the students achieved remarkable results. Their projects included creating small community libraries, acquiring essential food kits and clothing, and designing and providing crutches for hospitals.

The course was held 34 times, and a total of 199 projects were completed. Some of these projects even gained media attention and were featured in newspaper articles (Correio Paulista, 2019).

The culture of the Unifesp Osasco programs was quite different from that of the MBA program. Unlike the MBA program, the undergraduate courses were entirely free of charge. Additionally, professors, after a three-year tenure track, acquired job stability. They were not paid per course but received a fixed salary and were required to teach a minimum of 120 hours per semester (equivalent to two sixty-hour courses per semester). Professors were also encouraged to engage in outreach activities and research.

However, I observed some limitations within the institution. The teaching culture appeared more traditional, relying heavily on teacher-centered methodologies with fewer opportunities for student-centered learning. In my view, there were opportunities to better integrate rapid innovations in education and establish formal mechanisms for incorporating student feedback into course evaluations. Additionally, there was no structured program for continuous improvement to enhance course quality.

The administrative processes also presented challenges. They were relatively complex and often delayed the implementation of updates to course content and offerings. Practical issues such as inadequate classroom facilities, inefficiencies in inter-departmental coordination, enrolment barriers, and administrative workloads occasionally hindered course quality. These challenges highlighted areas for potential development and improvement (Arantes do Amaral, 2020).

Nevertheless, working at a public university provided me with the opportunity to create pilot courses and explore the use of ProjBL and ProbBL in different contexts, expanding its application and impact.

Using ProjBL in pilot courses at the Federal University of São Paulo, Osasco Campus

In 2015, I launched the *Project Elaboration and Management* course as the institution's first multi-campus pilot program. The course was elective, offered without academic credits, and participation was not mandatory for students.

The course was delivered in a blended format, with a few face-to-face meetings and several online activities. It involved 70 undergraduate students from three different campuses of Unifesp, located in various cities. The students developed projects for 14 NGOs, making extensive use of information technology tools. Participants expressed that developing projects for community partners was highly motivating. However, the pilot project revealed several challenges, such as scheduling conflicts, distances between campuses, and high dropout rates—factors that negatively impacted the course (Arantes do Amaral et al., 2018). I speculate that the dropouts were due to the course being non-credit and elective. Some students informed us that, while they enjoyed the course, they dropped out to focus on mandatory courses.

In November 2015, I offered another pilot course, *Laboratory of Social Projects*, as an outreach initiative involving both community members and university students. This course was free of charge. The 72 participants learned project management principles and applied them to 13 projects on behalf of eight community partners. The course enabled intense knowledge-sharing among participants. However, it also faced high dropout rates, scheduling conflicts, and a lack of participant commitment (Arantes do Amaral, 2017). The workload required to design and deliver this course was substantial. I believe that the dropouts were partly influenced by the university's location, which lacked sufficient public transportation, and by the fact that the course was offered free of charge, as this can sometimes lead to lower levels of commitment from participants (Celik & Çağıltay, 2024).

In 2021, during the COVID-19 pandemic, I had to transition my undergraduate courses from face-to-face to entirely online formats. Moreover, I could not propose activities involving visits to community partner facilities to avoid the risk of contagion. Compounding this, community partners were under considerable stress due to the pandemic and could not participate. Therefore, I offered the undergraduate course *Project Elaboration and Management* to students in the Economics Department using a different approach: a Data Science Olympics competition. I chose this format because these students had already studied several data science concepts in previous courses. A Data Science Olympics would help them review these concepts in a practical, team-based project.

The students' preparation for the competition followed a combination of problem and project-based learning approaches, with problems to solve and clearly defined deliverables and milestones. Although designing and delivering this course required significant effort, the results were remarkable. Every team was highly motivated to win the competition. In the process, they developed both project management and data science skills. However, they also encountered challenges, including team member dropouts, lack of commitment from a few participants, and difficulties scheduling online meetings (Arantes do Amaral et al., 2023).

Using ProjBL in graduate courses at the Faculty of Education, University of São Paulo

From 2017 to 2023, I volunteered as an affiliate professor (i.e., without receiving any salary or grant) in the graduate program of the Faculty of Education at the University of São Paulo (FEUSP). Contributing to this graduate program was particularly appealing to me because it offered resources that Unifesp Osasco lacked, such as smart classrooms. Additionally, I was excited by the opportunity to teach K-12 schoolteachers from São Paulo, as this would help promote the use of ProjBL in various schools.

My goal was to teach graduate students the concepts of Project-Based Learning (ProjBL) and Systems Thinking, combining the ProjBL approach with other active learning methodologies, such as flipped classrooms, problem-based learning, and simulation-based learning.

In 2018, I offered the course *Project-Based Learning* to 33 graduate students. This was a highly engaging experience, as I employed a ProjBL approach to teach ProjBL: the students worked in teams, with each team tasked with creating a book chapter describing the implementation of ProjBL in different Brazilian schools. To accomplish this, the students visited schools in São Paulo that used ProjBL in their courses, conducted interviews with teachers and students, and documented their findings. The final product was a book compiling all the experiences (Arantes do Amaral, Araújo, & Hess, 2018). This course provided students with a comprehensive immersion in ProjBL, connecting theory with practice and encouraging reflective learning (Arantes do Amaral, 2021).

In 2019, I explored the combination of problem-based learning and simulation-based learning in a Systems Thinking course offered to 11 graduate students in a face-to-face format. The students worked in teams and made extensive use of simulation software in a technology-enhanced environment (smart classroom). The course fostered group modelling activities, which facilitated intensive knowledge sharing (Arantes do Amaral & Fregni, 2021b).

During the first semester of 2020, as the COVID-19 pandemic began, I delivered an online *Project-Based Learning* course to 20 graduate students. The course focused on exploring neuroscience concepts that could enhance the effectiveness of ProjBL-centered courses. Students worked in project teams to create short videos demonstrating potential applications of neuroscience in various educational settings. The course enabled long-lasting learning by linking theory with practice, encouraging knowledge sharing, and supporting the retrieval of previously learned content (Arantes do Amaral & Fregni, 2021a). In the second semester of 2020, still under the constraints of the COVID-19 pandemic, I delivered another online course, *Systems Thinking*, to 20 graduate students at FEUSP. This course combined ProjBL and the flipped classroom approaches to promote long-lasting learning. Students were tasked with reading materials prior to class, participating in synchronous online activities to reinforce their understanding, and working in teams to develop projects. These projects culminated in brief videos analyzing the dynamics of real-world systems. From this course, I learned that integrating critical thinking, ProjBL, and the flipped classroom approaches significantly enriches the learning experience (Arantes do Amaral & Fregni, 2021c).

Using ProjBL in the Technology in Educational Design program

In the first semester of 2022, I requested a transfer to the Unifesp Rectorate Campus to teach courses in the Technology in Educational Design program. This program is the only one at Unifesp that offers online courses. It is a two-year program structured around a ProjBL approach. Each semester includes several short courses and *Integration Projects*, designed to give students the opportunity to apply what they learn in the short courses to practical scenarios.

To ensure alignment between the content of the short courses and the *Integration Projects*, we hold several collaborative meetings involving all professors. This planning process is both time-consuming and complex.

There are four types of *Integration Projects*: the first focuses on open educational contexts, the second on formal educational contexts, the third on non-formal educational contexts, and the fourth on corporate educational settings.

During the first semester of 2023, I collaborated with another professor to lead the *Integration Project on formal educational context*. The course followed a ProjBL approach, with students working in teams to create educational artifacts for a K-12 public school. The students adhered to the Design Thinking process throughout the project. We observed that integrating Design Thinking with project-based learning significantly motivated students, enhanced their problem-solving and project management skills, and fostered interdisciplinary learning (Arantes do Amaral & Gamez, 2023). Additionally, working on real-life projects with a public school increased their determination to learn.

Using ProjBL and ProBL in MOOCs

In addition to teaching regular courses, I have also offered massive open free-of-charge online courses (MOOCs) as part of outreach initiatives. My goal has been to provide educational opportunities to people from across the country. From 2022 to 2024, I delivered five MOOCs—Data Science, R Programming Language, Scratch Programming Language, Visual Thinking, and Systems Thinking—to a total of 2,145 students from all states in Brazil.

In these courses, students worked on individual projects, creating artifacts related to the course subjects. I employed a combination of problem-based learning and project-based learning: students learned by doing, solving problems, and working on individual projects (Arantes do Amaral, 2025).

To deliver these courses, I utilized free tools such as Google Sites, Loom, Google Groups, Adobe Sketchbook, YouTube, and Facebook, along with paid artificial intelligence tools like ChatGPT, DALL-E, and ZeroGPT. Offering these courses has been challenging, as it involves not only interacting with hundreds of students but also the significant task of creating the virtual learning environment and managing the bureaucratic processes required for course approval by the University Outreach Committee.

Methodology

The core data set consists of 20 peer-reviewed journal articles, authored or co-authored by me between 2000 and 2023. These articles were chosen because they reflect six distinct phases of my professional practice, each marked by a different teaching context (e.g., business school, interdisciplinary program, MOOC, blended graduate course, etc.). These six experiences were selected not for chronological completeness, but for their analytical richness: each presents a unique set of cultural tensions, institutional constraints, and pedagogical adaptations that allow for deep reflection on the implementation and evolution of PBL.

Each of the 20 articles is based on empirical research, involving either quantitative, qualitative, or mixed-method designs. Some include surveys, statistical analyses, and formal assessments of learning outcomes, while others present qualitative data from interviews, project evaluations, or document analysis. Several also feature systemic analyses of the educational environments in which they were conducted—mapping interrelated factors such as institutional policies, student demographics, faculty working conditions, and technological affordances. To avoid a simple summary of past work, I approached these articles as reflective artifacts—not only as products of previous research, but as a structured window into my own pedagogical development. I engaged in a multi-step analytical process:

Selection: I identified six key experiences that exemplified different challenges, formats, and institutional cultures relevant to PBL.

Mapping: I created a timeline and matrix cross-referencing articles by context, format, student profile, pedagogical approach, and institutional support.

Thematic Coding: I conducted inductive coding to identify recurring tensions and themes, such as job insecurity, community engagement, institutional resistance, emotional labor, and student autonomy.

Synthesis and Interpretation: I analyzed how these themes emerged across cases and reflected on how my evolving responses were shaped by broader cultural and institutional forces.

This interpretive process allowed me to re-experience and critically reinterpret my own teaching—not to celebrate it, but to examine how pedagogical agency is constrained or enabled by structures of power, resource distribution, academic culture, and labor conditions. Rather than reproducing what is already published, this article seeks to offer new meaning by repositioning those experiences within an autoethnographic framework that foregrounds reflection, critique, and cultural insight.

By treating published studies as both data and documentation of lived professional life, this approach brings transparency and scholarly rigor to the autoethnographic narrative. It also contributes to current debates in the PBL literature by surfacing invisible academic labor, institutional contradictions, and the emotional demands of innovation in contexts that are often resistant to change.

Findings

Table 1 presents the key findings on the use of ProjBL and ProbBL in various educational settings.

ProjBL and ProBL contexts	Findings
MBA courses (face-to-face)	• The creation of a network of community partners was a lengthy and complex process. • Project themes addressing challenges faced by disadvantaged groups sparked students' motivation to complete their projects. • Continuous improvement efforts led to the development of a robust project-based learning method. • The modern MBA program culture encouraged professors to promote real-world projects and allowed quick course adjustments. • Student evaluations contributed significantly to improving the quality of the courses offered. • Well-designed classroom environments facilitated teamwork activities. • Proximity to transportation networks (e.g., subway and bus lines) made it easier for students from community partners to participate in activities. • The student cohort consisted of young professionals with at least five years of work experience. • The course could only be offered in face-to-face settings. • I faced limited professional growth opportunities due to precarious, short-term, per-course contracts.
Undergraduate (face-to-face courses)	• An established community partner network and a mature course methodology significantly facilitated the courses development. • Although less complex, project themes addressing issues faced by disadvantaged groups effectively motivated students to complete their projects. • A bureaucratic organizational culture and slow decision-making processes delayed course adjustments. • Various challenges affected course quality, ranging from inadequate classroom environments to academic rivalries between professors and departments. • Opportunities existed to offer pilot courses in diverse academic settings.
Pilot-courses (multi campi blended courses, outreach courses	• There were many challenges involved in providing blended multi-campus courses, such as the distances between campuses, which make face-to-face meetings difficult, high dropout rates, and schedule conflicts.

and distance learning courses)	• Outreach courses allow intense knowledge sharing between participants; however, there are several challenges, such as high dropout rates, schedule conflicts, lack of commitment, and high teacher workloads. • The distance learning course, centered on ProjBL and aligned with the students' field of expertise and previous courses, worked very well even without the participation of community partners. However, students faced challenges such as team member dropouts and communication issues. The COVID-19 pandemic further added stress to the course.
Graduate courses (face-to-face and distance learning courses)	• The integration of Problem and Project-Based Learning (ProjBL) approaches with flipped classroom and simulation-based learning proved highly effective. • Incorporating neuroscience principles into ProjBL centred courses significantly enhanced long-term retention and learning outcomes. • Utilizing a ProjBL-centered course to teach Project-Based Learning encouraged profound reflection on the underlying theory.
Interdisciplinary Project-based learning courses (blended courses, involving several teachers)	• The planning and delivering process involve a complex joint planning and management • There are challenges in managing the participation of external organizations such as companies, non-formal education institutions and schools.
Massive Online Courses	• Delivering free MOOCs is an incredibly enriching educational experience. The combination of problem-based learning and project-based learning provides learning opportunities to thousands of students. • The process of designing and delivering these courses involves a significant workload and relies heavily on free tools as well as paid AI tools.

Table 1. Key findings.

Discussion

The findings below emerge from a critical reinterpretation of 23 years of applying problem- and project-based learning (ProbBL and ProjBL) across diverse contexts. These reflections are now reorganized to respond directly and sequentially to the three guiding research questions.

Research Question 1: What institutional and cultural dynamics support or hinder the use of ProbBL and ProjBL in higher education?

- On Problem and Project-Based Learning

ProbBL and ProjBL can be successfully implemented in a wide range of settings—including face-to-face, distance, blended, multi-campus, and massive formats. However, their success depends heavily on institutional support, leadership culture, and faculty autonomy. These findings align with studies that demonstrate the adaptability of project-based learning in diverse contexts (Malyuga & Petrosyan, 2022; Yeh, 2010; Hilger et al., 2007; Verstegen et al., 2023).

- Navigating Institutional Culture

Different institutional cultures either support or hinder innovation. Organizational norms can either enable or constrain faculty agency. These dynamics significantly affect the sustainability of ProbBL and ProjBL initiatives, echoing Camacho et al. (2018). This also addresses the broader question of how to uphold transformative pedagogies in environments that lack structural or material conditions for their success.

- Surfacing Hidden Labor

The invisible work behind ProbBL and ProjBL —including emotional labor, administrative overload, and negotiation of bureaucratic systems—often goes unrecognized. These barriers complicate the sustainability of active learning practices despite their pedagogical benefits. This tension is central to sustaining pedagogical innovation in institutions that may not culturally or materially support them.

Research Question 2: How do conditions such as job stability, student autonomy, or community engagement shape the outcomes of these pedagogies?

- Designing Meaningful Projects for Students

Student autonomy and emotional engagement are vital to the success of ProjBL. Projects that are personally and socially meaningful foster intrinsic motivation, collaboration, and knowledge-sharing (Harun et al., 2012). This reflects the conditions that truly support student motivation and autonomy in non-compulsory settings.

- Breaking Down University Walls

Community engagement enhances student learning and provides mutual benefits for external partners. These partnerships demonstrate how outreach supports pedagogical depth and relevance. Langhout et al. (2002) also highlight the importance of such collaborations. This analysis underscores the value of civic engagement within dominant academic cultures.

- The Importance of Boldness and Experimentation

Sustaining ProbBL and ProjBL in precarious environments demands emotional resilience and a willingness to take risks. Educators often operate beyond their comfort zones and must be prepared to challenge institutional norms. Hung et al. (2019) emphasize that bold experimentation is essential for pedagogical innovation. This connects with questions around how job stability—or lack thereof—shapes the identity and agency of innovative educators.

Research Question 3: What broader lessons about teaching, learning, and innovation emerge when reflecting on two decades of practice?

- The Importance of Continuous Improvement

Teaching is an iterative design process that benefits from cycles of reflection, feedback, and refinement. Continuous improvement enhances the learning experience and aligns with the reflective teaching model advocated by Alves et al. (2017).

- Publishing and Sharing Findings

Disseminating reflections through academic publication enables critical engagement with one's own teaching and contributes to the broader field. Review processes also offer valuable feedback that strengthens both practice and research (Bloom, 1999).

- Improving Teaching Skills

Effective ProbBL and ProjBL teaching develops over time through experimentation, failure, and growth. Educators must commit to long-term development and view teaching as a lifelong learning process. Boss and Larmer (2018) underscore the need for sustained investment in pedagogical expertise.

These findings collectively underscore that ProbBL and ProjBL is not a universally applicable method, but rather a culturally embedded and structurally contingent practice. Its success hinges not only on design but also on alignment with institutional values, labor conditions, and emotional realities.

Conclusion

This article argues that the long-term sustainability and transformative potential of problem- and project-based learning (ProbBL and ProjBL) depend less on the techniques themselves and more on the cultural, structural, and emotional contexts in which they are enacted. Through the lens of analytic autoethnography, I have shown how ProbBL and ProjBL are continuously negotiated within institutional constraints—including precarious labor conditions, bureaucratic rigidity, limited resources, and academic norms that often undervalue innovation and community engagement. These insights echo those of Camacho et al. (2018), who emphasize the cultural barriers educators face in promoting active learning, and Hung et al. (2019), who underscore the institutional inertia that often resists pedagogical change.

The core contribution of this study lies in making visible the invisible: the behind-the-scenes labour, emotional intensity, and cultural negotiations required to uphold active learning in complex educational environments. Rather than proposing a new model or framework, this article offers a critical lens to understand what it takes—emotionally, politically, and structurally—to sustain PBL over time, in line with the calls of Boss and Larmer (2018) for long-term commitment to teacher development, and Langhout et al. (2002), who advocate for integrating civic engagement into higher education.

For educators, the findings suggest that meaningful innovation often requires informal alliances, strategic risk-taking, and emotional resilience. For administrators, the study highlights the need to create material and symbolic conditions—such as job stability, interdisciplinary space, and recognition of teaching labour—that genuinely support active learning cultures.

Ultimately, this reflection contributes to the PBL literature not as a recipe for replication, but as an invitation to critical inquiry. It invites educators and researchers to view pedagogy not just as classroom technique, but as a site of cultural resistance and institutional possibility—a space where values, politics, and identities are constantly at play.

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Challenges, Opportunities and Educational Design for Interdisciplinarity in a PBL Environment

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Abstract

In this article, we examine the challenges and opportunities perceived by university staff when planning and executing interdisciplinary activities for students in the problem-based and project-centred environment at Aalborg University. Using a qualitative approach, we interviewed 15 participants from nine pilot projects organizing interdisciplinary activities in higher education. The findings highlight various challenges to interdisciplinarities, such as building common ground to be "comfortable being uncomfortable", framing and facilitating interdisciplinarity and balancing different disciplines in student recruitment. They also present multiple opportunities, including increased awareness of one's own professional identity, a positive relationship with employability, the possibility of asking more fundamental questions about

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disciplinary practice, increased outlook when facing complex problems and the use of problem-based learning (PBL) as a frame of reference for interdisciplinarity. Based on the findings dimensions of educational design that are critical to interdisciplinary activity planning.

Keywords: Interdisciplinarity; integration; problem-based learning; educational design model

Introduction

Problem-based learning (PBL) is often presented as a pathway towards interdisciplinary learning (Jensen et al., 2019), and interdisciplinarity is an inherent feature of PBL.

> "Inter-disciplinary learning relates to problem orientation and participant-directed processes, in that the solution of the problem can extend beyond traditional subject-related boundaries and methods." (Graaff and Kolmos, 2003 p. 658)

Given this definition, interdisciplinarity is evidently integrated into PBL and is closely connected to the complex and wicked nature of real-life problems. However, interdisciplinarity extends beyond PBL-focused institutions, resonating with a broader trend in higher education towards interdisciplinarity playing a more significant role in educational programmes. According to Bear and Skorton (2019), the world needs students with interdisciplinary competencies; as Telléus (2019) notes, wicked problems like climate change, overpopulation and insufficient food production do not fit neatly within the disciplinary categories of the departments and faculties of science. Therefore, the integration of interdisciplinary activities into education can help to prepare students to work on problems that call for knowledge of more than one discipline.

There are many ways to integrate interdisciplinarity into education, and special attention has been paid to the role of "distance" between disciplines. Klein (2010) distinguishes between narrow and broad interdisciplinarity; in narrow interdisciplinary, disciplines have compatible methods, paradigms and epistemologies, whereas broad interdisciplinarity "*occurs between disciplines with little or no compatibility, such as sciences and humanities*" (Klein, 2010, p. 18). An example of narrow interdisciplinarity may be found in the AAU Cubesat Project at Denmark's Aalborg University (AAU) in the field of engineering, which combines electronics and physics (space science) (Kolmos et al., 2020). Another example may be found at Chalmers University of Technology, Sweden, where students can follow a track of extra-curricular courses across existing programmes related to a common theme of societal relevance (Enelund & Briggs, 2020). An example of broad interdisciplinarity may be found in the "Experts in Teams" course at the Norwegian University of Science and Technology (NTNU), which is offered to master's students across the STEM (science, technology, engineering and mathematics) fields as well as the social sciences and the humanities (SSH) (Wallin et al., 2017).

Other research, however, indicates that the integration of interdisciplinarity poses challenges for higher education. Based on evidence from multiple sources, Braßler and Sprenger (2021) highlight several barriers faced when integrating interdisciplinarity into curricula (e.g., conflicts stemming from interdisciplinary misunderstandings, different terminologies, diffusion of responsibility, sense of disturbance among students stemming from unfamiliarity, and additional workloads for staff). At the organizational level, Braßler and Sprenger (2021) also mention mono-disciplinary structures, competitiveness across disciplines and coordination difficulties. Notably, Richter and Paretti (2009) assert that students generally lack the ability to connect interdisciplinary subjects to their own more narrowly defined field of study.

In this study, we examine the integration of interdisciplinary learning opportunities for students within a PBL environment. This is relevant because past strategic and practical initiatives linking PBL and interdisciplinarity have faced significant challenges. For example, in a longitudinal single-case study, Braßler (2020) studied the role of interdisciplinarity when bringing PBL to traditional universities, exploring the related opportunities and challenges on the individual, team and organizational levels. More specifically, the identified barriers to PBL included diverse PBL-hindering examination regulations, varying definitions of the term "problem", varying understandings of PBL and limited willingness to stay open to other disciplines' views on PBL and education in general (Braßler, 2020). The problem is a paradox considering the inherent relationship between interdisciplinarity and PBL; PBL-focused institutions and teachers must find actionable solutions to move forward. To further the integration of interdisciplinary learning opportunities within PBL environments, this study offers a teacher's perspective, guided by the following research question:

What challenges and opportunities do teachers experience when planning and carrying out interdisciplinary educational activities in a PBL environment?

Based on the staff's reflections on challenges and opportunities, we further ask: *What are the implications of these challenges and opportunities for educational design? What are important dimensions to consider when designing interdisciplinary educational activities?*

The main contribution to the field of interdisciplinary research is to advance the practical understanding of the intersections between PBL, interdisciplinarity and pedagogical design. This is achieved by emphasising educational design dimensions for interdisciplinary activities based on teachers' insights gained from practising in a PBL environment. Figure 1 presents these seven design dimensions, which are important to consider when designing interdisciplinary educational activities.

Throughout the remainder of this study, we first present the methodology, including the context of the study, before moving on to the findings and discussing them in relation to other and potential future studies.

Methodology

This study's methodology is based on a qualitative approach whereby we interviewed faculty members at Aalborg University to reveal their experiences with designing and carrying out interdisciplinary educational activities. This section details the context of the study as well as the employed data-collection and data-processing strategies.

Context of study

The context of this study is Aalborg University, a PBL university founded in Denmark in 1974. From 2022 to 2024, various pilot projects were initiated and studied as a part of a university-wide strategic project initiated by AAU management called "SSH-STEM integration". The purpose of these pilot projects was to gain experience with interdisciplinary educational activities. This paper reports on the staff's perceptions throughout these projects with a specific focus on the challenges and opportunities that the staff experienced. It dives deep into the nuances of the projects, leading to suggestions for educational design in an interdisciplinary context.

Aalborg University has well-defined PBL principles across all faculties. These principles emphasise the use of the problem as the starting point, project organization, cooperation, exemplarity and students' responsibility for their own learning achievements (Askehave et al., 2015). However, there is diversity in the way PBL is implemented across the university's different faculties. For example, within the faculty of engineering and science, half of the ECTS points each semester are allocated to projects for which students work on real-life problems, sometimes (and preferably) in close partnership with external partners. A similar system is in place within the SSH and health faculties, though with variations in their curricular structures.

Aalborg University has a research-informed approach to educational development that entails the use of interdisciplinarity in its educational practice as well as its conceptual models to achieve a greater understanding of educational dynamics. For example, based on practical experiences, various interdisciplinary project types have been defined within a conceptual framework (Kolmos et al., 2024), different learning outcomes of interdisciplinary system projects have been presented based on student perceptions (Routhe et al., 2023) and studies of students' experiences with the so-called AAU Megaprojects have demonstrated the complexity of large-scale interdisciplinary constellations across SSH and STEM (Bertel et al., 2022). The AAU Megaprojects, launched in 2019, proved to be challenging for the university, as the interactions between groups across STEM and SSH fields leaned more towards "borrowing" knowledge from other disciplines without truly interacting rather than providing genuine interdisciplinary interaction and integration. While the intention was for students to initiate cross-group collaboration, boundary crossing proved to be a difficult task and was therefore limited (Bertel et al., 2022). Based on experimentation with different project types leading up to 2022, Aalborg University incorporated the integration of SSH and STEM competencies across AAU as a strategic goal in its 2022–2026 university strategy, dubbing the project "SSH/STEM integration". To carry out this goal, a process was initiated whereby the university developed an SSH-STEM integration model. In this model, interdisciplinarity is linked to a process in which students develop the competencies "*to collaborate with other disciplines to solve problems that require interdisciplinary collaboration*" (Aalborg University, 2022).

Data collection

To explore the staff's understanding of interdisciplinarity and their expectations and experiences regarding the creation of learning opportunities for students to collaborate across disciplines, we conducted qualitative semi-structured interviews with teachers carrying out pilot projects. This type of interview was chosen to gain in-depth insight into teachers' perspectives (Savin-Baden & Major, 2013). The semi-structured interview guide was peer-reviewed by members of the author team.

The interviewed staff included facilitators from STEM, SSH and health fields. Some were in the planning phase of their pilot project, though most of them had already carried out their project.

The interviews were all conducted in person and participants were selected due to their engagement in the nice interdisciplinary projects at Aalborg University, which were part of the university-wide SSH-STEM integration initiative (Aalborg University, 2022). In some of the interviews, more than one participant was present. The interviews were originally planned as one-on-one interviews, but participants were allowed to bring in more members in due to shared coordination. The interviews with more than one participant allowed for interplay between different perspectives, potentially providing richer data. Table 1 shows an overview of the pilot projects and the number of associated interview participants.

Overall, the participants were affiliated to various departments including Sports Science and Physiotherapy (Health), Energy, Techno-anthropology and Mechanical Engineering (STEM), Business, Culture and learning, and Communication (SSH). The project scopes were mainly focused on students working with cross-cutting problems related to health, sustainability, design, technology and innovation. The interviews lasted approximately 45 minutes. All interviews were conducted in Danish aside from one, which was conducted in English.

Project	Approach to interdisciplinarity	Time frame	Interview participants
P1	Broad	Three years	1
P2	Narrow	Semester	3
P3	Broad	One day	2
P4	Broad	One day	3
P5	Narrow	Semester	1
P6	Broad	On-demand	1
P7	Broad	Semester	2
P8	Broad	Three days	1
P9	Narrow	Semester	1

Table 1. Overview of pilot projects.

Data processing

The interview data were recorded and transcribed, and the transcriptions from each interview were read by two people (the interviewer and the coder) to gain an initial impression of patterns in the collected experiences. The data was then coded in NVivo using three pre-defined themes: opportunities, challenges and educational design. The choice of codes was directed by the research questions. When the coding process was carried out, the quotes from each theme were read, and quotes were selected for further analysis to express the nuances in the themes. The data revealed multiple dimensions of the educational design, leading to new subcodes during a second coding round. The interviewer validated the quote selections to ensure that the data represented their overall impression from the interview session and the transcripts.

Findings

In this section, we present the findings in relation to the three aspects laid out by the research question: challenges, opportunities and dimensions of educational design.

Challenges

The challenges reported by staff in relation to planning and facilitating interdisciplinarity cover three themes: 1) creating common ground and being comfortable with being uncomfortable; 2) framing and facilitating interdisciplinarity; and 3) balancing disciplinary backgrounds in student recruitment.

Creating common ground and being comfortable with being uncomfortable
The interviewees considered allocating time for students to create common ground highly important.

> “So, they all said that they needed more time to get to know each other. This was really interesting. So, the way it was accelerated—everybody came together, and we had little bios, and we met online, but we immediately jumped into the content … If we had had one or two days of them getting to know each other first and trust each other and understand a little bit, I think we would have gone further.” (P1)

This quote underlines the importance of students getting to know one another and, in turn, building up trust, confidence and a common language to navigate the interdisciplinary learning process. Other staff members suggested that students should get acquainted with the competency profiles and learning objectives in the written curricula of the other disciplines (P2).

Some of the staff members asserted that whether students had previously gone through similar interdisciplinary processes represented a relevant factor. As one staff member put it, students with such experience were “more comfortable being uncomfortable” (P1). Another staff member pointed out that being in an interdisciplinary programme made a considerable difference when dealing with collaboration across programmes (P2).

This sense of being comfortable being uncomfortable is also demonstrated by the staff’s reflections on students’ attitudes.

> “I think it is important, based on my experience, to work with feeling safe and motivated, and if this is not there, then you will not get them on board. If they are sitting there closed-minded because they are insecure

> or they do not think it is cool in any way, then you can present them with whatever—it will be like facing a wall." (P3)

Evidently, they consider students feeling safe and motivated to be crucial. Another staff member added to these psychological considerations, pointing to challenges stemming from students having a lack of curiosity and being unwilling to take risks, which they attributed to students' focus on grades (P4).

Framing and facilitating interdisciplinarity
Overall, the interviewees indicated that staff must step out of their comfort zone when facilitating interdisciplinary projects.

> "And we put teams together of people [staff] who had never worked together before because we say we must do that ourselves and model it for the students. And, you know, that was not easy, especially for professors who reach a certain point in their career and become experts in a field. So, stepping out of their comfort zone is also a challenge." (P1)

In an exemplary way, P1 staff demonstrated their ability to "walk the walk" by organising interdisciplinary activities in an interdisciplinary coordination group.

In another project (P9), students worked in relation to the intended learning outcomes outlined in their own disciplinary curriculum. Still, staff experienced that they were less in control than in a disciplinary project on account of them not knowing what the teams from the other disciplines were doing.
Another area of concern was how to frame the process. In one project, cases were used as a starting point for students' interdisciplinary process, but the interviewees considered the creation of these cases to be a challenge.

> "Actually, the hardest part when you are doing these things is to formulate a case, which, when it is so interdisciplinary, is something that all programmes can relate to." (P3)

One of the staff members observed that students had a hard time transferring their knowledge from the interdisciplinary setting to the disciplinary setting and vice versa, especially if the students were resistant to something new outside disciplinary borders.

> "While they gave great feedback on the courses, great feedback on the workshop, they had trouble relating it back to their own work and their own concerns and their own skill set, and they had trouble seeing what they could contribute." (P1)

Another staff member argued that students tend to be discipline-bound and that even if interdisciplinary activity is strongly related to a generic field (e.g., project management), students may consider it to be irrelevant if they cannot link it directly and immediately to their primary discipline (P5). This suggests that students want to transfer what they already know to new situations; thus, transformation through which students develop new understandings and procedures must be actively facilitated. However, the interviewees asserted that facilitating interdisciplinary activities is highly time-consuming.

> "But I think that the barrier in our system is that it [interdisciplinary activities] takes extra time compared to what we are used to … and I think that this is sometimes a reason that such activities are not initiated, as it is considered easier to do business as usual." (P2)

Recruiting students and balancing disciplines

The recruitment of students in the case of extracurricular activities is considered a core challenge when planning interdisciplinary activities.

> "There are always some who will join such activities, but there are also many who do not want to attend or will prioritize their time differently. So, this is actually one of the things that has been the hardest—to get them to show up." (P3)

This challenge to get students to "show up" is also the case for more flexible platforms through which students can attend whenever they want (P6).
Due to these recruitment challenges, there is a risk of facilitators struggling to balance the disciplinary (i.e., primary institution/programme) distribution of students in a way that achieves the interdisciplinarity aimed for.

> "Well, about one-quarter to half of the students from the semester will participate, and sometimes even more. Sometimes, it is three-quarters of the students. And this is, in fact, a problem, at least for us, as they end up joining a team including themselves mostly. Then they do not get to know new people or new staff. Then it is getting more of the same. Then it is just the same. This is a bit of a challenge." (P7)

Paired with the recruitment challenge, this balancing issue further complicates the educational design in the case of extracurricular activities, as staff do not know who will ultimately show up.

Opportunities

These challenges point to many opportunities that may arise from successful efforts to overcome the challenges. Moreover, this analysis reveals openings for new learning opportunities.

Overall, the interviewees stressed the importance of students having a successful experience with interdisciplinary activities.

> "With STEM-SSH collaboration, it is like it has to be a success in the way that one can leave with an experience clarifying what I can … what I need the others for, I think." (P4)

Such experiences can form a baseline for increased curiosity, openness, initiative and what one staff member called the "ability to choose and make connections" (P1). Furthermore, the empirical material exhibits indications of deeper learning, as will be elaborated in the following five themes: 1) increased awareness of professional identity; 2) link between interdisciplinarity and increased employability; 3) tendency to ask more fundamental questions about disciplinary practice; 4) increased outlook when facing complex problems; and 5) use of PBL outcomes as frames of reference.

Increased awareness of professional identity

The ability to explain one's own competencies was highlighted by the interviewed staff as an important step towards getting to know one's own discipline (P3). Especially in areas where the educational programme is relatively new, it is considered a strength when students are aware of how their discipline can contribute to real-life challenges in an interplay with other disciplines.

> "As a student, you should participate to explore your discipline. Consider what you can do yourself. Especially for some of the educations, where you do not know precisely what you can contribute with … It becomes extremely clear when you are sitting together with others and solving a specific problem. What is it that you contribute with that differs from the others?" (P8)

Furthermore, the interviewees related increased awareness of one's own professional identity to real-life practices by emphasising that students will experience the same kind of interactions in interdisciplinary activities when they start their careers.

> "It is the way it is; in the real world, there is a counterplay. We help each other, and we each have our role." (P3)

The ability to spot contradictions, know when to step in to help and know how one's role is combined with those of others thereby constitute important competencies.

Linking interdisciplinarity to increased employability

Awareness of one's own professional identity, as discussed above, was linked by staff to a higher degree of employability.

> "They come with some disciplinary competencies, which they put into play, and this provides such a—well, it strengthens them in terms of

> building on and understanding their own discipline and [they] likewise become stronger in their profiles and then, hopefully, they will get more easily employed because it will be easier for them to explain what they can do …" (P8)

Another staff member emphasized the importance of aligning education with work, asserting that interdisciplinary activities play a role in providing a "truer" picture of professional practice.

> "They learn that we are different, and we have different agendas, and this is a preparation to work with customers … What frustrates them is actually what they have to go through … it is exactly what they will experience when they come out in industry …" (P7)

This quote brings forward the idea of frustrations as a positive and inevitable part of real-life professional practice, which is essentially what students are preparing for.

Asking more fundamental questions about disciplinary practice

The assertion that interdisciplinary practices can increase one's understanding of their own discipline is elaborated by the following quote, which indicates a deeper level of knowledge, including through the asking of more fundamental questions about disciplinary practice.

> "It requires a constant revisiting of our assumptions and our priorities and what we thought we knew." (P1)

In another pilot project, staff members indicated that students were left with a clearer picture related to the question of what the whole domain—in this case, SSH—can contribute to society.

> "They [students in the humanities] experienced that they could contribute with something in the discussion that others were not aware of. It is a recurrent question: What can the humanities contribute? … So, I think that one of the experiences was that the humanities students became more aware of what they could contribute in practice." (P4)

In the same way, one could ask: What can STEM education contribute? This is dependent on the theme and, more precisely, the problem that the students address alongside students' awareness of the domain in which they work.

Increased outlook when facing complex problems

The pilot projects were created around complex and cross-cutting study areas, such as sustainability and design. Staff considered interdisciplinary activities to be important when it comes to helping students reach a level where they can face complex problems beyond a reductionist approach.

> "They somewhat understand that there is something bigger; there are connections that are characterised differently in different disciplines. There are some technical infrastructures, some users, some actors and some institutions. It is about having a systemic understanding. I think that will give students a little or another kind of respect and acknowledgement of other disciplines in play." (P5)

This systemic understanding (or "system thinking") is thereby important for students' approach to other disciplines. Other staff members elaborated on this notion of "something bigger".

> "So, the students can approach those new evolutions—and those new developments in science, technology and society—with an understanding that they didn't have before." (P1)

Another staff member pointed to the outlook needed when working with complex energy systems to illustrate the need for cooperation between different disciplines.

> "Students have become very aware in these discussions of huge power-to-X facilities, windmill parks, solar cell parks and so on. That it is not something you can establish from a technical viewpoint only. … There are so many aspects to this. And we cannot realize something without the societal and humanistic problems that are embedded in such changes." (P4)

Overall, the increased attention paid to system comprehensiveness suggests that increased interdisciplinary work is warranted. In the case of the above quote, the staff member was very concerned with contextual factors and that which the students should know about. Although it may not be a part of the solution, they can contribute from their own disciplinary perspective; it is about knowing the limitations of their discipline as well as knowing what lies beyond it.

Using PBL outcomes as frames of reference

The university context behind the initiatives provides both PBL principles and the integration of intended PBL outcomes in the curricula. One staff member noted that this integration can serve as a stepping stone to argue for interdisciplinarity as part of assessment criteria.

> "There are these intended PBL outcomes in the curricula already, which maybe can be used. In the exam, for example, you can have a dialogue considering how this kind of collaboration has turned out, what they have gained from it and what their approach has been. So, this is, in any

> case, one thing that opens for making it [interdisciplinarity] explicit." (P2)

Another area related to intended PBL outcomes in curricula is the ability to reflect on one's own learning processes. This kind of reflexivity was pointed out by a staff member.

> "Maybe such a day could be rounded off by focusing on the process—that they simply write down what they have wondered about that day … One should take seriously that this is about interdisciplinarity and a way to get acquainted." (P4)

However, another staff member asserted that a "one-disciplinary-group" PBL practice is not enough to move students beyond their initial boundaries.

> "The awesome thing with this boundary-crossing work is when you get out on the other side and experience that it doesn't bite. Then, you have crossed boundaries, and you learn an awful lot of this not being what they are used to. You do not just sit in your own group …" (P3)

This quote serves as a reminder that, although intended PBL outcomes are integrated into the curriculum, it is important to stress interdisciplinary processes in a way that does not reduce PBL to disciplinarity from within. It is a matter of moving not just the content but also the people across boundaries when designing PBL for interdisciplinarity.

Pedagogical dimensions when designing for interdisciplinarity

During the interviews, different reflections and considerations regarding the educational designs under discussion were raised by the interviewees, and we subsequently coded these reflections into seven overarching dimensions (see Figure 1). Balancing the different presented dimensions can create a basis for pedagogical considerations when designing interdisciplinary educational activities. We argue that these dimensions in the design of interdisciplinary activities are highly interdependent. Thus, an overview of these dimensions as a tentative framework—or, more modestly, a tool—can likely aid the design of interdisciplinary activities in higher education. This is not to say that we cover every possible dimension of educational design, but we do touch on at least some of those prompted by our empirical data.

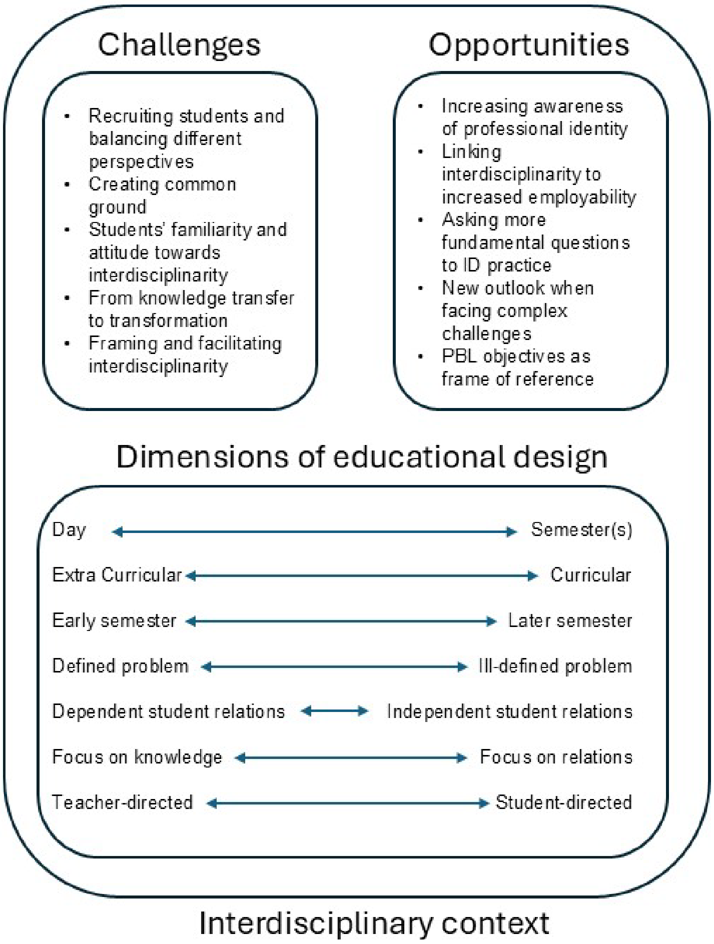

Figure 1. Pedagogical dimensions when designing for interdisciplinarity.

One-day vs. full-semester activities

The pilot projects differed in length, ranging from half a day without preparation to a semester-long project (around 15 ECTS). In this study, the interviewees expressed that short-term activities bring about some frustration.

> "A day is just nothing, to be completely honest. We can sit here and have all kinds of ambitions, but it can only be a beginning. It can only be that you can look at something and that you can sow some seeds. If you want dialogue, discussion, curiosity—it is more like creating an approach to things … The highest level we can reach is to contribute to a problem identification and get to know other disciplines." (P4)

However, this frustration is relative to the ambition of the broader SSH-STEM initiative. One could also argue that working on problem identification or getting to know other disciplines in half a day is a relatively efficient use of time; this is especially true if the framework conditions do not allow sufficient time for long-term activities.

Curricular vs. extracurricular

Even though one programme has incorporated the notion that students should become acquainted with different project types (including interdisciplinary projects) into the curriculum and other interdisciplinary activities have been obligatory for some students, the majority of the nine pilot projects were established as extracurricular activities. The interviewees did, however, bring up the possibility of linking the interdisciplinary activities to the curriculum, indicating that such a link would be a positive enabler.

> "And this is where I am thinking that, if it is curricular, … it is not extra-curricular, the more they feel it as a part of their disciplinary development, the safer, the more understood, the more sense it makes for them to be a part of it even though it becomes complicated—it is a part of their study." (P4)

While extracurricular activities do give way to certain recruitment barriers, as discussed earlier, they are also far more open, enabling considerably different disciplines to tap into the process.

Early vs. later semesters

Staff expressed a diverse range of opinions on whether students should be given the opportunity to work interdisciplinarily at the beginning or in the later part of the educational programme. These differences seem to have been at least partially driven by the structure of the programme. In the following case, staff argue for an early integration of interdisciplinary activities.

> "It all has to come together, and here it is a challenge that the later semesters, at least in our study programme, the more locked the projects are and the more fixed the framework is—there has to be closure. It is maybe broader in the earlier semesters; there might be more freedom. And it is there [the integration of interdisciplinarity] is, because the curriculum is getting more and more specified during the study." (P9)

In contrast, in another programme, staff argued for the integration of interdisciplinary activities in the later semesters, once the students have become more solution-oriented (P5). In this manner, one can argue for different timings for the integration of interdisciplinarity from an alignment-based perspective.

Defined vs ill-defined starting point

Compared to collaboration in intra-disciplinary settings, defining the thematic framework for interdisciplinary student collaboration across programme boundaries proved to be more challenging. To what extent should the starting point—the problem—be defined from the outset of the activity? To open an activity to students from a broad spectrum of disciplines, the interviewed staff members expressed a preference for broad, ill-defined issues over well-defined problems.

> "I think that you start, when you are looking at what is the problem, to solve the problem … they are in the phase of a project before you start problem-solving, and what characterizes this phase is that you learn to handle uncertainty. So, you can say that this day, it is not a problem-solving day; it is what it takes to make a good problem identification." (P4)

Such problems may still lead to positive experiences for the students, especially if they are aware that the experience involves a certain level of unpredictability. The ability to work on uncertain ground is arguably an integral part of learning to work in an interdisciplinary setting:

> "We couldn't tell them exactly at the beginning what they were going to learn so … they had to trust us, but, you know, … I think students who were not interested in that didn't apply." (P1)

The fact that organizers often provide relatively broad and open frameworks for interdisciplinary activities points to a potential dilemma between inclusiveness and student expectations. On the one hand, the attractiveness of the activity relates to the opportunity to engage in a concrete issue, often with the ambition of "making a difference". On the other hand, broad, ill-defined issues require extensive discussion before the problem can be properly defined—let alone solved.

One potential solution to this dilemma entails limiting the number of disciplines involved and letting the object of collaboration be a concrete (material) product. The following quote illustrates a project involving narrow interdisciplinarity (collaboration among students from different engineering disciplines).

> "I think the biggest challenge is if it is not defined. Then, I can imagine that it gets—that it might cause problems or frustrations, in any case, considering the storyline. Because what is this about, why are we doing this … I have not experienced that it went badly. But again, I think that one of the explanations is that exactly that project with the car—it has been so well defined. Everyone could understand what it was all about and what their one role in it was." (P9)

Dependent vs. independent student relations

In one of the pilot projects, the balance between dependent and independent student relations was described as an important aspect of educational design for interdisciplinarity.

> "It [dependency] is a delicate balance. There must be a dependency, or else there is no collaboration, but it must not be too strong because if one group does not deliver … then it should not affect other groups in a way where they cannot finalize their project. But, on the other hand, if the dependency becomes too loose (and maybe is non-existent), there is no collaboration—because what should you collaborate about." (P9)

In another pilot project, the lack of dependency between students' learning was not considered a problem, as the idea was to create a knowledge base for further collaboration by offering micro-credits to individual students.

> You get to follow your own interests, specialize or get some outlook and more perspectives on one's own projects. We believe that it will strengthen the students, their programmes, and their hand-ins so that they get more perspectives. The idea is that the students get so much flexibility that they can specialize. (P6)

The idea here is that the students gain an outlook that they, in various ways, can relate to their disciplinary work. Therefore, students are not merely collaborating interdisciplinarily; rather, they are shifting their perspectives and expanding their disciplinary outlook.

Knowledge vs. relations as the primary outcome

As noted earlier, some projects take a system or a product (e.g., a car, an energy system) as their starting point, which can also serve as the focus of a more traditional disciplinary semester project. However, there is added value in interdisciplinary activity that may not be immediately obvious to those who fail to consider learning outcomes.

> "So, I think… Well, it is not because they learn something different that they could not learn in a normal student project—I could have defined other [projects]. So, it is more all that additional—this is about interacting with others, to be able to work with other teams towards a common goal." (P9)

In another pilot project, one staff member presented the focus on knowledge and that on relations as equally important, highlighting both collaboration and learning processes.

> "Not all of them worked together because I think so much of that learning happens when working through the hard parts, and getting to the other side is working with other people. And that was as much… This was as much a project about collaboration as it was about sustainability and creativity and trans-disciplinarity. It really was about learning and grappling with collaboration." (P1)

In other cases, the primary outcome is related to generic competencies, which are open to all disciplines rather than any single specific discipline. One example of this is a focus on innovation and entrepreneurship, which is more concerned with getting students from different disciplines together to relate their knowledge to the process of value creation.

> "The contribution we come with relates to innovation, and, as we are used to saying, it does not have to be domain-specific—we help to support them. We experience that the students have considered the workshops to be exciting no matter the discipline. It is this kind of scaffolding; there is a pedagogical process for this—how you work together … Then, it is not a matter of who knows the most or who can do the most but instead how we can use this in an innovation process." (P4)

In another case, staff expressed that using such process framings—in this case, project management—can result in students perceiving the interdisciplinary activity as irrelevant, as it is not domain-specific (P5).

Finally, one staff member touched more fundamentally upon the learning experience as a process of social formation.

> "There is somehow a social interplay which is played out and which really does not have anything to do with what we are handling … it is some kind of social formation process." (P8)

This focus on social formation, or maybe more precisely "Bildung", links interdisciplinary activities to comprehensive life skills.

Teacher-directed vs. student-directed

In every interview, the staff characterized themselves as facilitators who need to support or scaffold students in their learning process, embodying the self-directed characteristics of a PBL process. In the following example, one of the staff members described the mutual collaboration between them as facilitators and the students.

> "But, you know, there is in any case an initiating meeting where the two facilitators meet with the two groups. Then, you set the tone considering the further direction." (P2)

The level of teacher control also depends on various factors, such as the length and goals of the learning process. If the activity is, as was the case in several of these projects, only a single day, then there is a greater need for scripted activities than if the students work on a project over the course of the whole semester.

The discussion about teacher-/student-directed learning is also heavily related to the problem-design process; the learning processes differ in how much direction staff want to set out for their students.

> "Well, in some way, it is the idea of having project catalogues versus no project catalogues at the university. Should you make a project catalogue that the students tap into, then they might get further in the process and maybe they can make an article on the other side of the project? Yes, a project catalogue, it gives … you know, this thing about getting a problem field together and such things—they miss out on that." (P8)

The mentioned project catalogue presents a list of project proposals made by the facilitators for the students to choose from. While it is merely a starting point on which students can elaborate, they might "miss out" on the learning related to the problem design itself. This learning objective may be taken care of through other learning activities, but it is nonetheless important to consider in the design of interdisciplinary activities alongside alignment with the rest of the curriculum. It is a question of how much uncertainty the students can cope with and, at the same time, how much freedom they must have to take ownership of the process.

Discussion and conclusion

Figure 1 provides an overview of the challenges and opportunities associated with interdisciplinary student activities, as revealed in this study. Furthermore, it highlights the identified dimensions for educational design, where the interviewed staff were able to point to both challenges and opportunities depending on the interdisciplinary context.

Challenges

As a potential challenge, this study highlights the ability to create common ground as one of the basic requirements for interdisciplinarity. Repko (2007, p. 15) phrases this challenge as follows:

> "Creating common ground is like building a bridge in order to span a deep chasm. The near side is the place of identifying the sources of conflicts between insights; the opposite side is the place of combining as many insights as possible. Unless the interdisciplinarian builds the bridge of common ground to connect the two sides, the process of integration and producing an interdisciplinary understanding cannot proceed."

Evidently, the process of creating common ground is a pre-condition for disciplinary integration. However, an even more mundane challenge lies before that: attracting students to sign up (at least for extracurricular activities) and bringing an open attitude towards other disciplines. Only once these tasks are accomplished can we begin to discuss other obstacles, such as ensuring transfer and even the transformation of learning to and from the event. However, overcoming barriers to the transfer and transformation of knowledge is important for interdisciplinary activities to be successful—and this study indicates that doing so is far from easy to facilitate. For students to be able to transfer their experiences to a new context, they must be able to analyse the problem at hand as well as the new situation (Habbal et al., 2024, p. 152). This ties the transformation process in interdisciplinary settings to PBL processes, and the time needed to move through such processes.

Another area in this study is the staff's ability to walk the walk in co-constructing the pedagogical basis of the event across different disciplines. In one of the pilot projects, the staff cited co-teaching as an important element. A similar positive relationship between co-teaching and interdisciplinary courses is highlighted by Rooks et al. (2022), among others.

Furthermore, staff noticed that students sometimes consider that which is "not domain specific" irrelevant. This may be counteracted by the notion of levelling (Beddoes, 2020), a strategy aimed at preventing the disciplinary capture of other disciplines to ensure that each discipline's goals, needs and wants are equally valued and addressed. This attention on levelling relates to the challenges of defining a suitable case but also to the balance in the number of students from each discipline. One discipline being overly dominant could lead to the disciplinary capture of the other discipline as well as a lack of motivation among the minority. As noted by Macleod and Veen (2020), the problem design (or, as dubbed by staff in this study, the process of making an inclusive case design) is important for equality in interdisciplinary teams.

Opportunities

This study's analysis of the pilot projects points to new possibilities. One argument to come from this analysis is that interdisciplinarity is linked to higher employability, which has been recognized by previous studies (e.g., Friedrichsen et al., 2024). There are, however, more possibilities linked specifically to potential learning outcomes. The pilot projects have contributed a new outlook on complex challenges created with regard to cross-cutting areas of study. This approach resembles those covered in other studies of interdisciplinarity across STEM and SSH fields, most prominently those related to sustainability (e.g., Braßler & Sprenger, 2021; Horn et al., 2022) and design (e.g., Graff, 2022; Han et al., 2021; Kiernan et al., 2019). The interviewed staff further highlighted that they believe interdisciplinary activities increase students' awareness of their home discipline. This supports findings from Taylor (2018) on final learning outcomes that enabled students to assess viewpoints, methods and outputs from other disciplines as well as their home discipline.

Furthermore, the opportunity to ask more fundamental questions about disciplinary practices is highlighted in this analysis to counteract the stereotyping of SSH/STEM fields. In a comprehensive study of SSH integration into civil engineering education, Josa and Aguado (2021) highlight barriers to incorporating SSH in civil engineering curricula, including misconceptions about what SSH involves in relation to civil engineering. Olmos-Peñuela et al. (2014) argue that such misconceptions of the "others" may arise from disciplinary stereotyping of the social value of the different disciplines. Others emphasise the synergy between STEM and SSH fields (e.g., Sharma et al., 2023, p. 68), arguing that "*While STEM education is often seen as the key driving technology progress, it is the humanities and social sciences that help to shape the ethical and social considerations of that process*". While it may be argued that this statement emphasizes what SSH can bring to STEM rather than the other way around, it is an example of a more fundamental position that may help organizers as well as students to understand how the synergy between SSH and STEM is viewed in certain contexts.

In terms of characterizing enablers for the integration of different disciplines, STEM and SSH might entail different perspectives. Borrego and Newswander (2010, p. 80) conclude that while the humanities literature operationalizes integration through critical awareness and emphasizes intellectual skills, engineering and science proposals operationalize integration as teamwork and emphasize interpersonal skills. This represents a deeper layer of analysis than that presented in this study, and the staff members did not address these differences between SSH and STEM by themselves but instead centred more on the problem/challenge that the students are tasked with facing together. Nevertheless, such considerations of different academic cultures and epistemologies could be interesting to explore further.

On another level of abstraction, staff interrelated the intended learning outcomes of interdisciplinary learning activities with the intended learning outcomes of PBL; this perceived interrelationship, due to constructive alignment, influences the design of the interdisciplinary activities. Scholkmann et al. (2023, p. 116) conclude that it is important to provide a very clear picture of the problem or concern that one is addressing by integrating different disciplines. However, the question is whether students are prepared for the design of interdisciplinary problems, effectively granting students the freedom to define what they want to work with. As effectively put by Ming et al. (2023, p. 12): "*Developing interdisciplinary education inevitably involves balancing between two valued principles: granting students freedom in shaping their identities while crossing disciplinary boundaries versus ensuring students gain genuine and meaningful interdisciplinary experiences*."

Design dimensions

Looking at the design dimensions for interdisciplinary activities revealed in this study (see Figure 1), there are also indications of the PBL context of these pilot projects, e.g., the dimensions of defined vs ill-defined problems, or teacher-directed vs student-directed. As such, the dimensions are not that different from those used in designing other PBL activities. However, the interdisciplinary context adds a new perspective on these dimensions, and new questions for pedagogical reflections can be put forward. Can interdisciplinarity be the cornerstone of a full semester? Is interdisciplinary nice to have (extracurricular) or need to have (curricular) according to staff? In which semester are the students properly acquainted with their own discipline so that they can introduce it to others? Can the students cope with ill-defined problems in a student-centred and interdisciplinary environment simultaneously? How much interdependency between students is needed to motivate students to build a common ground and integrate their disciplinary knowledge? Do the students need to solve a problem to stay motivated, or is it enough to 'just' analyse one? Is it naive to think that students can reach interdisciplinary learning objectives as an added value to the disciplinary outcomes, or are there trade-offs that need to be considered? The purpose of the dimensions offered for educational design in an interdisciplinary context is precisely to inspire such inquiries.

Final remarks

Finally, this study supports the assertion that interdisciplinarity is a complex matter. Thus, we will conclude with a quote from an interviewed staff member that encapsulates the challenges associated with planning and carrying out interdisciplinary activities.

> "We dreamed, like, what if we made a programme that was for people like us? The programme we wished had existed when we were doing our education. Because this interdisciplinary and transdisciplinary work especially—it is not easy. It is hard to do. Because there are so many assumptions about, kind of, priorities, criteria, foundational knowledge. That we do not speak the same language … Like even when everybody is willing to do it and excited about it, it's still hard because it requires—because that step into the unknown and dealing with the others and

dealing with the other kinds of points of view and holding these things in balance. It's—it's always dynamic, and it's always shifting. And that's very—that's very hard to do." (P1)

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Problem-based Intervention via Task-based Scenarios

Analysis of Practical Skills Acquisition Relations in Vocational Electrical Technology

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Abstract

The inability of vocational electrical technology (VET) students to transit from school-to-work after graduation shows that the practical skills needed for employability are far from being achieved. This has caused an increased unemployment rate among VET students. Hence, this study ascertained the relationships between problem-based intervention via tasks-based conduit wiring scenarios in VET students' practical skills acquisition (PSA). Specifically, this study determined the sequential mediation effects of intrinsic motivation and ability beliefs on problem-based and practical skills acquisition relationship. A cross-sectional study design was adopted for the study. Data was collected from 78 VTE students that gave their consent to participate. The outcome revealed that problem-based intervention is a positive and significant predictor of VET students' practical skills acquisition tasks. The result also revealed sequential mediating effects of intrinsic motivation and ability beliefs

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on problem-based and practical skills acquisition relations. This study is unique in that it examines how intrinsic motivation and ability beliefs sequentially mediate the link between problem-based interventions and the development of practical skills in vocational electrical technology (VET) students. By addressing the critical gap in employability skills through task-based conduit wiring scenarios, it provides novel insights into enhancing school-to-work transitions for VET graduates.

Keywords: Problem-based learning; Practical skills acquisition; Intrinsic motivation; Ability beliefs; Vocational and technical education; Electrical technology; Domestic conduit wiring.

Introduction

Globally, the place of Vocational and Technical Education (VTE) in fostering the needed and demand driven industrial/technological workforce cannot be overemphasized (Ernest & Ansah, 2013; Urama, & Ndidi, 2012). VTE is at the frontline of providing technical and vocational skills to prospective VTE graduates to either secure employment, or become self-employed in their various areas of studies such as vocational electrical technology (Bakare & Orji, 2019; Federal Republic of Nigeria, 2013). Hence, well-organized and quality practical skills acquisition among students is fundamental to achieving this goal. Nevertheless, the inability of vocational electrical technology students to transit from school-to-work after graduation shows that the practical skills needed for employability are far from being achieved. In addition, empirical evidence has shown that vocational electrical technology students have low-class participation in practical skills outcomes due to the type of teaching and learning method applied by lecturers (Atsumbe et al., 2018; Husain et al., 2012; Olelewe et al., 2021; Orji, 2015; Orji & Ogbuanya, 2018, 2020; Tugwell, 2020; Zhang et al., 2020). There is need for an appropriate learning method that can improve vocational electrical technology students' practical skills learning outcome in developing countries like Nigeria.

In recent time, practical skills acquisition (PSA) has become a popular demand in Nigeria higher education due to its perceived remarkable role in facilitating students skills development, school-to-work transition and self-reliant decisions (Okolie et al., 2021; Orji & Ogbuanya, 2020). Idoko, (2014) defined PSA as the process of developing new skills, practice, and ways of performing a task, gained through training or experiences. Similarly, (Okwelle & Ojutule, 2018), conceptualized PSA as a planned training process that ultimately leads to efficiency in a given trade. In the same vein, practical skills and competencies are essential for all individuals to live and contribute to their society's development (FRN, 2013). Unfortunately, the level of practical skills acquired by vocational electrical technology students through lecture methods is characterized by passiveness, thus not encouraging. Prior studies (Orji & Ogbuanya, 2020) have suggested that students PSA needs further investigation to understanding how active instructional approach like problem-based learning experience can impact on students' practical skills outcomes, and behaviour to address their skills needs. Previous studies on PSA (Idoko, 2014; Okwelle & Ojutule, 2018; Raimi & Adeoye 2002) notwithstanding, little is known about how problem-based learning might enhances students PSA. This indicates an important empirical and theoretical gap that requires further investigation.

Our study seeks to fill this literature gap by not only looking at the problem-based learning and PSA relationship but also the psychological mechanisms through which problem-based learning might influence such relationship. Orji & Ogbuanya, (2018) defined PBL as a learner-centred pedagogical approach in which a real problem scenario or task serves as a stimulus for applying problem-solving, collaborative and self-directed learning skills among learners. Likewise, Dolmans et al., (2005) defined PBL as a self-directed, constructivist, contextual and collaborative process that provides opportunities for students to improve their problem-solving, creative/critical thinking, reflective and teamwork skills using a problem scenario. PBL has the potentials of improving VET student's practical skills acquisition purposefully. (Orji & Ogbuanya, 2020) produced a vital contribution towards the establishment of a link between PBL and student's practical skills acquisition. Their study suggests that students exposed to new learning environment with an appropriate learning strategy tends to improve the time and effort committed to a given practical skills activity. Although (Orji & Ogbuanya, 2020) investigation provided a useful insight, it considered just the student's engagement in practical skills acquisition. The study did not obviously examine the actual practical skill involvement which shows the degree to which students are making active progress in the practical activities presented. Also, existing studies on PSA (Ogbuanya & Chukwuedo, 2017; Okolie et al., 2021; Okwelle & Ojutule, 2018) did not look at how PBL interventions and psychological mechanisms might influence VET student's practical skills acquisition. Therefore, an empirical enquiry is needed to fill this knowledge gap.

During PBL instructional delivery, some psychological mechanisms might intervene in the association between PBL experience and student's practical skills acquisition. Self-determination (Deci & Ryan, 1985) and implicit theory of ability (Dweck, 1986) emphasized intrinsic motivation and ability beliefs as the two important psychological components that can influence students interest to acquire practical skills. This mechanisms according to LaForce et al., (2017) influences students view of their present capability at a given practical task and the self-confidence and belief to execute behaviours necessary to produce specific performance attainments. Despite that previous studies have found that PBL improved students' intrinsic motivation and self-efficacy (Massa et al., 2009), empirical research examining its serial mediating roles in the association between PBL experience and student's PSA is unexpectedly lacking. Theoretically, this study hinges on Self-determination theory (Deci & Ryan, 1985) which helps understand students become self-determined when their needs for autonomy, competence, and relatedness are fulfilled and implicit theory of ability (Dweck, 1986) which helps to clarify students interest to pursue and value different achievement goals, that leads to practical skills achievement.

Overall, this empirical research contributes to the increasing practical skills acquisition and problem-based learning experience literature by postulating and testing an indirect effect model that integrates intrinsic motivation and ability beliefs as intervening variables. The result of the study provides further empirical evidence that extends current conceptualization in this study area.

We hypothesized a model as shown in figure 2 to guide the authors to properly develop the following hypotheses that were afterward tested:

1. Problem-based learning experiences (PBLE) will significantly predict (a) practical skills acquisition (PSA) outcomes, (b) intrinsic motivation and (c) ability beliefs.
2. Intrinsic motivation will significantly predict practical skills acquisition (PSA) outcomes.
3. Ability beliefs will significantly predict practical skills acquisition (PSA) outcomes.
4. The effect of PBLE on practical skills acquisition from task 1-5 will be mediated by increased intrinsic motivation and ability beliefs as a result of the intervention.

Method

Procedures and participants

Eighty-eight (88) vocational electrical technology students in southeast universities in Nigerian consented to participate in the study. But only 78 students who meet the inclusion criteria were recruited. The sample size was determined to be statistically adequate for the study with the aid of Gpower software (Faul et al., 2007). The Gpower analysis revealed that a total sample of

88 would be adequate based on a *priori* statistical power of 0.95 at 0.05 alpha level to conduct multiple regression. Written permission was granted by the lecturers, and informed consent was obtained from the students. This study received ethical approval from the Faculty of Vocational and Technical Education Research Ethics Committee at the University of Nigeria, Nsukka. The demographic data in figure 1, showed that 24 (30.8%) participants were 16–18 years, 33 (42.3%) were 19–21 years, while 21 (26.1%) were between 22 years and above. Based on study hours among the treatment group, 19 (24.4%) study for less than an hour, 26 (33.3%) study between 1 and 3 hours, 16 (20.5%) study between 3 and 5 hours while 17 (21.8%) study for above 5 hours every week. Also, 30 (38.5%) of the participants were from University of Nigeria, Nsukka (UNN), 37 (47.4%) were form Nnamdi Azikiwe University (NAU) Awka, and 11 (14.1%) were Chukwuemeka Odimegwu Ojukwu University Uli. The vocational electrical technology programme in the institutions used were male-dominated. However, gender was not included in the demographic data because the few female participants did not meet the study inclusion criteria.

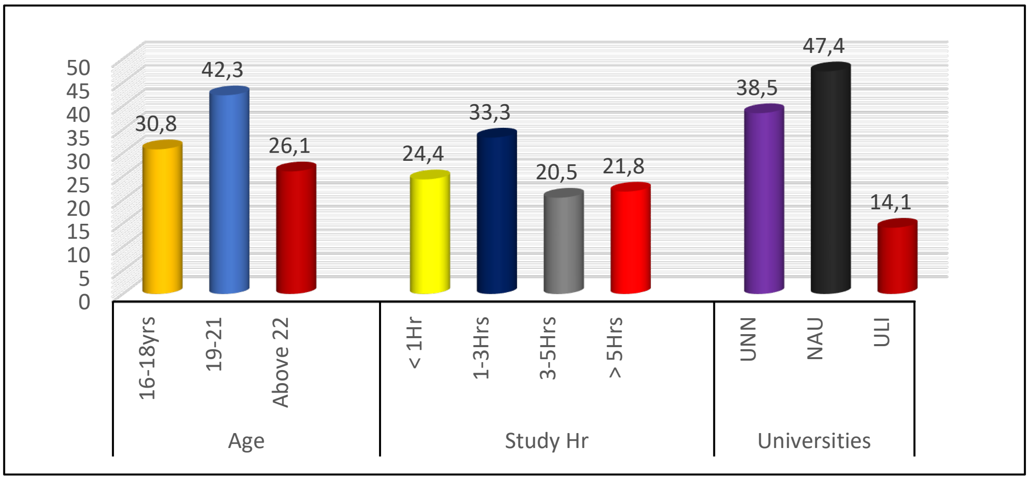

Figure 1. Demographic chart.

Following participant recruitment, the study focused on the implementation of a structured problem-based learning (PBL) intervention developed by the researcher. The intervention spanned eight weeks, with two 2-hour sessions conducted weekly. Students were divided into small collaborative groups and exposed to five sequenced performance tasks based on authentic problem scenarios in domestic conduit wiring (see Table 1). These tasks were carefully sequenced and included identifying the correct circuit positions; preparing the conduit for marking out and laying the appropriate boxes; demonstrating how to draw lighting cables; terminating and mounting components such as the ceiling rose, wall brackets, sockets, switches, and the cooker control unit (CCU); and inspecting the installation for straightness of fittings, loose cables, unterminated circuits or boxes, and the effectiveness of the earthing system. The

PBL process followed a consistent cycle: during the first session of each week, students analysed the problem scenarios, identified learning gaps, and developed hypotheses. In the second session, they engaged in peer teaching, group presentation of findings, and participated in structured reflection. Research assistants guided the sessions using the performance task and problem scenarios to ensure fidelity and consistency in delivery. At the end of the intervention, validated instruments were administered to collect cross-sectional data on students' PBL experiences, intrinsic motivation, ability beliefs, and practical skills acquisition through both questionnaires and performance assessments.

Task	Performance Task	Problem Scenarios
1	Identify circuit positions for: lightning points, sockets, water heater, cooker control unit, A/C and consumer unit.	Mr. Usman noticed that a lighting switch and an air conditioning socket were installed inside the toilet, while the consumer unit was located inside the bathroom. As a skilled craftsman, explain to your apprentice why these installations are unsafe and outline the correct procedure for positioning electrical fittings in wet or damp environments, referencing standard safety codes and best practices.
2	Preparing the conduit: for marking out, laying of appropriate boxes, laying of pipes, proper application of PVC gum and making a good bend.	Jude was assigned to complete a cable run and finalise the installation process. However, he encountered an obstruction that prevented the fishing tape from passing through the expected conduit path. As a professional, guide your apprentice on how to resolve this issue on-site and suggest preventive measures that should be taken during the initial planning and conduit installation stages to avoid such blockages.
3	Demonstrate how to draw light cable from distribution Board (DB) to the box, drop the lamp feed cable at the box, draw switch feed cable from the box 2 switch and back to box, draw life, neutral and earth cables from DB to the sockets, draw cable from DB to the CCU	Mr. Amadi neglected to accurately measure the distance between the distribution board and the designated points for the air conditioner and water heater. Consequently, the fishing tape could not reach either terminal point. Advise your apprentice on the importance of precise measurement before conduit installation and explain the correct procedures for determining cable lengths in residential wiring systems.
4	Terminate and mount the ceiling rose, the wall brackets, the sockets, the switches and the CCU.	After completing the termination and installation of lighting points, Mr. Johnson observed that the lighting in the sitting room was not functional. Upon testing the switch, it showed a weak current flow, insufficient to power any appliance. Additionally, slight electrical shocks were experienced when touching household appliances and even bathroom tiles. Instruct your apprentice on the likely causes of this anomaly, the appropriate diagnostic approach, and safety protocols to follow in identifying and resolving such faults.
5	Inspect for straightness of fittings, inspect for loose cables, inspect for unterminated circuits/boxes and inspect the effectives of the earth.	During inspection of his newly constructed home, Mr. Jacob discovered that the wall switch intended for lighting was instead controlling the ceiling fan, while the fan regulator controlled the lighting fixtures. Further, activating the lighting switch caused all lighting points to trip the circuit breaker. Educate your apprentice on the probable wiring errors that led to this situation and demonstrate how to correctly map, label, and connect control switches and regulators to their designated loads.

Table 1. Specific examples of performance task and problem scenarios used during the intervention

Measures

The instrument has two sections A and B. Section A comprises demographic information about the students while section B measured PBL experiences, intrinsic motivation, ability belief, and practical skills acquisition outcomes.

The student's problem-based learning satisfaction scale (SPBLSS) is a 12-items questionnaire developed by the researcher to measure electrical/electronic students' satisfaction of their problem-based learning experience based on previous literature reviewed (Munshi et al., 2008, Savery, 2015; Dolmans et al., 2005; Jacobs 2003, Patria 2015). Items of the SPBLSS were rated on a five-point scale ranging from (0 - Strongly Disagree to 4 - Strongly Agree). The SPBLSS total score can range from 0 to 48. Higher scores reflect the high level of PBL satisfaction and are based on a purposively set cut-off score of 20 – 48. Thus, a respondent with a score > 20 was considered to have a high level of PBL satisfaction. The Cronbach α is 931.

Students intrinsic motivation scale (SIMS) is a 9-items instrument adapted from the academic motivated scale (AMS) by (Pintrich et al., 1993). The SIMS was scored based on a 5-point scale of strongly disagree (0) to agree (4). The SIMS total score can range from 0 to 36. Higher scores on the SIMS shows a high level of intrinsic motivation associated with the learning environment used. The cut-off score was purposively set between 15 – 36. Thus, a respondent with a score of > 15 was considered to have a high intrinsic motivation level. The Cronbach α is .863.

Students' ability beliefs scale (SABS) is a 9-items questionnaire describing students' confidence in their electrical/electronic practical skills and abilities. The ability belief items were adapted from the Motivated Strategies for Learning self-efficacy subscale (Pintrich et al., 1993). Each item was measured on a 5-point Likert scale anchored by strongly disagree (0) and strongly agree (4). The SABS total score can range from 0 to 36. Higher scores on the SABS show a high level of ability beliefs associated with the learning environment used. The cut-off score was purposively set between 15 – 36. Thus, a respondent with a score > 15 was considered to have a high level of ability beliefs. The Cronbach α is .828.

Students practical skills rating scale (SPSRS) is a 34-items rating scale developed by the researcher after a due consultation with five electrical installation experts. The scale comprises five sets of tasks that were used to assess skills in domestic conduit wiring: task 1- identification of circuit positions (6 items), task 2 - conduit preparation (5 items), task 3 - drawing of cables (9 items), task 4 - termination and mounting of fittings (9 items), and task 5 - inspection and powering (5 items). The items were rated independently on a five-point rating options ranging from very good (4) – very poor (0). The facilitators used the items in the rating scale to rate the students' practical skills outcomes in carrying out domestic conduit wiring effectively. The total score for task 1 ranges from 0 to 24. A higher score on task 1 indicates a high level of dexterity in identifying circuit positions and is based on a purposively set cut-off score of 10–24. Therefore, a respondent with a score > 10 is considered to have a significant level of competence in identifying circuit positions; The total score for tasks 2 and 5 can range from 0 – 20. A higher score on task 2 and 5 indicates a high level of dexterity in conduit preparation, inspection and powering and is based on a purposively set cut-off score of 8–20. Therefore, a respondent with a score > 8 is considered to have a significant level of competence in those tasks. The total score for tasks 3 and 4 can range from 0 - 36. Higher scores on tasks 3 and 4 indicate a high level of practical skills in drawing cables, termination, and mounting of fittings and is based on a purposively set cut-off score of 15 –36. Therefore, a respondent with a score > 15 is considered to have a significant level of competence in those tasks. The Cronbach α is .863, .798, .810, .844, .901, .827 respectively.

Data Analysis

We used IBM Statistical Package for Social Sciences (SPSS) 25.0 and PROCESS macro 3.5 to analyses the data in this study. Specifically, the first three hypotheses were analysed using correlation and regression to ascertain association between the independent variable (PBL), dependent variable (practical skills acquisition tasks) and among the study intervening variables. The remaining hypothesis was tested using mediation analysis to investigate the mediating roles of intrinsic motivation and ability beliefs in the association between PBL and PSA.

Results

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. PBL	1								
2. Intrinsic Motivation	.610**	1							
3. Ability beliefs	.496**	.699**	1						
4. Task 1	.533**	.709**	.845**	1					
5. Task 2	.548**	.638**	.596**	.749**	1				
6. Task 3	.625**	.736**	.801**	.842**	.699**	1			
7. Task 4	.634**	.725**	.705**	.693**	.628**	.747**	1		
8. Task 5	.623**	.840**	.735**	.773**	.795**	.811**	.843**	1	
9. Overall PSA	.667**	.813**	.828**	.895**	.825**	.925**	.897**	.934**	1

Table 2. Bivariate Correlations of Problem-based Learning and the Practical Skills Acquisition Outcomes.

*PBL – problem-based learning, IM – intrinsic motivation, AB – ability beliefs, PSA – practical skills acquired (Task 1-5), Task 1- identification of circuit positions, Task 2 - conduit preparation, Task 3 - drawing of cables, Task 4 - termination and mounting of fittings, and Task 5 - inspection and powering. **. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).*

As revealed in Table 2, the bivariate analysis shows that PBL (r = 0.667, p < .01), intrinsic motivation (r = 0.813, p < .01) and ability beliefs (r = 0.828, p < .01), correlated significantly with the overall practical skills acquisition outcomes. Also, PBL (r = 0.610, p < .01), correlated positively and significantly with intrinsic motivation, and (r = 0.496, p < .01) ability beliefs. This indorses the necessity for the mediation analysis proposed in this research (Baron & Kenny, 1986).

Hypotheses	Variables	Adjusted R^2	F (1,77)	β	t	ρ
	PBLE → Task 1	.275	30.135	.533	5.489	0.000
	PBLE → Task 2	.291	32.600	.548	5.710	0.000
	PBLE → Task 3	.382	48.598	.625	6.971	0.000
H_1	PBLE → Task 4	.394	51.050	.634	7.145	0.000
	PBLE → Task 5	.380	48.198	.623	6.942	0.000
	PBLE → IM	.364	45.080	.610	6.715	0.000
	PBLE → AB	.236	24.779	.496	4.978	0.000
	IM → Task 1	.496	76.896	.709	8.769	0.000
	IM → Task 2	.399	52.120	.638	7.219	0.000
H_2	IM → Task 3	.536	90.013	.736	9.488	0.000
	IM → Task 4	.520	84.311	.725	9.182	0.000
	IM → Task 5	702	182.214	.840	13.499	0.000
	AB → Task 1	.711	190.183	.845	13.791	0.000
	AB → Task 2	.347	41.947	.596	6.477	0.000
H_3	AB → Task 3	.637	136.181	.801	11.670	0.000
	AB → Task 4	.490	75.017	.705	8.661	0.000
	AB → Task 5	.533	89.036	.735	9.436	0.000

Table 3: Summary of simple linear regression for practical skills acquisition (PSA), intrinsic motivation and ability beliefs.

β: Beta for standardized coefficient, Task 1: identification of circuit positions, Task 2: conduit preparation, Task 3: drawing of cables, Task 4: termination and mounting of fittings, Task 5: powering of circuits, IM: intrinsic motivation, AB: ability beliefs.

As revealed in Figure 2, we hypothesized that PBL experience would significantly predict PSA ranging from Task 1: identification of circuit positions, Task 2: conduit preparation, Task 3: drawing of cables, Task 4: termination and mounting of fittings, to Task 5: powering of circuits, ability beliefs, and intrinsic motivation. In Table 3 and Figure 2, the regression analysis shows that PBLE is a significant positive predictor of PSA at task 1 ($F = 30.135$, $t = 5.489$, $\beta = 0.533$, $\rho < 0.001$). The Adjusted R-square (0.275) shows that 27.5% of variance in task 1 is determined by PBLE. The regression analysis also shows that PBLE is a significant positive predictor of PSA at task 2 ($F = 32.600$, $t = 5.710$, $\beta = 0.548$, $\rho < 0.001$). The Adjusted R-square (0.291) shows that 29.1% of variance in task 2 is determined by PBLE. At task 3, the regression analysis shows that PBLE is also a significant positive predictor with ($F = 48.598$, $t = 6.971$, $\beta = 0.625$, $\rho < 0.001$). The Adjusted R-square (0.382) shows that 38.2% of variance in task 3 is determined by PBLE. The regression analysis also shows that PBLE is a significant positive predictor of PSA at task 4 ($F = 51.050$, $t = 7.145$, $\beta = 0.634$, $\rho < 0.001$). The Adjusted R-square (0.394) shows that 39.4% of variance in task 4 is determined by PBLE. At tasks 5, the analysis shows that PBLE is a significant positive predictor of PSA with ($F = 48.198$, $t = 6.942$, $\beta = 0.623$, $\rho < 0.001$). The Adjusted R-square (0.380) shows that 38% of variance in task 5 is determined by PBLE. Thus, the hypothesis proposed for the study is supported, implying that PBLE will aid in the enhancement of vocational electrical students' ability to identify circuit positions, prepare conduits, draw cables, terminate and mount fittings and power the circuit during domestic conduit wiring practical. Similarly, the regression analysis shows that PBLE is a significant positive predictor of intrinsic motivation (IM) ($F = 45.080$, $t = 6.715$, $\beta = 0.610$, $\rho < 0.001$). The Adjusted R-square (0.364) shows that 36.4% of variances in intrinsic motivation is determined by PBLE. In addition, the regression estimates revealed that PBLE is a significant positive predictor of ability beliefs ($F = 24.779$, $t = 4.978$, $\beta = 0.496$, $\rho < 0.001$). The Adjusted R-square (0.236) shows that 23.6% of variances in ability belief is determined by PBLE. Therefore, the hypothesis proposed for the study is supported, implying that PBLE will help to enhance the intrinsic motivation and ability beliefs of vocational electrical students' intrinsic motivation and ability beliefs during practical activities.

We hypothesized that intrinsic motivation would significantly predict PSA from task 1 to task 5. As indicated in Table 2, intrinsic motivation is a significant positive predictor of PSA in task 1 ($F = 76.896$, $t = 8.969$, $\beta = 0.709$, $p < 0.001$). Adjusted R-square (0.496) indicated that 49.6% of variances in task 1 are determined by intrinsic motivation. Hence, the hypothesis is supported for task 1, inferring that intrinsic motivation will aid in improving vocational electrical students' practical skills in the identification of circuit positions. In addition, intrinsic motivation significantly and positively predicted PSA in task 2 ($F = 52.120$, $t = 7.219$, $\beta = 0.638$, $p < 0.001$). The adjusted R-square (0.399) revealed that 39.9% of variances in task 2 are determined by intrinsic motivation. Hence, the hypothesis is supported for task 2, inferring that intrinsic motivation will aid in improving vocational electrical students' practical skills in circuit preparation. Similarly, intrinsic motivation significantly predicted PSA in task 3 ($F = 90.013$,

$t = 9.488$, $\beta = 0.736$, $p < 0.001$). The adjusted R-square (0.536) revealed that 53.6% of variances in task 3 are determined by intrinsic motivation. Hence, the hypothesis is supported for task 3, inferring that intrinsic motivation will aid in improving vocational electrical students' practical skills in drawing of cables. As indicated in Table 2, intrinsic motivation is also a significant positive predictor of PSA in task 4 ($F = 84.311$, $t = 9.182$, $\beta = 0.725$, $p < 0.001$) and task 5 ($F = 182.214$, $t = 13.499$, $\beta = 0.840$, $p < 0.001$). The adjusted R-square for task 4 (0.520) and task 5 (0.702) revealed that 52% of variances in task 4 and 70.2% of variances in task 5 are determined by intrinsic motivation. Hence, the hypothesis is supported for task 4 and 5, inferring that intrinsic motivation will aid in improving vocational electrical students' practical skills in termination and mounting of fittings and powering of circuits.

We hypothesized also that ability beliefs would significantly predict PSA from task 1 to task 5. As indicated also in Table 2, ability beliefs significantly predicted vocational electrical technology students PSA in task 1 ($F = 190.183$, $t = 13.791$, $\beta = 0.845$, $p < 0.001$) and task 2 ($F = 41.947$, $t = 6.477$, $\beta = 0.596$, $p < 0.001$). Adjusted R-square (.711) and (.347) indicated that 71.1% and 34.7% variances in tasks 1 and 2 are determined by ability beliefs. Hence, the hypothesis is supported for task 1 and 2, inferring that ability beliefs will aid in improving vocational electrical students' practical skills in the identification of circuit positions and preparation of conduit. In addition, ability beliefs significantly and positively predicted PSA in task 3 ($F = 136.181$, $t = 11.670$, $\beta = 0.801$, $p < 0.001$), task 4 ($F = 75.017$, $t = 8.661$, $\beta = 0.705$, $p < 0.001$) and task 5 ($F = 89.036$, $t = 9.436$, $\beta = 0.735$, $p < 0.001$) respectively. The adjusted R-square (.637), (.490) and (.533) indicated that 63.7%, 49.7% and 53.3% of variances in tasks 3, 4 and 5 are determined by ability beliefs. Hence, the hypothesis is supported for task 3,4 and 5, inferring that ability beliefs will aid in improving vocational electrical students' practical skills in drawing of cables, termination and mounting of fittings, as well as powering of circuits.

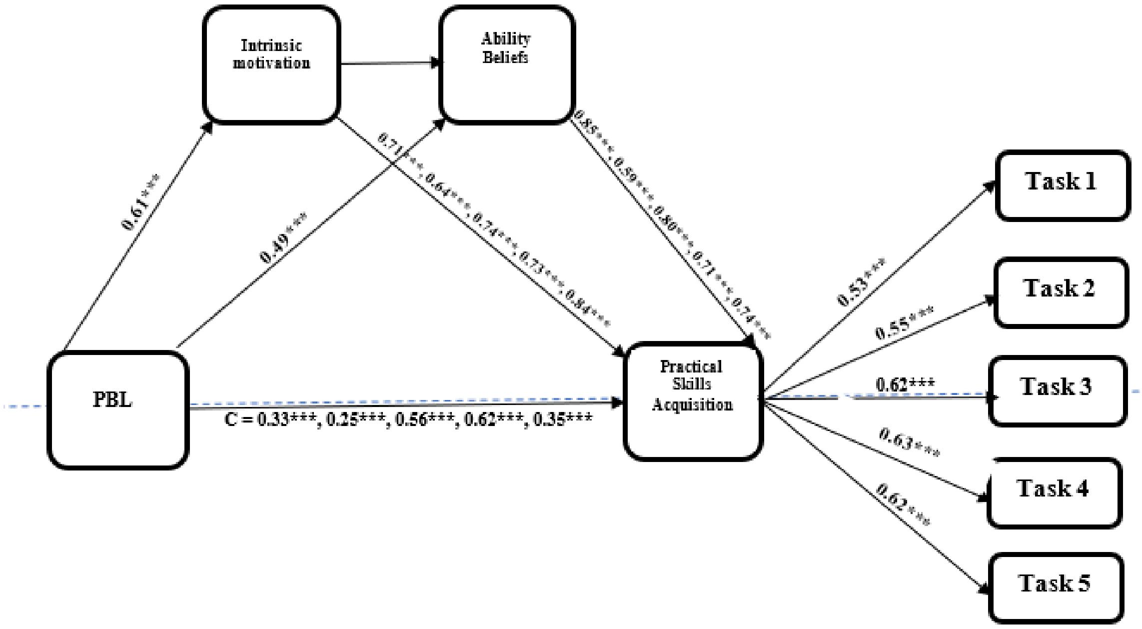

Figure 2. A sequential mediation model on practical skills acquisition.

Variables		Effects	Mediator	*β*	*SE*	*CI*	
						LL	UL
Task 1	Identification of circuit positions	Total		.334***	.061	.213	.456
		Direct		.053	.047	-.040	.146
		Indirect 1	AB	.333	.059	.224	.456
		Indirect 2	IM	.065	.037	.009	.137
		Indirect 3	AB →IM	.049	.029	.008	.106
Task 2	Conduit preparation	Total		.248***	.043	.161	.334
		Direct		.101	.048	.005	.197
		Indirect 1	AB	.131	.061	.203	.452
		Indirect 2	IM	.111	.047	.019	.203
		Indirect 3	AB →IM	.083	.037	.013	.161
Task 3	Drawing of cables	Total		.557***	.079	.398	.716
		Direct		.197	.068	.061	.332
		Indirect 1	AB	.263	.052	.171	.376
		Indirect 2	IM	.081	.037	.003	.151
		Indirect 3	AB →IM	.060	.029	.002	.116
Task 4	Termination and mounting of fittings	Total		.615***	.086	.444	.787
		Direct		.258	.085	.088	.428
		Indirect 1	AB	.174	.063	.053	.303
		Indirect 2	IM	.111	.042	.039	.201
		Indirect 3	AB →IM	.083	.034	.029	.160
Task 5	Inspection and powering circuits	Total		.346***	.049	.247	.445
		Direct		.081	.040	.001	.161
		Indirect 1	AB	.133	.038	.066	.216
		Indirect 2	IM	.197	.047	.106	.292
		Indirect 3	AB →IM	.147	.035	.085	.221

Table 4. Summary of Sequential Mediation Tests of direct and Indirect Effects on Practical Skills acquisition.

***$p < 0.001$; β – Beta for standardized estimate; *SE* – standard error; *CI* – confidence interval (*LL* – lower limit; *UL* – upper limit); Ind – indirect effect; AB – ability beliefs; IM – intrinsic motivation.

Table 4 revealed no significant direct effects of problem-based learning on task 1 (β = .053, *SE* = .047, *LL* = .040, *UL* = .146), and significant direct effects of problem-based learning on task 2 (β = .101, *SE* = .048, *LL* = .005, *UL* = .197), task 3 (β = .197, *SE* = .068, *LL* = .061, *UL* = .332), task 4 (β = .258, *SE* = .085, *LL* = .088, *UL* = .428) and task 5 (β = .081, *SE* = .040, *LL* = .001, *UL* = .161) of the practical skills learning outcomes via ability beliefs and intrinsic motivation. The data reveals significant specific indirect effects of ability beliefs on task 1 to task 5. The specific indirect effects of intrinsic motivation on task 1 to task 5 are also significant. The result shows that the sequential multiple mediation effects on task 1 (β = .049, *SE* = .029, *LL* = .008, *UL* = .106), task 2 (β = .083, *SE* = .037, *LL* = .013, *UL* = .161), task 3 (β = .060, *SE* = .029, *LL* = .002, *UL* = .116), task 4 (β = .083, *SE* = .034, *LL* = .029, *UL* = .160) and task 5 (β = .147, *SE* = .035, *LL* = .085, *UL* = .221) are significant. This suggests partial multiple mediation effects of intrinsic motivation and ability beliefs on PSA from task 1 to task 5 of the practical skills learning outcomes. The hypothesis is, therefore, supported.

Discussion and implications

The study employed task-based domestic conduit wiring scenarios to determine the association between PBL experience and PSA and the indirect sequential mediating effects of intrinsic motivation and ability beliefs. Our study made useful contributions to the study of PBLE, intrinsic motivation, ability beliefs, and Practical skills acquisition with respect to domestic conduit wiring as well as contributed to the assumptions that support the sequential mediating roles of intrinsic motivation and ability beliefs in the association between problem-based learning experience and practical skills acquisition. The study outcome revealed that PBLE is a positive and significant predictor of VET students PSA from task 1 to task 5. In other words, VET students PSA increase can be accredited to the problem-based intervention. Hence the more students get involved in finding solutions to practical problem scenarios in a PBL environment the more their practical skills experience increases. These results are in alliance with the study of Orji & Ogbuanya (2020) which established that a positive and significant association exists between PBL and engagement in practical skills acquisition among electrical/electronic technology students. Our study is also in agreement with the findings of Bedard et al. (2010), who determined that PBL curriculum is a significant predictor of electrical students' engagement. Our findings are congruent with the study Meti et al. (2024) and Bhosale, (2020) which found that PBL methodologies, such as designing electrical substations, significantly improve student engagement by involving them in real-world projects that require collaboration, problem-solving, and critical thinking. Similarly, our findings revealed that PBLE also predicted intrinsic motivation and ability beliefs significantly. This outcome shows that VET students' active participation in PBL environments helped to activate those psychological behaviours that made practical skills tasks exciting, engaging and enjoyable. This outcome validates the perspective that PBL experience helps to develop in students the confidence and belief to execute behaviours necessary to produce a specific performance, thus, increasing their practical skills outcome. These findings are congruent with the study of LaForce et al. (2017), which found that higher student ratings of PBL predict science intrinsic motivation and ability beliefs and predict higher student interest in STEM.

Furthermore, our findings show that intrinsic motivation and ability beliefs significantly predict VET students practical skills acquisition outcomes from task 1 to task 5. This implies that VET students whose intrinsic motives and ability beliefs increased as a result of the PBLE, participate actively in practical tasks that interest them without the necessity of material rewards. The enthusiasm is self-determined because the VET student has positive feelings while performing the task. This finding is comparable to the study of Orji & Ogbuanya (2020), who found that ability beliefs and intrinsic motivation are positive predictors of electrical/electronic technology education students' engagement in practical skills acquisition. The study is also in line with (Mwangi, 2018, Sheldrake et al., 2015), who found that ability beliefs significantly predict achievement. Additionally, the study is also in agreement with Cooper and Kotys-Schwartz (2022) who found that the introduction of project clients and real-world problem contexts can enhance students' intrinsic interest and accountability.

Our results revealed that sequential mediating effects of intrinsic motivation and ability beliefs were significantly supported. Thus, VET students' intrinsic motives and ability beliefs mediated the relationship between PBLE and practical skills acquisition. This suggests that VET students' exposure to PBL may not absolutely be the motive for their improved practical skills outcomes, rather they believe in their ability to be effective in the practical tasks of interest. Our finding is comparable to the study of Orji & Ogbuanya (2020), who found that ability beliefs and intrinsic motivation are multiple mediators of the of relationship between PBL and engagement in practical skills acquisition. These findings are also comparable with LaForce et al. (2017) who found that science intrinsic motivation and ability beliefs mediate the relationship between perceived PBL and student interest in a future STEM career. To the best of our knowledge, our study is the first to investigate the sequential mediating effects of intrinsic motivation and ability beliefs in the existing literature of PBL and PSA relationships. These results are how our study contributes to the existing knowledge of PBL, ability beliefs, intrinsic motivation, and practical skills acquisition.

Generally, the findings of this study offer important practical implications for vocational and technical education trainers. Specifically, our study suggests that trainers should use structured problem-based learning (PBL) activities that reflect real challenges found in the working environments. In our intervention, students engaged in five highly practical tasks, such identifying the correct circuit positions; preparing the conduit for marking out and laying the appropriate boxes; demonstrating how to draw lighting cables from the distribution board (DB) to the cooker control unit (CCU); terminating and mounting components such as the ceiling rose, wall brackets, sockets, switches, and the CCU; and finally, inspecting the installation for straightness of fittings, loose cables, unterminated circuits or boxes, and the effectiveness of the earthing system. Each task was linked to a realistic problem that electricians might face on the job, making the tasks highly relevant and applicable (Table 1). These activities helped students not only improve their technical skills but also increase their motivation and confidence in solving practical problems. For trainers, this means creating learning experiences that are hands-on, task-based and focused on problem-solving. It is also important to give timely and helpful feedback during these tasks to support students' belief in their own abilities. When students face meaningful problems and are guided in solving them, they are more likely to stay engaged and develop the practical skills they need for success in vocational careers.

Limitations and future research study

The positive outcome notwithstanding, limitations a bound in this study. First, study used self-report measures which may have resulted in self-report bias possible. Thus, the actual association between the study variables might be weaker or even stronger than the relationship observed in the study. The authors recommend the adoption of a different measure in future studies. Secondly, the sample size is very small. The generalization of the result of this study beyond the scope of this study should be done with caution. Nonetheless, G*power confirmed the sample big enough to warrant its generalization. In addition, 5000 resample bootstrapping method was also used, to ensure that the outcome of this study can be generalized (Hayes, 2013).

While this study offers valuable insights into the sequential mediating roles of intrinsic motivation and ability beliefs in problem-based learning environments, it also opens up several important areas for further research. The potential for future research to examine how these psychological constructs function across different vocational fields, such as plumbing, carpentry, or automotive technology, is vast and inspiring. This could determine whether the observed patterns are generalizable beyond electrical installations. In addition, the recommendation for longitudinal studies to assess the sustainability of practical skills acquisition and motivational gains over time, especially after student’s transition into workplace settings, is a call to action for all of us in the field. Another promising direction involves exploring how variations in trainers’ instructional styles, feedback strategies, and emotional support influence the development of ability beliefs and intrinsic motivation. Finally, with the rise of educational technology, future studies could compare traditional hands-on PBL approaches with hybrid or digital PBL models, such as those incorporating virtual simulations or augmented reality, to evaluate their relative impact on student engagement and practical competence.

Conclusion

Summarily, this empirical study has demonstrated that problem-based learning experience (PBLE) significantly predicts vocational students' practical skills acquisition (PSA) across all five performance tasks. The findings further suggest that this relationship is not merely direct but is sequentially mediated by students' intrinsic motivation and ability beliefs. These results extend our understanding of how PBLE can effectively support the development of practical competence in vocational electrical training programmes. Importantly, this study contributes to the growing body of literature by providing empirical evidence that the influence of PBL on skill acquisition is partly explained by its capacity to enhance learners' motivation and confidence in their abilities. Given the significance of these findings, further research is encouraged to replicate and expand this work across other vocational trades and instructional contexts to better understand the broader applicability of the proposed model. The need for such research is crucial to validate and strengthen this study's findings and enrich the literature on PBLE in vocational education and training.

Declarations

This work forms part of my doctoral research at the University of Nigeria, Nsukka, and was further enriched by insights and refinements during my postdoctoral fellowship at the University of the Witwatersrand, Johannesburg, particularly through access to its extensive library resources, analytical tools, writing center consultations, and participation in research seminars that influenced the development of this work.

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Using the Delphi Method to Understand Convergent and Divergent Perspectives of PBL Experts and Engineering Faculty in Aerospace Engineering

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Abstract

Problem based learning (PBL), though recognized as beneficial to student development, faces implementation challenges in engineering education. We conducted a Delphi study with PBL and (aerospace) engineering domain experts to understand challenges around learning outcomes, problem design, facilitation, and assessment. The context for the study was an introductory aerospace engineering course, transitioning from a traditional lecture to a PBL format. We found consensus among both expert groups as it relates to ideas about learning outcomes. However, with respect to problem design and facilitation, we observed a slower and more contentious convergence, with some ideas failing to reach consensus. From this, four salient issues emerged as potential barriers to PBL implementation that supports students in important aspects of their professional development: problem framing, making relevant connections to society, a deficit view of students, and discomfort with

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facilitation. Implications related to these issues are discussed, with consideration given to complications stemming from the isolated, individual-course implementations of PBL commonly found in practice.

Keywords: aerospace engineering; Delphi method; facilitation; problem-based learning; problem design

Introduction

Finding ways to authentically prepare and train students for engineering careers has been an important area of research over the last two decades (Direito et al., 2012; Mills & Treagust, 2003; Passow & Passow, 2017; Terenzini et al., 2001). Traditional pedagogies – i.e., lecture followed by well-structured problem sets (Jonassen, 2014) – are increasingly viewed as inadequate in preparing students for the profession (Direito et al., 2012). Problem-based learning (PBL), the focus of this study, is a student-centered pedagogy in which students learn by working through realistic problems under the guidance of an instructor (Servant-Miklos et al., 2019). However, non-traditional pedagogies like PBL are often met with resistance from both students and faculty (Du et al., 2022; Felder et al., 2011; Henry et al., 2012; Perrenet et al., 2000; Terenzini et al., 2001; Tharayil et al., 2018). Resistance to PBL can be attributed to a variety of challenges (Chen et al., 2021; Du et al., 2022; Mabley et al., 2020; Mora et al., 2017), and educators can find it difficult to adjust and effectively implement PBL in engineering environments even after receiving pedagogical training (Tik, 2014).

This study was motivated by the research team transitioning a traditional lecture-style introductory aerospace engineering course into one where problem-based learning (PBL) was the central instructional mechanism. In undertaking this transition, we sought to better understand how experts in PBL conceptualize the approach (e.g., what they view as essential to its theory and practice) and how aerospace engineering instructors perceive what can realistically be accomplished through PBL in an introductory course. These differing perspectives raised questions about how the course should be structured, what kinds of problems are most effective for fostering learning, and how facilitation and assessment practices might be aligned with both PBL principles and disciplinary expectations.

This study considers the most common form of PBL in engineering – an individual course implementation taken up at the discretion of an individual faculty member (Chen et al., 2021; Kolmos & de Graaff, 2014). The position of the authors of this paper is that of individuals who want to leverage the benefits of student-centered pedagogies, like PBL, but also operate within institutions where curriculum-coordination is minimal. Though we recognize and agree that an integrated-curricula would be more desirable from the perspective of the student experience (Kolmos & de Graaff, 2014) and programmatic coherence (Moesby, 2005), challenges associated with curriculum-level implementation and concerns stemming from isolated course implementations are beyond the scope of this study. However, limitations stemming from isolated-PBL implementations (representative of the context explored here) and their relevance to the findings and implications of this study are taken up in the Discussion and Conclusion sections.

This study explores this reality and its implications for PBL implementation, particularly in an introductory engineering course. By considering the perspectives of PBL experts and aerospace engineering faculty as domain-specific experts, two research questions are explored:

1. Where do PBL and domain-specific experts' ideas about PBL implementation converge?
2. Where do PBL and domain-specific experts' ideas about PBL implementation diverge?

We used the Delphi method – a method for reaching consensus among experts (Gordon, 1994; Green, 2014) – to consider elements of learning objectives, problem design, implementation/facilitation, and assessment of PBL in an undergraduate aerospace engineering course. While the typical aim of the Delphi method is to find consensus among experts, we leveraged it as a systematic approach to understand both consensus and lack thereof. Through this study we found consensus is more easily reached on the topics of learning objectives and assessment, while there are important areas of disagreement around problem design and facilitation. These areas of disagreement provide an avenue for fostering communication and collaboration between PBL and domain-specific experts so that adaptable and scalable PBL models can be created that overcome the implementation challenges often faced by engineering faculty.

In the next section, critical elements in the development and implementation of learning experiences are discussed through the lens of PBL literature with specific focus on problem design and facilitation, as these were areas of greatest disagreement. These elements informed our Delphi study design and engagement with the respective expert groups. That discussion is followed by a brief overview of the Delphi method.

Pedagogical challenges of PBL

The structure of our study was framed around consistent challenges in PBL implementation that fall into categories of problem design, facilitation, and assessment (Chen et al, 2021; Olewnik et al., 2023a). PBL is an active learning pedagogy in which "students are confronted with an open-ended, ill-structured, authentic (real-world) problem and work in teams to identify learning needs and develop viable solutions, with instructors acting as facilitators rather than as primary sources of information" (Prince & Felder, 2006). PBL, as envisioned in this study, has been classified as a case-based learning style in which students have high autonomy (Lavi & Bertel, 2024). Students work in self-directed teams that require significant learning of new course material (Borrego et al., 2013). The problem, not the instructor, is the primary vehicle for students' self-directed learning and knowledge construction (Hmelo-Silver, 2004; Kolmos & de Graaff, 2014). Here, we highlight specific aspects of these categorical challenges of PBL described in the literature, limiting that treatment to problem design and facilitation given that these aspects were the most contentious among experts.

Problem design

Designing good problems for PBL is a hallmark challenge, which must contend with the types of problems and characteristics like structuredness and complexity (Hung, 2016; Jonassen, 2000, 2010, 2014). Though there are approaches describing how problem design might be achieved (Garcia-Barriocanal et al., 2011; Holgaard et al., 2017; Hung, 2006; Pasandín & Pérez, 2021; Riis et al., 2017) operationalizing that literature is difficult because reporting on the operationalize context is often not sufficiently granular to inform translation into similar contexts (Olewnik et al., 2023a). This compounds other challenges of PBL related to lack of instructor training and scalable assessment strategies (Chen et al., 2021).

In engineering contexts, a contemporary focus on theory and math (Grayson, 1980) and meeting accreditation criteria (e.g., ABET in the United States) has fostered curricula rooted in well-structured problems (Jonassen, 2014; Lord & Chen, 2014) at the expense of more professionally relevant competences (Dym et al., 2005; Passow & Passow, 2017). Well-structured problems often take form in abstractions of real systems constrained such that students engage a "plug-and-chug" problem (Bucciarelli, 1994; Jonassen, 2014). Students rarely participate in even the development of objectives, requirements, and constraints that might be associated with activities of identifying and formulating problems (ABET, 2025); and even that is not fully representative of the activities that engineers might expect to engage to frame problems (Svihla

& Reeve, 2016). Thus, making students part of the problem design process is arguably an important need in PBL environments (Holgaard et al., 2017).

Implementation and facilitation

While the potential benefits of PBL are hard to refute (Beagon et al., 2019; Boelt et al., 2022; Galand et al., 2012; Kolmos & de Graaff, 2014; Kolmos et al., 2021; Strobel & van Barneveld, 2009; Terenzini et al., 2001; Warnock & Mohammadi-Aragh, 2016), successful execution can be a struggle for both faculty and students (Du et al., 2022; Henry et al., 2012; Mabley et al., 2020; McCracken & Waters, 1999; Mills & Treagust, 2003). The level of exposure to PBL environments can vary significantly from country to country and institution to institution. For example, Aalborg University uses PBL across their engineering curriculum. On the other hand, the use of PBL within engineering at the three U.S. institutions represented by this paper's authors is limited and at the discretion of individual course instructors. This is consistent with findings from Chen et al. (2021), which suggest that PBL implementations are more likely to be at course- rather than curriculum-level. Thus, PBL experiences encountered in engineering remain relatively rare and both faculty and students face significant discomfort in adapting to those experiences (Chen et al., 2021). Allowing students time to ramp into PBL work and increase their familiarity with the process over time has been recommended to counteract the uneasiness some students feel with this often-new style of learning (Blair et al., 2002; Mills & Treagust, 2003).

Additionally, a mixed-methods approach that balances traditional lecture-based coursework with PBL projects has been shown to be a successful way to approach PBL in an engineering curriculum (Blair et al., 2002; Perrenet et al., 2000) as it addresses this uneasiness on both the part of the student and teacher (Mills & Treagust, 2003), especially in engineering contexts (Perrenet et al., 2000). Finding this balance, however, is non-trivial. The addition of structure may make students (and faculty) more comfortable but may undermine some of the learning outcomes PBL seeks to promote (Henry et al., 2012; Hmelo-Silver, 2012).

The Delphi method and expert opinion

While there exist PBL experts, implementation of PBL is often done by instructors who lack sufficient training and that implementation takes place primarily at a course level (Chen et al., 2021; Tik, 2014). The introductory aerospace engineering course considered in this paper is taken by second-year engineering students and was added to the curriculum in 2014. The class meets once per week for 75 minutes. This course was added to the four-year curriculum by the Aerospace Engineering Course and Curriculum Committee, who then tasked a faculty member with designing and structuring the content. For the first 7 years, this course was a topics-based survey class. After receiving funding to restructure the course, the research team viewed this as an opportunity to incorporate PBL into the curriculum by making it the focus of the course. Because this course is not a prerequisite to other classes in the department, the research team had unprecedented freedom; the faculty member teaching it is the sole instructor of record and learning objectives and outcomes could be redefined.

Collaboration between PBL experts and non-experts seems like a pathway to overcome implementation challenges associated with PBL implementation, but such collaboration is limited in undergraduate engineering education. Considering this reality, we sought expert opinion in terms of how it might impact PBL implementation, which necessitated an understanding of convergent and divergent perspectives.

The Delphi method is a research tool that fosters "controlled indirect interaction among experts" (Fink-Hafner et al., 2019) in an effort to answer a given research question (Skulmoski et al., 2007). In this process, expert feedback is gathered, analyzed, and then reshared iteratively until a conclusion or consensus is reached or until the research goals have been achieved (Skulmoski et al., 2007). This approach has been successfully utilized in a broad range of research fields and applications (Adler & Ziglio, 1996; Clayton, 1997; Donohoe & Needham, 2009; Magana, 2017; Streveler et al., 2003; Woodcock et al., 2020) including, as it relates to our study, program planning in education (Delbecq et al., 1975; Green, 2014).

While the classical Delphi method utilizes one-on-one interviews to get individual participant responses for these iterative rounds of data collection (Fink-Hafner et al., 2019), modifications are often made to this structure to best fit the individual study being performed (Skulmoski et al., 2007). For example, e-Delphi refers to a variation of the Delphi method where data is collected through computer-based interactions (Donohoe et al., 2012). The modified Delphi is another variation of this process that reduces the researcher's heavy burden of successive one-on-one interviews by having individuals respond in parallel for structured discussions (Woodcock et al., 2020) or questionnaires. For this study, a modified e-Delphi method was used in which expert panelists responded to a series of electronically delivered surveys/questionnaires, which were developed after an initial round of focus group discussions.

Methods

This multi-case modified e-Delphi study considered two distinct systems of experts: (1) PBL in engineering experts and (2) aerospace engineering domain experts. PBL experts were researchers who had published multiple papers on PBL in engineering. Domain experts consisted of practicing aerospace engineering faculty. Because there is limited research on the use of PBL in aerospace engineering and because many aerospace engineering faculty do not have significant experience implementing PBL, both groups were critical for the Delphi study to capture the expert know-how that intersected both pedagogy and engineering domain knowledge. Consistent with the definition of case study research, multiple data sources were used (through two distinct focus groups and three rounds of continued data collection via Delphi survey responses) to deeply understand the ideology of each system (Creswell & Poth, 2016).

The Modified e-Delphi Method

Concept formulation and research team

For this study, the goal of using the modified e-Delphi method was to gather expert perspectives on the learning objectives, problem design, facilitation, and assessment of PBL for an introductory, 1-credit, second year undergraduate aerospace engineering course. The research team was led by two engineering faculty, one who teaches an introductory aerospace engineering course and one whose research is focused on improving teaching strategies in engineering education. The team also had two Ph.D. candidates whose research is focused on STEM education. Both worked in the K-12 STEM education space. Of note is that while everyone on the team is rooted in engineering education, the team is heterogeneous in terms of gender and work/professional experiences within engineering. In addition, an extensive systematic literature review of PBL, specifically as it relates to college-level engineering courses, was conducted in parallel to the Delphi study (Olewnik et al., 2023a) to ensure all participants of the research team had a thorough understanding of the current state of PBL in engineering prior to making decisions about how best to elicit expert opinions related to it (Fink-Hafner et al., 2019).

Recruitment of experts

After identifying potential experts in both PBL and aerospace engineering, recruitment emails were sent to potential candidates requesting their participation and ask for their recommendations for other experts in the field (Belton et al., 2019). The target recruitment was 15-20 total participants and even distribution of aerospace and PBL experts (Streveler et al., 2003), understanding that it is likely that some may not actively participate all the way through the process (Belton et al., 2019; Fink-Hafner et al., 2019). A total of 12 participants were ultimately secured for this study.

Engineering PBL experts

A Google scholar search of "PBL" and "engineering" was initially utilized to compile a list of potential experts. Authors of these papers were then searched independently to explore their body of work. Experts with at least three publications related to PBL and engineering, and explicit or implicit experience implementing PBL as presented through those publications (n=12) were contacted by email. Of the initial list of twelve experts, four did not respond and three declined, but did offer referrals for other participants. The remaining six participants agreed to participate in the study, with several offering additional referrals. Two additional experts were secured through the recommendation process. Of these eight experts, seven were able to attend the synchronous focus group meeting and therefore made up the panel of PBL in engineering experts included in this study. There were five men and two women representing institutions from the U.S. (3), U.K. (1), Northern Europe (2), and Australia (1). Information related to their experience and institutional context is shown in Table 1.

	Institution Type/Location	Role (Years of Instructional Experience)
Expert #1	Research University/Southeast US	Retired research scientist and PBL researcher (20+ years)
Expert #2	Research University/UK	Professor of communications systems engineering and PBL researcher (20+ years)
Expert #3	Research Uni./Southeast US	Director of learning sciences research in the college of engineering, PBL researcher (20+ years)
Expert #4	Research Uni./Northern Europe	Professor of engineering education and PBL researcher (20+ years)
Expert #5	Research University/Southeast US	Engineering department chair, PBL researcher (20+ years)
Expert #6	Research University/Northern Europe	Professor and PBL researcher (18 years)
Expert #7	Research University/Australia	Teaching faculty and PBL researcher (40+ years)

Table 1. Engineering PBL Expert Profiles.

Aerospace engineering faculty experts

The planned transition to a PBL environment motivating this study occurred within an introductory aerospace engineering course in the U.S. Instructors of a similar class at ABET-accredited U.S. universities were identified from class offerings listed online. A total of 12 experts were contacted, but only five participated in the study. Of these five experts, there were four men and one woman, representing institutions across the U.S. Information related to their experience and institutional context is shown in Table 2.

	Institution/Location	**Role (Years of Instructional Experience)**
Expert #1	Research University/North Midwest US	Retired aerospace engineering teaching faculty (20+ years)
Expert #2	Research University /Southwestern US	Aerospace engineering faculty, industry experience (10 years)
Expert #3	Research University /Southeastern US	Aerospace engineering faculty (10 years)
Expert #4	Research University /Southeastern US	Retired teaching faculty (30+ years)
Expert #5	Undergraduate Institution /Northeastern US	Teaching faculty, consultant (3 years)

Table 2. Aerospace Engineering Faculty Expert Profiles.

Data collection

The overall framework for the modified e-Delphi method is summarized in Table 3. The data collection strategy for each round of the study is detailed in this section.

	Round 0	**Round 1**	**Round 2**	**Round 3**	**Notes**
Methodology [1] *(including question type, etc.)*	Focus groups with a semi-structured, open-ended questioning script	Survey w/ Likert scale and open-ended qualitative questions	Survey w/ Likert scale and open-ended qualitative questions (shared with quantitative results from Round 1)	Survey w/ Likert scale and open-ended qualitative questions (shared with quantitative results from Round 2)	
Delivery medium	Face-to-face Zoom meetings	Emailed links to Google forms-based questionnaires	Emailed links to Google forms-based questionnaires	Emailed links to Google forms-based questionnaires	*To maximize convenience, participants were given a 1-week window in which to complete and return the questionnaire.*
Pilot/test strategy			n/a	n/a	
Estimated time to complete the activity[2]	60 minutes	30 minutes	30 minutes	30 minutes	*Total expected time obligation for participants to complete the study was 2 ½ hours[3].*

Target time to complete post-analysis by research team	3 weeks	2 weeks	2 weeks	2 weeks	*Total time required to complete the Delphi data collection and analysis is 9 weeks, with participant involvement for 7 weeks.*[4,5]

[1] Skulmoski et al. (2007)
[2] Belton et al. (2019)
[3] Participants were informed that this could change based on how quickly a consensus is formed during the modified e-Delphi process.
[4] This aligns with related research that indicates 2-3 months is an optimal time span in which to complete the surveys to keep participants engaged (Belton et al., 2019; Donohoe & Needham, 2009).
[5] As the Delphi method has been shown to be time-consuming not only for participants but for researchers as well (Fink-Hafner et al., 2019), the span of time utilized for this study should be selected such that it optimizes the time resources of both groups.

Table 3. Modified e-Delphi Protocol.

Round 0: Focus Groups

Following best practices, we used focus groups with semi-structured open-ended questions to generate issues for consideration in the survey rounds (Belton et al., 2019; Shmidt, 1997). Two distinct focus groups – one for each group of experts – were conducted virtually and were one hour in duration. Semi-structured questions related to design, facilitation, and assessment of PBL in engineering courses were used to guide discussion. The focus group with aerospace domain experts additionally considered learning objectives. Each session was facilitated by two members of the research team, one with qualitative research experience and one with content-area expertise. Discussions were recorded and subsequently transcribed for analysis.

Survey Round 1

The Round 1 survey consisted of both Likert-scale and qualitative, open-ended questions derived from the focus group discussions. Participants were given a series of statements related to problem design, facilitation, assessment, and learning objectives and were asked to rate their agreement with each statement on a 7-point bipolar scale (strongly disagree to strongly agree). Participants were also asked to provide rationale for their ratings (Belton et al., 2019) and were informed that they did not have to answer any questions in which they felt they lacked necessary expertise. The survey also included open-response questions to allow participants to share other relevant thoughts. Eleven of the 12 experts (5 aerospace, 6 PBL) completed the Round 1 survey.

Survey Round 2

Based on the analysis of the Round 1 responses a new survey was created with a revised series of statements that asked participants to reconsider any nonconverged statements from the previous round. Participants were again instructed to rate each statement, this time in terms of the importance they placed on each and offer open-ended explanations for their evaluations. Participants were also provided with information related to the results of the first round. This included the mean rating score and standard deviation for each Round 1 statement and a short summary of the overall sentiment of the open-ended data. The full, de-identified data set (including numerical responses and open-ended responses) was made available to participants as they worked through the Round 2 survey. In line with the Delphi method, providing group data to study participants is a way to broaden each person's understanding of other perspectives in an effort to move toward consensus. As in Round 1, 11 responses were gathered for this round of the study.

Survey Round 3

The final round comprised a much shorter survey, as only feedback regarding the four most divergent Round 2 statements was elicited from participants. Again, statements and response ideology (along with full open-ended responses) from the previous round were presented to the participants along with a final revision of the divergent statements. Rather than Likert-scale ratings, participants were simply asked to discuss their agreement or disagreement with the statement through open-ended responses. Like the previous rounds, eleven responses were collected in this concluding round of the study.

Data Analysis

Analysis for each round of the survey is explained in this section. While the Round 1 survey was analyzed largely quantitatively, the data analysis to determine statement convergence shifted from predominantly quantitative to predominantly qualitative as each survey round progressed.

Round 0: Focus Group Analysis Overview

Transcripts of the focus groups were reviewed and deductively coded to understand the content and key ideas expressed by the experts as part of a complementary study (Olewnik et al., 2023b). The transcript was structurally coded to help identify and categorize according to the key areas for PBL implementation considered in this study: learning objectives, problem design, facilitation, and assessment. The result of this analysis was a list of statements related to integrating PBL in an introductory aerospace engineering course, representing a specific application context application for study participants.

Survey Round 1 Analysis

The results of the Round 1 survey were investigated both quantitatively and qualitatively, starting with a quantitative analysis of the Likert-scale rating statements (Clayton, 1997). First, Likert-scale responses for each statement were analyzed to calculate an overall average score and an average score for each group of experts (Aerospace and PBL). The difference between the average scores for each group of experts was also calculated as a way of capturing the level of agreement between the groups. The standard deviation of the overall group was also calculated. As noted previously, this quantitative analysis was performed so that the relative convergence of the Round 1 questions could be shared with the experts during Round 2, thus informing participants of the group perspective (Clayton, 1997). To maintain participation in subsequent rounds – a noted problem for Delphi studies (Donahoe & Needham, 2009; Fink-Hafner et al., 2019) – the time obligation for subsequent rounds was minimized by considering statements with close statistical agreement as converged (Belton et al., 2019; Clayton, 1997). The research team identified statements with a delta between groups of experts of less than 0.5 points for the mean and an overall standard deviation of less than or equal to 1 as converged.

Data were then qualitatively considered, investigating the open-ended responses justifying each Likert-scale rating. The research team summarized the experts' sentiment from Round 1 and shared that, along with a link to the complete, open-ended qualitative data set with participants in Round 2 (Belton et al., 2019). Using the given rationale from each expert, the research team also performed a second convergence check to validate the quantitatively converged statements and to identify any additional statements that did not meet quantitative convergence criteria but that could be considered converged based on similar ideology and logic throughout the experts' statements (Belton et al., 2019). Finally, the research team discussed and considered the open-ended feedback from the experts to modify the divergent statements in a way that better reflected the experts' input. These modified statements were used to conduct the Round 2 data collection.

Survey Round 2 Analysis

Like Round 1, the data collected in Round 2 was first considered through quantitative strategies. The overall average score and standard deviation were calculated for each Likert-scale statement, however instead of this being the primary source of convergence used in this round, it was used mostly to identify trends for the researchers to use as they discussed the open-ended content for each statement. The team met and examined the experts' suggestions and ideas related to each Round 2 statement to determine what level of convergence was met for each. Statements that still were clearly divergent, as defined by a standard deviation greater than two, were used as the starting point for the final round of the study.

Survey Round 3 Analysis

The research team met to compare the open-ended responses from each expert against the latest statement provided in the third-round survey and categorized each response as having either “agreement,” “partial agreement,” or “disagreement” with that statement. The results of this rating were used to determine whether convergence was achieved for this final round of statements.

Findings: Delphi study progression

In this section, the outcomes from the modified e-Delphi survey are presented round-by-round. We limit presentation of findings to topics of problem design and facilitation because the statements related to learning outcomes and assessment quickly converged among the experts and proved less insightful and interesting. Design and facilitation, on the other hand, had a more contentious convergence process and for some ideas there was no convergence. The convergence process for each topic area is presented in Tables 2 and 3. Each table presents the quantitative results of the survey and how statements evolved (in some instances, two or more statements were merged – e.g., statements 1.5 and 1.6 merge as 2.4 in Table 2) based on feedback from the experts. Quantitative results are broken out by domain expertise for the first round because this was the first-time input from both groups was considered simultaneously, so seeing initial convergence/divergence by domain is presented. Though the convergence process is shown for all statements, we focus on the statements that appeared most tenuous and thus required additional rounds and/or combination with other statements to reach convergence, if they did.

Delphi study progression: problem design

For problem design (Table 4), we eventually found consensus among experts for all 14 of the initial statements. Four of the initially proposed statements were found to be uncontroversial within the panel of experts and converged in the first round of the study (1.3, 1.8, 1.10 and 1.14). Most statements, however, required revision to move toward consensus within the group.

Some revisions were just to clarify meaning or to include wording to address a specific area of concern exposed by the experts (1.2, 1.7). However, there was a recurring concern for many of the statements that were presented. Experts expressed concern about whether the ideology for a given statement was appropriate for a single-credit, second-year aerospace engineering course, where students are still relatively inexperienced in terms of their engineering coursework and general engineering practice. This was specifically seen in statements (1.4, 1.9, 1.12, and 1.13), and therefore updates to the wording to address these concerns were added as needed for the statement revisions for the subsequent round. A final revision strategy that emerged in the analysis of the problem design statements was combining survey statements. Specifically, if two statements conflicted (such as statements 1.5 and 1.6), the expert feedback for both statements was used to generate an updated version of the statement that addressed the topic with one statement only (e.g., statement 2.4).

There were two statements related to problem design that experts had distinctly opposing views on, however, and these statements did not converge based on the revision strategies. The first, statement 1.1, yielded a full range of Likert-scale responses from the experts, with their ideology ranging from agreement supported by the logic that "when students are given autonomy they form agency and are more motivated to learn" to disagreement related to the opinion that "the students, in general, do not have the knowledge they need to design meaningful problems." Much of the other feedback either loosely supported those two divergent views or was based on the previously discussed concerns related to having young engineers with little experience attempt a task like this. To offer a more centralized statement that reflected both sides of the argument, the research team modified this statement for the second round to create statement 2.1. While experts acknowledged the change in the statement, feedback was still split in the second round for many of the same reasons in the previous round. No improvement in convergence was achieved with this updated statement, as the standard deviation increased between the first and second rounds. The statement was again updated to address the specific expert concerns (such as clarifying the scale of the problem itself and recognizing the need for second-year students to have guidance in framing a problem) to form statement 3.1. The responses from this final revision indicated clear agreement and therefore the statement was judged to be converged. Through this progression, however, the resulting statement ideology merged with another existing statement (1.4 evolving to 2.3) and ultimately contextualized framing the problem as a function of requirement and constraint setting only.

The other statement that required additional convergence was statement 1.11. Expert feedback seemed nearly convergent after the first round except for one expert who simply needed more clarity in the question. However, after reformulating the statement to improve clarity, convergence was still not achieved. In this case, the revised second-round statement did not offer clarity to the experts effectively and instead introduced more disagreement and confusion (per their feedback). Statement 3.2 was provided as a final revision that eliminated the points of contention the experts shared throughout the study and this final statement converged in the third round. Like the previously discussed statement, however, the resulting statement that the experts were able to find consensus with had shifted to reflect less the idea of helping society introduced by the "greater good" term in Round 1 and more of a how-it-connects-to-society ideology that was already captured in an existing statement (1.9/2.6).

Round 1 Statements Group mean (SD); PBL mean; Aero mean *Convergence Categorization*	**Round 2 Statements** Group mean (SD) *Convergence Categorization*	**Round 3 Statements** *Convergence Categorization*
1.1 Students should be given the opportunity to design their own problems. All: 4.09(2.07); PBL: 4.80; Aero: 3.50 *Not converged*	2.1 We should have students identify and frame their own problem within a given problem context. All: 4.27(2.20) *Not converged*	3.1 Given a general problem topic that students will be given 2 weeks to solve, we should have students participate in framing their own problems by generating appropriate lists of requirements and constraints that will guide their problem solving. *Qualitative*
1.2 Problems should be designed with a clear understanding of the learning objectives and how the project/problem will meet those objectives. All: 5.64(1.63); PBL: 6.20; Aero: 5.17 *Not converged*	2.2 We should design problems such that they address specific learning outcomes for the course. All: 5.91(1.14) *Quantitative*	
1.3 Problems should be designed such that students work within constraints and requirements that simulate engineering practice. All: 6.18(1.17); PBL: 6.0; Aero: 6.33 *Qualitative*		
1.4 Students should be tasked with identifying the constraints and/or requirements for their problems.	2.3 We should task students with identifying the constraints and/or requirements for specific problems and, as introductory level underclassmen, ensure they are supported as they build their proficiency in this area.	

All: 5.78(1.30); PBL: 6.50; Aero: 5.20 *Not Converged*	All: 5.82(1.89) *Quantitative*	
1.5 A single, large/system-level problem that is broken into smaller subproblems should be utilized to offer depth of understanding within the aerospace engineering field. All: 4.64(2.01); PBL: 4.20; Aero: 5.00 *Not converged*	2.4 We should utilize a series of different problems to cover a range of topics and solution strategies students might encounter in the aerospace engineering field as opposed to focusing on a single, larger problem context that offers more depth.	
1.6 A series of different problem types should be utilized to cover a wide range of topics and solution strategies within the aerospace engineering field.		
All: 5.82(1.47); PBL: 6.00; Aero: 5.67 *Not converged*	All: 5.82(1.54) *Quantitative*	
1.7 Projects should be designed such that each team's work is interdependent on other team's work. All: 3.70(2.16); PBL: 2.75; Aero: 4.33 *Not converged*	2.5 We should design problems such that students are required to collaborate with other students in their team, but not require collaboration outside of the team for an introductory course.	
1.8 Projects should be designed such that they require collaboration among students (i.e., students are not able to simply divide the work, do it in isolation, and compile their findings at the end).		
All: 6.18(0.87); PBL: 6.00; Aero: 6.33 *Quantitative*	All: 6.00(1.34) *Quantitative*	
1.9 Projects should be designed such that they help students develop an understanding of society.	2.6 We should design problems/projects such that they help students understand how the aerospace engineering field integrates with society.	

All: 4.36(1.63); PBL: 4.80; Aero: 4.00 *Not converged*	All: 5.36(1.69) *Quantitative*	
1.10 Problems should be designed to be exciting for students in order to engage them and keep them motivated. All: 6.45(0.82); PBL: 6.60; Aero: 6.33 *Quantitative*		
1.11 Problems should be designed such that students feel their projects have a purpose for the greater good. All: 4.27(1.62); PBL: 4.00; Aero: 4.50 *Not converged*	2.7 We should design projects so that they show students how the aerospace field connects to the greater good to help engage a diverse group of students. All: 4.55(2.07) *Not converged*	3.2 We should design problems that allow students to see how the aerospace engineering field impacts society. *Qualitative*
1.12 A variety of different problem types should be utilized to reflect authentic engineering practice. All: 6.09(1.51); PBL: 6.60; Aero: 5.67 *Not Converged*	2.8 We should utilize a variety of different problem types (selection, case analysis, design, etc.) to broaden students' exposure to the range of problems they will face in engineering practice. All: 5.64(1.12) *Quantitative*	
1.13 Projects should be designed such that they help students develop problem-solving skills. All: 6.91(0.30); PBL: 6.80; Aero: 7.00 *Quantitative Convergence*		
1.14 Problems should be authentic to the practice of engineering. All: 5.55(1.69); PBL: 5.60; Aero: 5.50 *Not Converged*	2.9 We should design problems to be authentic to the practice of engineering; meaning that student engineers should experience some of the messiness of practice through simplified scenarios. All: 6.27(0.90) *Quantitative*	

Table 4. Problem Design Statement Convergence.

Delphi study progression: facilitation

For facilitation (Table 5), several initial statements converged without revision (1.1, 1.2, 1.3, 1.5, 1.6, 1.13, 1.14, 1.15) and one statement (1.16) was deemed redundant. A few statements (1.7/2.2, 1.8/2.3, 1.9/2.4, 1.10/2.5, 1.11/2.6) required minor revisions and clarification to reach consensus but revealed some deeper beliefs or attitudes about the nature of the faculty-student relationship and responsibility for learning and knowledge acquisition. This is particularly true of 1.7/2.2 and 1.8/2.3, where we concluded that convergence was contentious owing to a deficit view of students among some experts.

Statements 1.7/2.2 focus on relevant, adjacent prior knowledge that might be valuable to students engaged in PBL scenarios. For example, students engaged in an analysis problem might bring to bear software like Excel or MATLAB as part of the problem-solving tasks. Experts indicated a concern that a lack of such prior knowledge would put more onus on the class to teach those skills. Sentiment among experts was that "surface level" introduction to software is okay, but a need to teach too much would lead to a class being "over-stuffed" with content. This type of feedback seemed more concerned with the logistics of the course and how much content could be covered. Other experts were more concerned that worrying about students having all necessary knowledge or directly teaching certain skills would actually undermine the classroom: "…if you expect to give them all the skills in advance then you're not really doing problem-based learning…"

Statements (1.8/2.3) related to students as "junior colleagues" was viewed as an ideal aim for a PBL environment, but some experts bristled, especially aerospace experts. The most extensive comment, that seemed to summarize the group sentiment stated:

> "In theory, this would be great, in practice you'd probably lose 50%+ of the class. Actual engineering requires people to do self-learning to find solutions, given that they have the basic fundamentals down. For intro students, they don't know the fundamentals yet, and the US primary school system does not really teach self-learning that much. So you'd get a lot of students flailing around and being lost. There will be a handful who thrive and do a lot of their own searching and learning, but we should teach to the whole class, not just the really good students."

Ultimately, experts saw treating students as junior colleagues as desirable, but potentially something that might be difficult to achieve given variability among students.

A series of statements related to the amount of lecture (1.12/2.7/3.2) that should be used in PBL were contentious. Though a qualitative convergence was found, the final statement (3.2) is sufficiently vague as to hide some of the deeply held beliefs and attitudes of experts toward lecture. For some experts, lecture is vital to teaching: "Traditional lectures are the best way of transmitting factual information which may be required for projects" or important to reinforcing student independent learning: "Lecturing should always follow student research to deepen and broaden what they have already discovered." On the other end of the spectrum, lecture has no place in a PBL setting, and the final statement is moving in the wrong direction:

> "The revised statement is meaningless – 'we should have variety' is not the same concept as 'we need to move away from traditional lectures.' The goal here is to ensure that the move to a new pedagogy doesn't get weighed down by faculty bringing their dependence on lectures with them."

One series of statements (1.4/2.1/3.1) related to challenging students through the introduction of "chaos" did not converge. While a few experts agreed with the final statement or offered minor changes, many did not agree. The divergence of opinion among experts included a deficit view of students ("…should be presented as an option for excellent students…more suitable for later year group"), concerns over the student experience ("…introducing mid-course changes in expectations, no matter how realistic, will detract from the student experience"; "introducing new challenges will only confuse the students"), and a view that disrupting the process is important to student professional preparation ("the chaos isn't about the experience at the time, it's about building resilience for everything that follows"). The lack of convergence appears to be rooted in divergent perspectives on how education should prepare students.

Round 1 Statements Group Mean (SD); PBL mean; Aero mean *Convergence Categorization*	**Round 2 Statements** Group mean (SD) *Convergence Categorization*	**Round 3 Statements** *Convergence Categorization*
1.1 Failure should be both valued and accepted as a part of the learning process. All: 6.36 (.81); PBL: 6.40; Aero: 6.33 *Quantitative*		
1.2 PBL is best utilized if/when students are fully immersed in the PBL experience throughout the course. All: 6.00 (1.18); PBL: 5.60; Aero: 6.33 *Qualitative*		

1.3 As teams work through their problems/project, facilitators should ask probing questions that promote an increased depth of understanding of the problem and related content. All: 6.55 (.52); PBL: 4.60; Aero: 4.83 *Quantitative*		
1.4 Facilitators should introduce chaos into problems if and when they feel it can be managed. All: 4.18 (1.40); PBL: 4.60; Aero: 3.83 *Not Converged*	2.1 We should introduce chaos (such as new or additional challenges) into problems if and when they feel it can be managed, keeping a close watch on morale to ensure this does not have a negative impact on students having an introductory experience with aerospace engineering. All: 4.27 (2.41) *Not Converged*	3.1 We (as faculty) should introduce new or additional challenges into problems if/when we feel it can be managed, keeping a close watch on morale to ensure it does not have a negative impact on the student's introduction to aerospace engineering. *Not Converged*
1.5 There should be multiple facilitators for a course taught with PBL so that different facilitators can take on a different role (such as "Teacher" and/or "Client") within the PBL framework. All: 4.73 (.65); PBL: 4.60; Aero: 4.83 *Quantitative*		
1.6 Student/team progress should be monitored using milestone checkpoints to ensure students are "on track" before they advance to the next phase of the project. All: 6.64 (.67); PBL: 6.20; Aero: 7.00 *Qualitative*		
1.7 Careful consideration should be paid to ensure students have the background skills (such as fabrication skills, software-specific skills, etc.) needed to complete the project.	2.2 We should teach the background skills needed to complete a given project (such as fabrication skills, software-specific skills, etc.) in class along with the content.	

All: 5.00 (1.95); PBL: 4.80; Aero: 5.17 *Not Converged*	All: 4.91 (1.76) *Quantitative*	
1.8 Students should be treated as junior colleagues (as opposed to the traditional teacher-student relationship) to help build a mindset that more closely reflects a practicing engineer. All: 5.18 (1.33); PBL: 5.40; Aero: 5.00 *Note Converged*	2.3 We should treat students as junior colleagues (as opposed to having a traditional teacher-student relationship that focuses on one-directional knowledge transfer from the teacher) to help build a mindset that more closely reflects a practicing engineer. All: 5.45 (1.75) *Quantitative*	
1.9 A variety of different team sizes and groupings should be utilized to reflect authentic engineering practice. All: 3.82 (1.83); PBL: 4.20; Aero: 3.50 *Not Converged*	2.4 We should keep team sizes consistent between groups for logistical purposes. All: 5.82 (1.54) *Qualitative*	
1.10 Facilitators should take care to not have preconceived ideas about what the “correct” solution is to problems that are posed. All: 5.27 (1.68); PBL: 5.80; Aero: 4.83 *Not Converged*	2.5 Facilitators should have a general idea of the expected outcome for given problems but should take care to be open to new solutions posed by students. All: 6.09 (1.38) *Quantitative*	
1.11 Facilitators should build a class culture where the process is more important than the outcome. All: 5.55 (1.57); PBL: 5.20; Aero: 5.83 *Not Converged*	2.6 Facilitators should build a class culture where both the process and outcome are highly valued. All: 6.00 (1.00) *Qualitative*	
1.12 Traditional lecturing should not be utilized in a PBL curriculum. All: 3.27 (2.24); PBL: 4.40; Aero: 2.33 *Not Converged*	2.7 We should utilize traditional lecturing on an as-needed basis in a PBL curriculum. All: 5.36 (2.25) *Not Converged*	3.2 We should use different teaching practices (discussion, lecturing, etc.) as needed to best help students progress forward in their problem-solving work. *Qualitatively*

1.13 Faculty should be enthusiastic about the content area and problems that are posed. All: 6.36 (1.03); PBL: 6.00; Aero: 6.67 *Quantitative*	
1.14 Facilitators should understand the mindset and level of a young undergraduate and ensure their communication and expectations match this level (as opposed to speaking at a high-level researcher or industry professional level). All: 6.00 (1.00); PBL: 5.60; Aero: 6.33 *Quantitative*	
1.15 Upperclassmen who have previously taken the course should be utilized as teaching assistants to improve facilitation (and additionally offer growth opportunities for the upperclassmen) All: 6.36 (.81); PBL: 6.20; Aero: 6.55 *Quantitative*	
1.16 Class time should be spent in two-way discussion as opposed to one-way communication solely from the instructor. All: 5.73 (1.42); PBL: 6.00; Aero: 5.50 *Redundant*	

Table 5. Facilitation Statement Convergence.

Discussion

Two research questions were considered in this study: 1) Where do PBL and domain-specific experts' ideas about PBL implementation converge? and 2) Where do PBL and domain-specific experts' ideas about PBL implementation diverge? Our interaction with PBL and aerospace domain experts considered four general areas – learning outcomes, assessment, problem design, and facilitation – but design and facilitation proved to be the most contentious topics, so we focused our reporting on those. Specific points of convergence, contention, and divergence for design and facilitation are shown in Table 6.

	Well implemented PBL experiences…
Convergent	… include students in the identification of problem constraints and requirements
	…address specific course learning outcomes through a series of problems (breadth) rather than a single semester-long problem (depth)
	…simulate engineering practice, exposing students to different types of problems and the messiness of those problems
	…establish student teams of consistent size and limit collaboration to within those teams
	...excite and motivate students' engagement through interesting problems and facilitators who are enthusiastic about the problem topics
	…recognize failure as a valuable part of the learning process
	…are full PBL-immersion throughout the course (i.e., student-centered problem-engagement is the primary pedagogical approach)
	…use probing questions to promote deeper understanding and engagement
	…include multiple facilitators who can assume different roles as needed and who adapt their mindset to the experience level of students; integrate PBL-experienced upperclassmen as facilitators
	…teach background skills for tools (e.g., software, fabrication tools) if necessary for producing problem deliverables
	…monitor student progress using milestone checkpoints
	…have some sense of the boundary for the expected solution outcomes but are open to new solution paths
	…create a culture where both solution process and product are valued
	…position students more like junior colleagues/engineers who co-construct knowledge with facilitator/expert guidance rather than relying on one-directional transfer of knowledge from expert (teacher) to novice (student)
Contentious	…allows for different teaching practices (e.g., discussion, lecture) as needed to help students
	…engage students in framing of problems
	…help students understand how aerospace engineering integrates w/ society
Divergent	…introduce new or additional challenges to a problem after engagement begins to simulate the emergent or changing nature of problems in practice

Table 6. Summary of convergent, contentious, and divergent ideas among experts.

We eventually found consensus among experts as it relates to problem design, though for two issues – problem framing and the connection of aerospace engineering society – this proved contentious. For facilitation, we generally found consensus, but one issue related to facilitation strategies (i.e., lecture or not) was contentious, and one issue (i.e., introducing emergent issues) did not reach consensus. Through the Delphi process we identified four specific issues that reflect potential points of contention between PBL and domain experts: problem framing, the social impact of (aerospace) engineering, a deficit view of students, and the fraught nature of facilitating student engagement with more open-ended, less well-structured problems. As these issues are intertwined and transcend the categories of the study, we address them directly. Additionally, we consider potential complications stemming from isolated-PBL implementation as described in the Introduction.

Framing of problems

Involving students in the framing of problems was ultimately reduced to having students identify constraints and requirements. In converging to this, the element of design and framing is slowly excluded from the original idea through progressive rounds of the Delphi study. The experts' feedback suggests either they were unfamiliar with what framing entails ("Faculty should not just let students do whatever they want") or a discomfort with students taking ownership for designing and framing problems ("asking students to 'create a problem' then 'solve the problem' muddles the process of defining objectives and constraints and how a design should adhere to them") and perhaps losing the design intent.

Framing a problem is more than just understanding requirements and constraints (Holgaard et al., 2017; Svihla & Reeve, 2016), and involves consideration of impacted stakeholders, understanding the root cause of the problem, and considering multiple approaches to solving that problem, which is beneficial for students in their problem-solving abilities. This ideology was distinctly opposed by some of the experts, however, who believed either that students were too young and inexperienced to tackle problem framing or that it was not the right place to implement an activity like this ("While it is important to establish a definition of (to 'frame') a problem and to agree upon the problem definition with the client and design partners, this is not the place to establish ownership"). In so much as engineering acts in the service of design (Dym et al., 2005) and framing is an essential element of design problems (Dorst, 2019), students should be provided with multiple opportunities to develop and practice this skill throughout the curriculum. Arguably, problem framing is an increasingly important skill for humans to develop as a complement to the ever-improving problem solving capability of artificial intelligence (Cukier et al., 2022).

Given this, middle years PBL environments seem like an ideal place for that development, especially since the middle years are often focused on engaging core theory (Lord & Chen, 2014) with little attention on non-technical facets of problem solving, like framing. In isolated-PBL implementations, limiting students' framing work to requirements and constraint identification may be more realistic. More substantive framing work by students would be more appropriate in systemic-PBL models -- i.e., programs in which problem- and project-based learning are coordinated across the curriculum (Kolmos & de Graaff, 2014), where students have multiple problem-based experiences that can support progressive engagement with framing. Our findings indicate that work is needed to advance faculty knowledge of and comfort with involving students in the framing of problems.

Broader connection to society

Another area where convergence did not come easily was in the category of problem design that integrates and connects aerospace engineering to society. Dissenting feedback on the original statement seemed rooted in the use of the words "greater good" with expert sentiment stating "[Greater good] is a very subjective concept. The greater good has many, many dimensions, many not quantifiable" and "I do not understand what this statement means in the context of the subject of this survey." These concerns were still voiced in the second round, with experts suggesting explicitly that the statement could be modified to say "something like 'the ways in which the aerospace field connects to...'. Not everything aerospace is for the greater good." Overall, experts struggled with PBL and broader societal conceptions in ways similar to students (Servant-Milkos & Kolmos, 2022).

Through these modifications, however, the idea of aerospace engineering having a *positive* impact on society was lost, and simply the impact of the field on society was captured. Research suggests that engineering students, particularly underrepresented groups like women and persons of color, often lean towards fields where they can clearly see the positive impact their work can make on humanity (Capobianco & Yu, 2014) and their respective communities (McGee & Bentley, 2017). Our experts specifically noted that they were unfamiliar with this research, which may explain divergence from the initial sentiment of connecting with a "greater good." While generally we agree that not everything in aerospace engineering can or should be cast in terms of a greater good, developing PBL environments that do some of this work has potential to broaden participation in aerospace engineering (and other engineering disciplines), which generally lacks diversity (Roy, 2019).

Deficit view of students

Among some experts, a deficit view of students seemed to undermine or constrain ideas about what facilitation strategies could work. Deficit thinking holds to assumptions about what students cannot do owing to individual traits, prior experiences, and/or cultural and community deficits (Davis & Museus, 2019). Deficit thinking has long been observed as applying to individual students from historically oppressed and marginalized groups (Valencia, 2010) but has, over time, also come to consider educational systems (e.g., schools) as reinforcing deficits in students' abilities (Davis & Meuses, 2019). This limits opportunities for students' participation and important forms of learning in engineering and is particularly harmful to students from underrepresented populations (Long III & Mejia, 2016; Mejia et al., 2018; Minichiello, 2018).

In the introductory PBL context explored in this study, in addition to students' lack of fundamental knowledge, perceptions that half of students cannot be self-led learners were cited as a limiting factor in how students might be expected to work in a more independent fashion. The implication is that facilitation strategies that require students to direct their learning should be deferred to a later time in the curriculum. However, further delaying students' engagement with self-led learning experiences does not resolve the issue. Being a self-led learner matters to the profession and is expected of good problem solvers (Passow & Passow, 2017). There is a need to disrupt forms of educational engagement that fail to develop this skill and reinforce deficit perspectives in the first place. PBL environments are ideal spaces to develop and refine that skill. However, isolated-PBL is likely to amplify the deficit-view of faculty and impede the ways in which students are allowed to become self-led learners.

PBL facilitation is uncomfortable

We identify meaningful overlap between a statement from problem design and a statement from facilitation that required all three rounds. In problem design, there was a difference of opinion between PBL and aerospace faculty around the extent to which students should be allowed to formulate their own problems. The modification of this statement over each round saw additional guardrails placed on the framing of the problem. Aerospace engineering faculty expressed a desire to know about, and have some control over, the progression and end point of the problem. There was also a difference of opinion around the idea of introducing (controlled) chaos into the isolated-PBL environment. Unexpected challenges and required changes in direction are a meaningful, and common, part of authentic engineering problems (Jonassen, 2014; Passow & Passow, 2017). However, implementing this in a classroom setting where the learning objectives are still met, and student morale does not suffer is an area of concern and there is a need for further research to support faculty in this role.

Facilitation in a PBL environment is a fragile and fraught balancing act. Our experience with isolated-PBL environments is that students are often concerned (perhaps even afraid) about working in teams and engaging with problems that are not completely defined. Yet, the statements from faculty in our study suggest that educators may be as afraid (if not more) than students about the open-ended nature of PBL problems, in line with existing literature (Chen et al., 2021; Henry et al., 2012; Hmelo-Silver, 2012). The introduction of even "controlled chaos" further moves the problem into an open-ended space where the outcomes of the student work will likely possess increased variability and there are greater chances for failure. Thus, pedagogical training, facilitator characteristics, and scaffolding strategies are vital considerations for successful implementation of PBL (Ertmer & Glazewski, 2019; Hmelo-Silver et al., 2019).

Conclusion and implications for practice

This study demonstrates the value of engaging multiple groups of experts to inform the implementation of new pedagogies. Specifically, it showcased the value of considering the opinions of PBL and aerospace engineering experts when implementing an isolated-PBL experience in a single course within a 4-year curriculum. Our findings highlight areas of consensus while exposing contentious issues that threaten to undermine the transition of a course from a lecture format to PBL. While there is consensus among these experts as it relates to learning outcomes and assessment, the contentious issues related to problem design and facilitation practices are such that realizing those learning outcomes will be difficult, if not impossible.

Though we followed best practices, we note three important limitations associated with the implementation of our Delphi study. First, the findings of this work are limited by the number of expert participants. Though we believe the perspectives and derived findings are representative of the broader engineering education community, it may not fully capture the variability of that community. Of note, our study lacks perspective of experts from institutions in regions like Asia and Latin America. Second, the asynchronous and anonymous nature of the modified e-Delphi study may have impacted convergence, as it naturally limits the nature of interaction among the experts. Third, the consideration of four categories – learning outcomes, assessment, problem design, and facilitation – may have limited the level of feedback given constraints on individual experts' time.

Considering the study's findings and limitations, we conclude with two broad implications of this work as it relates to isolated-PBL implementations. First, as it relates to the key findings, contentious issues that impact problem design and facilitation signal specific ways in which faculty perceive PBL as a risky endeavor. Lack of formal pedagogical training alongside pressures related to research output and teaching evaluations might make this a risk not worth taking. As we have argued elsewhere (Olewnik et al., 2023a) design-based research at the granularity of individual problems is needed to further inform design and facilitation practices in PBL. In consideration of this study, that research should bring together PBL and domain experts to capture and analyze deep forms of data that contend with these issues to inform pedagogical training. Such research should capture problem design intent, faculty intent and reflection on facilitation strategies, faculty-student interaction, and the extent to which individual student learning aligns with design intent. This is necessary to give more confidence to faculty who may consider PBL but want to see more specific evidence of successful application. Formalizing an engineering PBL community of practice, with regular, research-informed training opportunities would be a valuable outcome. Complementing the formation of such a community, institutions should do more to incentivize and support the adoption of student-centered pedagogies, like PBL. This idea is not new but continues to be reinforced by technological advances (e.g., devices, online demonstrations) that make access to problem relevant knowledge increasingly ubiquitous.

Second, as it relates to overcoming the current study's limitations, replicating the general study protocol employed here, but expanding to include additional PBL and domain (including other engineering disciplines) experts, alongside synchronous conversations that consider more focused topics could yield more robust understanding of the issues. This includes a need to expand the pool of experts to a range of institutions and regions/cultures. Additionally, conducting such a study synchronously and in-person over several days with a more focused set of issues may yield more nuanced understanding within the community. This would further inform the classroom-based research envisioned above. It may also set stronger foundations for a still somewhat disparate PBL community of practice that can collaborate on problem design and facilitation strategies, as well as assessment methods that align learning outcomes with problem design and facilitation strategies. Furthering the development of this community is critical to a synergistic research-to-practice cycle that enables more effective implementation of PBL.

Future work should contend with the transition from isolated- to systemic-PBL implementations. Such work is necessary to overcome inherent challenges of isolated-PBL tied to the student experience (Kolmos & de Graaff, 2014) and a need for curricular coherence (Moebly, 2005). It poses important questions related to the design, facilitation, and assessment of PBL scaled across the curriculum beyond the scope of this study.

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Towards a Theory of Generative AI in Problem-based Learning

Insights from a Design Experiment at Aalborg University

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Abstract

This article presents a design experiment in which generative artificial intelligence (GAI) was topically integrated into a Problem-based Learning module in a pedagogical study programme with the intention to generate insights for both, future GAI-in-PBL practice and theory. Based on various data (student reports, notes, a focus group interview, transcripts of teachers/researchers' discussions), three design elements were assessed regarding their potential to help students to develop their own learning practices with GAI, and regarding how the emergent practices and dynamics enrich existing PBL theory. The analysis revealed students' weariness, shame and fear for/of using GAI, but also how the PBL process enabled them to develop their own reflective and nuanced GAI practices built on their own learning, integrating community, communication and trust. The experiment also revealed co-knowledge construction amongst students, while

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stakeholders and teachers were seen as figures of authority on how to approach GAI.

Keywords: Generative artificial intelligence; ChatGPT; Problem-based Learning; students; design experiment; exploration

Introduction

Scholars and practitioners currently are not shying away from heralding the potential of generative artificial intelligence (GAI) for learning purposes, praising the technology's advantages as to "better meet students' learning needs, improving their efficiency and grades" (Yu, 2023: 5) by virtue of "its ability to respond to user prompts to generate highly original output" (Chan & Hu, 2023: 2), thus enhancing language learning (e.g., Crompton & Burke, 2023), helping with brainstorming ideas (e.g., Atlas, 2023), or provide customized scaffolding and feedback (e.g., Dai et al., 2023). And while the usefulness of GAI for certain types of learning needs to be acknowledged, it needs also to be stressed that recommendations on how to integrate this technology with learning processes seem to come primarily from a perspective under which learning is being conceptualized as a mainly cognitive enterprise, building on knowledge conceptualizations previously institutionalized.

The present study took offset in a concern that the learning possibilities of GAI heralded at the moment are not fully suited to account for learning in an active learning context such as Problem-Based Learning (PBL). PBL builds on learning conceptions that embrace the sociability, materiality and open-endedness of the learning process, thus opening for understandings of knowledge as socially and contextually constructed (e.g., Hung et al., 2019). Thus, in this paper we are exploring how GAI that can be understood not as a tool for certain learning, but as a technology that is part of the learning process owned by students under those premises.

Previous research has shown that students in PBL environments create their own (divergent) logics and practices when appropriating digital learning technology, often answering to the demands of the PBL-process (Sørensen, 2018). Concomitantly, there is evidence that what guides students' learning processes in technology-enhanced PBL not necessarily is the technology's affordances, but their preferences and interests in terms of modes of studying and interacting (Scholkmann, 2017). Also, students in a PBL-environment have been shown to perceive digital technology useful for amongst others engagement, communication and efficient collaboration (Silin & Kwok, 2016) –

functions that are not necessarily addressed in current scenarios of how to integrate GAI with learning.

To not prematurely follow existing suggestions about GAI-use for learning, the present study followed an open exploratory approach to gain insights into how GAI can be integrated in accordance with active, embedded and problem-based learning principles. The call for integrated and exploratory approaches towards GAI in learning has recently been raised for example by Carvalho and colleagues, who stated that learning in a world in which AI plays a role will need "[p]edagogical practices that emphasize human skills (creativity, complex problem solving, critical thinking, and collaboration) (…) for supporting one's ability to communicate and collaborate with AI tools in life, learning, and work." (Carvalho et al., 2022: 2).

Due to the novelty of the phenomenon, we chose Design-Based Research (DBR) as an approach integrating teacher, student, stakeholder and researcher perspectives (Design-Based Research Collective, 2003). With the design experiment as DBR's preferred method (Reimann, 2011), we infused GAI as a topic in an introductory module in one of Aalborg University's (AAU) pedagogical master programs, where we focussed on students exploring their own and other students' use of the technology. Due to DBR's ambition to contribute to development of both, concrete pedagogical practice and learning theory (Reimann, 2011), the research question we are asking for this article is: *What are theoretically grounded focus points for future scenarios of GAI-PBL-integration based on the insights gathered during a design experiment on this topic?*

Design-based research as methodological approach

DBR as an educational research paradigm

Design-based Research (DBR) builds on the idea of "experimenting to support learning" (Reimann, 2011: 40). A pedagogical intervention is designed and executed under authentic conditions (Anderson & Shattuck, 2012), with the intention of "testing and revising conjectures about both the prospective learning process and the specific means supporting it" (Cobb & Gravemeijer, 2008, after Reimann, 2011: 40). Within that, DBR goes beyond the immediate and short-term adjustment of the didactics applied, but builds on targeted and theoretically grounded data gathering which provides the potential to extrapolate towards a situated theory or learning (Reimann, 2011).

Elements that need to be operationalized in a DBR-study are *iterative cycles* of design, enactment, analysis, and redesign; *collaboration* with practitioners to address real-world problems in authentic contexts; *theoretical and practical goals* aiming to develop theories and practical solutions simultaneously; an *interventionist approach* that implements and tests in real-world settings; *rigorous and reflective inquiry* to refine both the design and the theory; *contextual relevance* ensuring that the research accounts for the complexity and context of the environment; *stakeholder involvement* in the design and evaluation process; and *scalability and sustainability* of the interventions (Brown, 1992; Collins, 1992; Design-Based Research Collective, 2003; Barab & Squire, 2004). Moreover, in an educational design experiment also factors such as the specific *educational context* and the *learning theories underpinning the pedagogical approach* need to be made explicit (Campanella & Penuel, 2021).

DBR also been called out for its "messiness" (Hanghøj et al., 2022: 222) when it comes to a clear isolation of influential or less influential factors in the design process (cf. also Dede, 2025). However, the approach's validity can be found in its embracement of "participatory design traditions of Scandinavia" (Campanella & Penuel, 2021: 3) and its potential to "not only produce better interventions but also to transform people and systems" (Hoadley & Campos, 2022: 207) in the sense of "a form of scholarly inquiry" (Bell, 2004).

The design experiment in the present study

A general overview over the design experiment executed for this study can be found in figure 1, while the specific elements will be explained in more detail below.

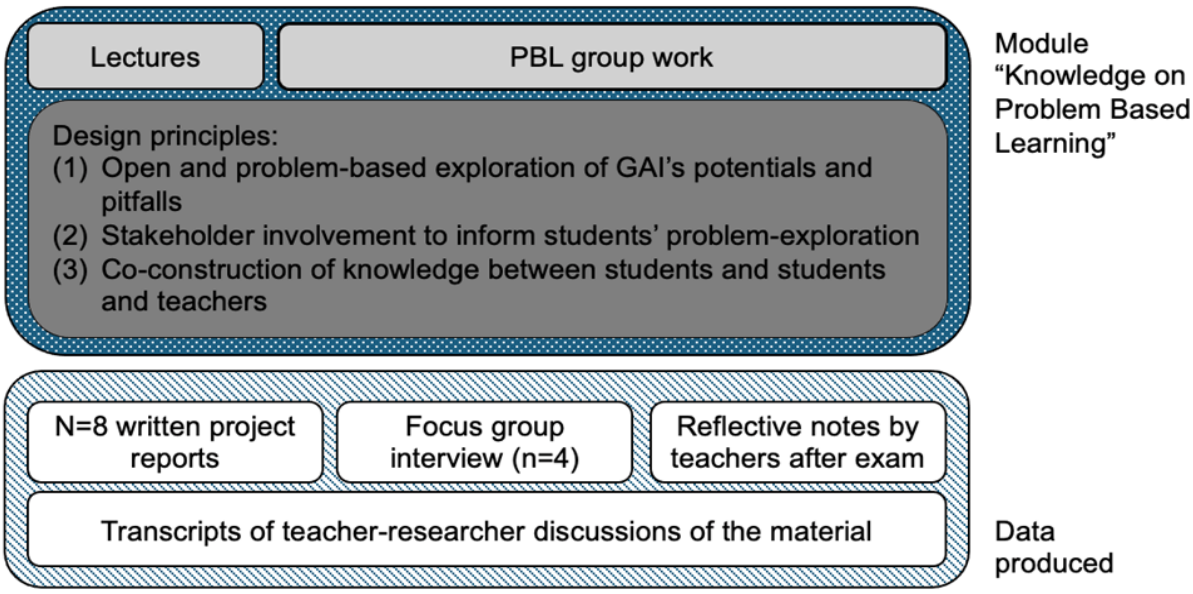

Figure 1. Overview over the design experiment and data produced.

The module "Knowledge on Problem-based Learning"
The design experiment took place at the level of the module "Knowledge on Problem Based Learning" as part of an existing master's degree programme in the Humanities. The program's focus is on learning from both a pedagogical

and organizational angle, and it is studied by students with either university bachelor's degrees or professional bachelor's degrees plus work experience. The purpose of the module is for students to get familiar with AAU's specific PBL approach (Aalborg University, 2015) both practically and theoretically.

The module is conducted in a combination of lectures and parallel PBL project work, accredited for with 10 ECTS in total. Digital technology is addressed in line with the overall set of rules in the department. PBL project work is conducted in groups of up to six students as a minor empirical case study, where the problem to be worked on is self-chose by the group (Aalborg University, 2015). The module closes with an oral group exam based on a written project rapport. The module is offered once a year (autumn term) and in the present iteration was taken by n=60 students.

Making generative AI a topic based on PBL design principles

Dure to its novelty and sudden broad accessibility, in 2023 we as teachers decided to integrate GAI (specifically ChatGPT in the then student-available version 3.5) into the module as a topic based on three PBL design principles: i) an *open and problem-based exploration* of the new technology's potentials and pitfalls for educational processes; ii) the *involvement of stakeholders* to inform students' exploration of the problem; and iii) the *co-construction of knowledge and understanding* as part of the PBL-group work and of the collaboration with the teaching team.

While the first principle primarily was seen as rooted in the general PBL-practices of AAU, the specific operationalization added to the module was a dedicate focus on GAI. ChatGPT was deliberately not presented as a learning tool with fixed properties, but as an object of exploration and learning, with students being encouraged to cultivate their own focus points of interest and problem definitions. This also comprised small experimentations with prompting and didactically facilitated reflections on the answers retrieved. Most prominently, however, the PBL project work was defined as to be focusing on a self-defined problem in relation to GAI and learning.

The second principle was operationalized by dedicating one lecture to an open talk with three visitors: a teacher from a neighbouring program, a digital learning consultant from the institution's Centre for Digitally Supported Learning and a company representative. Those talked about the opportunities and concerns that exist from their perspectives around the use of ChatGPT in education and answered questions by the students.

The third principle was operationalized again through the existing PBL-practice at AAU, where group work is obligatorily supervised and facilitated by a teacher or other person with subject-specific seniority. In addition, this principle was specifically operationalized by both teachers supervising group work on this assignment being educational technology researchers that also were part of the research team.

Data produced

For the production of data we oriented our study towards recommendations that DBR experiments build on collaborative research approaches (Gorard et al., 2004) and multiple data sources (Reimann, 2011). This meant that a variety of data was secured, namely:

- Eight written *project rapports* by the students
- *Notes* taken after exams by two members of the research team
- A *focus group interview* with four students from different groups
- *Recordings of the research team's discussion* of the material gathered

The corpus of *project rapports* consisted of eight out of a total of n=12 rapports handed in as assignments, as four PBL-groups decided to not consent to their products being used for further analysis.

Notes were taken after exams by the two members of the research team that also acted as teachers and subsequent facilitators on the course. They contained immediate impressions and resonance to the topics discussed during the oral defences of the project-reports and comprised one to two handwritten pages, each.

The *focus group interview* took place after completion of the module with four students on a voluntary basis and followed a semi-structured setup. Questions were directed towards experiences during the design experiment and how this had changed and shaped students' GAI-in-PBL practices. A special element of the interview was the use of picture card material as visual prompts to instigate open and playful communication amongst participants (Glegg, 2019). The four informants were divers in terms of gender, age, educational background (university bachelor or professional bachelor) and work experience outside university (see table 1).

Pseudonym	*Gender*	*Age (years)*	*Bachelor's degree*	*Work experience (years)*
'Tobias'	male	23	University	2
'Signe'	female	23	University	2
'Marie'	female	27	professional	2
'Karen'	female	46	professional	22

Table 1. Overview of informants with background information.

Recordings of the research team's discussions were made in two analysis meetings, where all four members of the research team discussed the topics emergent from the student reports (meeting 1) and from the focus group interview (meeting 2). The research team consisted of the two researchers that also acted as teachers and facilitators on the module ('researcher 1' and 'researcher 2'); an additional researcher also representing digital educational development aspects due to their affiliation to AAU's respective academic support unit ('researcher 3'); and a research assistant that was integrated as co-researcher due to their recent completion of the program that the module under study was part of ('researcher 4').

Analytical approach

The analytical approach for this study followed DBR's ambition to provide new insights for pedagogical practice and pedagogical theory alike. Therefore, our analysis of the data was guided by a focus on the design principles underpinning the experiment. We conducted an inductive analysis cutting across the various data, meaning that potentially all data could inform any aspect of the design experiment and its underlying theory.

The analysis was rooted in Gadamer's notion of philosophical hermeneutics (Gadamer, 2006), with a focus on the social conditions that lead to interpretations of GAI in the PBL context by both the students and the research team, which were understood as interpretative entities in the hermeneutic process (Højberg, 2014). As 'text' in this analysis we treated all tangible material such as written study rapports and transcripts. However, following research tradition of Digital Hermeneutics (e.g., Capurro, 2010; Chan et al., 2015; Romele et al., 2020), also GAI was treated as textual, meaning that the perspectives students and the research team conveyed about this technology was understood as interpretations in itself.

The analysis was conducted in NVivo, version 14, and resulted in nine main categories with 251 coded references in nine major categories. For the present analysis, references coded under the first five categories ('Students perspectives on GAI'; 'Learning dynamics'; 'Stakeholder perspectives'; 'Co-construction'; and 'Preconceived and changing understandings in the research team') were analysed thematically following sub-questions relating to the three design principles (cf. table 2).

Design principle	*Operationalization*	*Sub-questions*
Open and problem-based exploration of GAI in a PBL-environment	• General principles of project-oriented PBL • Integration of generative AI as a topic into lectures • PBL group work centred on GAI as part of students' learning processes	Design: Which *perspectives* and *learning dynamics* emerged when GAI was made a topic in the PBL process? Theory: What are new insights informing theory that argues for open and problem-based learning approaches under a GAI-perspective?
Stakeholder involvement to inform students' problem-exploration	• Invited guests in relation to GAI • Students' own choice of informants for their project work	Design: How did *stakeholder perspectives* play out in the process? Theory: What are new insights informing theory that argues for stakeholder involvement/real-world problem integration in learning processes under a GAI-perspective?
Co-construction of knowledge between students and students and teachers	• Group work supervision by two learning and education technology researchers (also part of the research team)	Design: In how far *did co-construction take place*, and who was partaking in such co-construction? Theory: What are new insights informing theory on co-construction in learning under a GAI-perspective?

Table 2. Design principles, operationalizations and sub-questions.

In the following, the findings of our analysis will be presented in line with the sub-questions relating to the three design principles above. An elaboration of the insights for PBL theory will subsequently be presented in the discussion.

Findings

GAI-perspectives and learning dynamics

The first part of the analysis was based on n=179 references in the categories "Students perspectives on GAI" and "Learning dynamics", together, which were the most frequently coded reference in the material. This resulted in findings under this part of the analysis needing further differentiation, which was done by clustering them in three overarching topics, which were labeled as: i) *PBL as a way to overcome hesitation and fear towards using GAI*; ii) *emergent GAI-practices;* iii) *anchoring of GAI-integration in categories of personal relevance*; (see table 2). Each topic was informed by different aspects, which will be subsequently illustrated by quotations in tables 3, 4 and 5.

PBL as a way to overcome hesitation and fear towards using GAI

As a first topic regarding GAI-perspectives and learning dynamics there was a notion of the open exploration of GAI helping students to overcome hesitations and fear towards using the technology. Findings here unfolded in a chronological perspective, visualized overarchingly in table 3, where developments can be read from right to left.

From the student reports and subsequent discussions in the research it became clear that many students on the module experienced ambivalence and fear towards the use of the new technology. These fears presented as based on several aspects, such as worries about “correct” use of the technology so as not to be called out for plagiarism, fear of sanctions and expulsion but also fear of learning incorrect facts and losing the ability to think critically (cf. aspect Various fears). Fears seemed also to be tied to students calling for clear regulations on GAI-use, not least because they expressed the desire to take responsibility for their own learning processes (cf. aspect Call for regulations). Moreover, students themselves elaborated on their initial challenges regarding GAI during the focus group interview. Here, participants expressed that they initially were lacking GAI-knowledge and competences (cf. aspect lack of GAI knowledge and competences). Moreover, they conveyed that several of them initially experienced using GAI as somewhat shameful and to be hidden from each other (cf. aspect GAI use as shameful).

During the focus group interview students also engaged in a discussion how the module had changed their initial view on GAI. They reported that they had developed a more open and explorative approach based on the PBL-process. For example, they elaborated how the explorative approach had initiated openness for the different possibilities of the technology, and that using ChatGPT was not to be considered “cheating”, necessarily anymore (cf. aspect Development of an explorative approach). There was also a sense of added nuance and “demystification” (cf. aspect Added nuance and demystification). Finally, several students expressed their interest in developing competences on how to use it beyond what they already knew how to do by themselves (cf. aspect Wish for competence development).

Various fears	*Call for regulations*	*Lack of knowledge*	*GAI use as shameful*	*Development of an explorative approach*	*Added nuance*	*Wish for competence development*
[T|here is a lot of fear (..). There is a lot of focus on the poles right and wrong; that you can use [ChatGPT] correctly and that you can use it incorrectly. (…) [S]tudents are afraid of being accused of plagiarism, or that they can risk being thrown out of their studies and of sanctions if they use it incorrectly. And then [also that] you can learn something wrong if you “don't think about it carefully" (…). Then there are also worries about the students losing their ability to think critically (…). (researcher 4, meeting 1)	I think gennerally students find that [Chat GPT] is positive, but it would be more positive for them (…) if there were guidelines that they feel they need to be successful [when using] it. (researcher 3, meeting 1)	[B]asically, it was about my ignorance, I think. That I actually didn't know what [chatGPT] was. (…) At the time I also thought it was cheating, because I didn't know what it was. (…) I didn't know enough about it.” (Karen, focus group)	Yes, it's a bit shameful. That you hide behind something and are ashamed of it. And something like: Well, maybe you should admit that, too? Have I used it? (Tobias, focus group).	I (.) think that the whole process we had around ChatGPT, and (...) having to go out and investigate, or, just (..) to have an open discussion about ChatGPT and how people can use [it], (..) kind of opened my eyes to, okay, you can actually use it for other things than just [cheating]. In other words, you can actually do more than just generate a text that you then put into an assignment. Well, it can be a work tool. (Marie, focus group)	And then it was just nice to be able to talk about it, and find out what is it really, get it demystified, and find out, okay, I can actually be a little more comfortable in it, much more confident in it (...) (Marie, focus group).	Now [that| you mention teaching. (...) How can we use [GAI] when we are out (…) in the process of fieldwork? (…). So, how can it become an element of our learning? (Tobias, focus group)

Table 3. Aspects under topic ‘PBL as a way to overcome hesitation and fear towards using GAI’.

Emergent GAI-in-PBL practices

In addition to the developmental perspective, students also began to engage in new practices integrating GAI into their PBL processes. Aspects and quotations underpinning this topic can be found in table 4.

It became obvious that students began to engage in community building with each other around the use of GAI (cf. aspect Community around GAI). This went closely together with the emergence of a shared language to navigate the use of the technology (cf. aspect Shared language). Intertwined, yet separate, students also expressed the importance of being transparent in PBL-groups about GAI-use to establish consensus and trust with fellow group members (cf. aspect Building trust). Regarding the call for regulations, several students conveyed that they had started to integrate GAI-use into their PBL group contracts. By that the impression emerged that what had previously been understood as a task to be cared for externally, had at least partly gone over to an internal group-based overtaking of responsibility (cf. aspect Group-based regulation).

Moreover, students also discussed how they concretely were using GAI (aspect GAI use) and where they perceived limitation of the technology (aspect Reflections on limitations). Students were seeing advantages of using GAI as part of their project work in gaining a better overview and help elaborate on learning content, while they saw limitations in it not being able to substitute a human project supervisor, as it was lacking understanding of context and was perceived as not being able to challenge them in unexpected ways.

Community around GAI	*Shared language*	*Building trust*	*Group-based regulation*	*GAI use*	*Reflections of limitations*
[T]hat I wasn't alone with it, and that I didn't need to sit and be ashamed that maybe I hadn't looked into it, or maybe I didn't know what to use it for. But that I could go to [that] we were [using it] together (…). (Tobias, focus group)	[T]hat's also kind of what we found out in our project (…) That it was a good idea to have the conversation about how to use [chatGPT]. Both we in our group talked about it, but also those we talked to [talked about it]. It was very much like: Well, we need to know when it has been used. And how, because we would like everyone in the group to be informed. (Signe, focous group)	It can easily create mistrust if you are not very transparent about it (..). You also have to be sensitive (…) I think it's (…) also about how safe you feel in the group (Marie, focus group)	And we now create our own guidelines for how we use [chatGPT] and how we feel about it, and how we will subsequently use it. (…) now it is actually stated as part of our group contract. So if we (..) want to use chatGPT, then we have the dialogue about it, and we make the others aware of it. So yes, I just think it's also interesting that now it's part of the process. (Tobias, focus group)	I think in the future I will be able to use [chatGPT] as a sparring partner, or someone who might just be able to help elaborate on some texts, or translate a text, or explain some concepts in a different way. I don't think I'll use it to write anything for me. But I think I'll use it as a help. (Karen, focus group)	This thing about [ChatGPT] not being able to make you reflect (...) as a supervisor would. Yes, this self-reflexive mindset that you have at a university - at least here at Aalborg University - it can't really come up with [ChatGPT]. (Signe, focus group)

Table 4. Aspects under topic 'Emergent GAI-in-PBL practices'.

Anchoring GAI-integration in categories of personal relevance

In addition to the two topics above, a third topic emerged from the analysis on students' GAI-perspectives and learning dynamics. Students seemed to root their integration of GAI not in narrow learning goals but rather found motivation and inspiration in categories of personal relevance, as visualized in table 5.

Student 'Karen', for example, reported to make use of GAI specifically to help her understand theory that she was not sure she grasped during class (cf. aspect Specific use). Student 'Signe' notably conveyed that her GAI-use primarily was inspired by "fun" activities such as finding recipes, however also because she still felt hesitant to use it for study-related purposes (cf. aspect Private use). In addition, 'Marie' elaborated on the relevance of learning about GAI not only as part of one's own competence development but as part of the program they were studying, where they, as learning experts, would be expected to be knowledgeable about the technology's role for learning and cheating, respectively (aspect Future professional relevance). Moreover, 'Marie' engaged in some elaboration of transfer between what she experienced as part of a PBL group and what she could see as potential use of GAI in her previous professional field (occupational therapy, cf. aspect Transfer).

Specific use	*Private use*	*Future professional relevance*	*Transfer*
I [would never use ChatGPT] to write anything for me (.). But (.) I often use it in relation to when we read some theory (..) for example now we had this with [names specific theory], right? Where I sit and read it, I ask [ChatGPT], can you try to explain [this theory] right? Well, then it's a help for me, because then I get it in a different way. I am well aware that some of it may well be wrongly worded, but it is still such a support for my understanding. (Karen, focus group).	I don't use it that much for [study] tasks or anything like that. More for fun, for example if I need to find some recipes or if I need to do something. Because I [don't] want to know how to [use it for study-related tasks]. (Signe, focus group)	[Knowledge about GAI] is incredibly relevant in relation to our study with learning and change processes, because we have to deal with learning and change processes. And presumably, many of us will come across some form of teaching where you have to stand in front of students. Here, it is quite important that you know (…) how chatGPT can be used. So we also know what to pay attention to so that we can see how [students] have used it. And whether they have used it in the right way. (Marie, focus group)	Once I found out what [chatGPT] could do, I couldn't stop clapping my (..) hands in relation to occupational therapy. Because there are a lot of supported housings that have people who find it difficult to structure a task and plan (…) Here people can use [chatGPT] independently and instruct it how detailed [a plan] should be. (Marie, focus group).

Table 5. Aspects under topic 'Anchoring GAI-integration in categories of personal relevance'.

Stakeholder involvement to inform students' problem-exploration

Findings on the second design principle are based on n=11 coded references in the category 'Stakeholder perspectives', which had a much lower number than the references underpinning the analysis for the first design principle. Accordingly, the findings presented in the following emerged as more focused and without further sub-topicalization. However, also for design principle 2 several aspects emerged as underpinning insights into the sub-question which stakeholder perspectives played out in the process (cf. table 6).

As a first aspect it became obvious that the students were incorporating the experience of other students as their stakeholder perspectives, exclusively. This could primarily be seen in the project reports, with all eight of them taking this perspective, despite students being presented with a teacher's, a digital consultant's' and a workforce representative's view during the lecture. However, as became clear during the focus group interview, given the newness and perceived uncertainty of the situation, students decided to focus on their own leaning about GAI use by researching other students' use of the technology. This was explained for example by 'Karen' during the focus group, who pointed out how by interviewing students from another program her PBL group learned how to use ChatGPT in new ways (cf. aspect Other students as the primary source of reference).

The perspective of the original stakeholders brought on to the module got incorporated into students' learning processes under a role model perspective. For example, during the focus group, 'Marie' pointed out that the fact that the stakeholders were not as hesitant towards the technology as students themselves felt they had to be gave inspiration to here to be more open in exploring GAI as part of her own learning processes (cf. aspect Stakeholders and teachers as role models). This was supplemented also by discussions in the research team, where it became obvious that also the decision by the teachers to make GAI a topic in the module served as a model how to exploratively approach it.

Other students as the primary group of reference	*Stakeholders and teachers as role models*
[With] the group that we were talking to, they were [engineering students] who just had complete control of [chatGPT], and they almost taught us about the various plug-ins you can get for it. (T)hey put in their module descriptions (…) and then everything you can ask about it and 'play ball' [with it]. Well, it's crazy. I don't think I'll ever go that far, but I actually really think it was fascinating. (Karen, focus group)	[W]hen we were presented with the case, I was just so incredibly surprised that there were three people who had a challenge with chatGPT, but all of them were actually relatively positive towards it. It surprised me a lot, especially when it came from the education side (*laughter in the background), because I think it was such cheating. (Marie, focus group)

Table 6. Aspects under topic ´Stakeholder perspectives'.

Co-construction of GAI-knowledge and practices

Findings on the third design principle and related sub-questions referring to the intended co-construction of knowledge between students themselves and students and teachers, the analysis was based on n=14 references coded in the category 'Co-construction', supplemented by n=18 references coded in the category 'Preconceived and changing understandings in the research team'. Again, these categories were coded substantially less often than the categories relating to learning perspectives and dynamics, which consequently resulted in fewer aspects and no sub-topics to come out of the analysis, as can be seen in table 7.

Throughout the analysis it seemed that co-construction between students was experienced as closely intertwined with the aspect Community around GAI (section Emergent GAI-in-PBL) and with the aspect Other students as the primary group of (section Stakeholder perspectives). Coded as co-construction, several references from both the focus group and researchers' second meeting related to students engaging in mutual discussion about GAI, with actions such as referencing each other or learnings they took from other people in their PBL-groups (cf. aspect Co-construction between students). Co-construction with teachers on the other hand could primarily be seen as a practice where students took inspiration from teachers, but no indicators of longer-lasting mutual collaboration between the two groups on students' understanding of GAI could been found in the material (cf. aspect Teachers as inspiration).

Co-construction between students	*Teachers as inspiration*
I was in a group with someone who came directly from another bachelor's degree, and they had used [ChatGPT], and it was something with some PowerPoints, and summaries (…) and (..) it was (..) nice that we could talk about it. (Marie, focus group]	When we wrote our project, with [researcher 3] as our supervisor, [they] also brought the perspective that there are young people who use [G]AI on Snapchat to have a conversation with a friend and for being together with others. (…) (Tobias, focus group)

Table 7. Aspects under topic 'Co-construction of GAI knowledge and practices'.

Discussion and implications

The present study was based on the concern that many learning advantages ascribed to GAI today are neglecting perspectives of active and open learning, such as Problem-Based Learning (PBL). Thus, in this paper, we dove into an exploration of how GAI could be understood not as a tool to reinforce certain types of learning, but as a technology that becomes interwoven with learning processes owned by students. For that, we followed a Design-Based Research (DBR)- approach, where, as a design experiment, we infused GAI in learning as a topic of exploration into an introductory module in one of Aalborg University's (AAU) pedagogical master programs. We collected data such as student reports, interviews, field-notes, and recorded discussions in the research team with the ambition to contribute to the development of both, pedagogical practice and active learning theory on GAI in the context of PBL. The research question guiding these efforts was: *What are theoretically grounded focus points for future scenarios of GAI-PBL-integration based on the insights gathered during a design experiment on this topic?*

In the following, we will sum up on this question with as specific focus on how our findings contribute to theory on learning in a PBL context. We will also raise the question in how far findings on the three design principles tested, i.e. the open and problem-based exploration of GAI in a PBL-environment, stakeholder involvement and co-constructive processes, can eventually enrich an emergent theory of GAI-in-PBL.

Discussion of the results in relation to PBL learning theory

Open exploration of GAI in a PBL-environment
With respect to the findings on to the first design principle, it seemed that the open exploration of GAI as part of students learning in a PBL context helped to decrease students' initial hesitations towards the technology. Specifically, the PBL-process opened spaces for exploration without shame of not-knowing and fear of being called out for academic misconduct. Students expressed growing degrees comfortability when experimenting with the technology as part of their learning processes. They also seemed to have developed a more nuanced understanding of its possibilities and felt more comfortable to express their desire to learn more about how to use GAI in their learning journeys (cf. PBL as a way to overcome hesitation and fear towards using GAI). In addition, the analysis showed a set of emerging GAI-in-PBL practices by students themselves, such as building a community around GAI, finding a shared language and mutual trust, as well as negotiating rules for using GAI in their PBL-work, specific scenarios of GAI use and emerging reflections on the limitations of applying GAI in a PBL context (cf. Emergent GAI-in-PBL practices) Finally, it became obvious that students rooted their reflections on their emerging GAI-practices in categories of personal relevance (cf. Anchoring GAI-integration in categories of personal relevance).

All these findings resonate closely with learning theories and research underpinning PBL and the value of an open and self-directed learning process (for an overview cf. e.g. Holgaard et al., 2017; Milner & Scholkmann, 2023). By giving problem ownership, including ownership of problem definition, to students, they were able to shift from a teacher-led to a self-defined topical exploration of GAI, and to develop strategies for future use of the technology (Thomassen & Stentoft, 2020). Also, learning and knowledge-making became social rather than transmitting (Cambridge et al., 2024).

What the present design experiment added in terms of a GAI-perspective was, firstly, the outstanding role of emotions. Emotions have been brought to learning researchers attention more frequently in the last years, as they are crucial for the ways students engage in learning processes (e.g., Quinlan, 2016; Pekrun, 2019). Also, students expressing concerns towards GAI-use due to fear of legitimacy, learning and social belonging has been demonstrated in at least one other study so far (Chan & Hu, 2023). So, while PBL-related learning theories still seem to not have engaged with this crucial aspect, our findings point towards them having a strong influence on the PBL-process (also in relation to other aspects such as the role-modelling of teachers and stakeholders). Related to GAI-in-PBL specifically, emotions of caution might not be out of place given the inherent intransparency of the technology. As they can help students to build a differentiated and adequately critical attitude, they should be incorporated into an understanding of students PBL-processes under the premise of students learning to think critically and reflectively (Lolle, Scholkmann & Kristensen, 2023).

Secondly, both the emergent GAI-in-PBL practices and the fact that students were tying their GAI-exploration to what felt personally relevant to them confirm and amend findings on students' divergent and situationally practices of digital tool use (Scholkmann, 2017; Sørensen, 2018). They also resonate with a recently published study demonstrating that also in more 'traditional' forms of teaching students tend to pivot towards their own, sometimes 'hidden' practices of GAI-use (Corbin et al., 2025) – practices that were openly encouraged in our design experiment. By that, the findings potentially support amending PBL learning theory with an acknowledgement of the "messiness" that GAI is bringing into learning processes (by not being fully predictable), which was met by students by seeking for what mattered to them as a strategy to navigate this messiness.

Stakeholder involvement to inform students' problem-exploration

Regarding the second design principle, the findings indicated that what was intended in the design experiment did not fully live up to the expectations. Instead of choosing between the various stakeholder perspectives the students were presented with, students unanimously focused on other students' GAI-experiences as an offset for their explorations (cf. section Stakeholder involvement to inform students' problem-exploration). However, it must be acknowledged that in PBL learning theory stakeholder involvement is most often operationalized by a longer-term cooperation with external stakeholders (Holgaard et al., 2021), and not a single session in which different stakeholders presented their perspectives. Therefore, it seems what students did was a logical choice under an unprecise operationalization of the design principle which would eventual call for refinement in future iterations of the design experiment (Design-Based Research Collective, 2003).

However, the accidentally poor operationalization may well have resulted in new insights to amend PBL learning theory under a GAI perspective: Firstly, they add to the perspective discussed above, that under a condition of uncertainty, students seemed to revert to a perspective closes to their own. Secondly, what stood out clearly was that the stakeholder perspectives served as a cue for contextualization of the GAI-phenomenon. This finding draws attention to the role of authority figures in the PBL-process, which for the students seemed to provide cues on how to interpret the problem. While the PBL-literature generally tends to understand PBL-learning processes as a transfer of power and authority from teachers to the PBL-group (Duek, 2000), it has recently been pointed out that also in the seemingly "democratic" PBL-process the dominance of the lecturer as an authoritative figure prevails due to the uneven distribution of power in the educational system (O'Brien et al., 2022). Considering the advancement of PBL theory, these findings therefore add to the growing number of researchers calling for re-visiting the assumption of the PBL-arena as a power-equal and democratic space. With respect to GAI specifically, they also call for a deeper consideration who in students GAI-use is constituted as figure of authority. As public discourse around the non-neutrality of AI is evolving (Hare, 2022), students' desire for orientation regarding responsible AI use especially in the open-ended PBL process should not be dismissed preliminarily, but made a vital part of both GAI-in-PBL theory and practice.

Co-construction of GAI-knowledge and practices

Regarding the third design principle, the findings revealed co-constructive processes to take place mostly amongst students themselves and thus intertwined with other community-building and language-making aspects in their GAI-practices. Co-construction with teachers happed only very limited, however accounts of teachers inspiring student perspectives and reflections on GAI in learning occurred in the material (cf. Co-construction of GAI-knowledge and practices).

Again, these findings resonate with aspects already elaborated above, and confirm PBL theory in that they provide evidence for co-constructive knowledge professes in student groups (Lee et al., 2017). Moreover, they supplement the arguments made before for a future integration of authority as a topic in GAI-integrated PBL. Finally, the thematic overlap in some of the findings add to the argument that a clear separation of design elements might not always be possible in PBL (Hanghøj et al., 2022).

Limitations

It must be emphasized that the available results were collected with a group of master's students in a pedagogical programme. Thus, it cannot be ruled out that this group's particular view of GAI has influenced the analysis' findings, e.g. in relation to the focus on the emotional and social rather than the strategic or technological. Furthermore, this study was based on the knowledge and competence status of all the actors in the period summer 2023 – spring 2024, where, for example, concerns about cheating in the use of G-AI emerged. In addition, it cannot be ruled out that the voluntary participation in the focus group interview produced specific results. Finally, this study has not used a contrasting research design, which means that the results in relation to the PBL pathway must be considered with reservations for possible self-confirming trends.

Conclusion

What the present study and the design experiment have brought to the fore was that an open, exploratory PBL-approach was in fact able to add nuance to the picture of what learning might mean under a GAI-perspective. Adding to the potentialities of GAI *for* learning vented in part of the literature to date, the present study brought to the fore how practices of learning *with* and *about* GAI can be instigated through active student-led exploration. Moreover, the analysis indicated that such practices amend PBL theory in that they alert us to hitherto overlooked aspects of the PBL-learning process under a GAI perspective – specifically, the influence of emotions elicited by the technology, students' being guided by their immediate learning needs and the question of role-models and authority in a GAI-entangled PBL process.

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PBL Tutors' Conceptions of Teaching Problem-Solving

A Phenomenographic Exploration

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Abstract

Problem-solving (PS) is taught and practised in many higher education institutions across various disciplines. However, there is a lack of understanding of how to teach PS in a way that aligns with the specific principles and methods associated with its pedagogy. This study aimed to understand how tutors of Problem-Based Learning (PBL), a problem-centered instructional practice, conceptualize teaching problem-solving (CoTPS). Through qualitative interviews followed by phenomenographic analysis, we developed a model of CoTPS, which analyses how PBL tutors conceive problems in instruction, the process of problem-solving, and their role in

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tutorial groups. The categories of description, forming a hierarchy of inclusivity, enabled us to identify the least and most complex conceptions of teaching problem-solving. This model allows PBL tutors and, more broadly, higher education teachers to reflect on their conceptions and enables academic developers to create programs that enhance both conceptual understanding and practical application of problem-centred instruction.

Keywords: Conceptions of problem-solving; PBL tutors; PBL tutors' conceptions; Problem-based learning; Phenomenography

Introduction

The development of generic skills, particularly problem-solving, has become increasingly important in contemporary education. Research indicated that collaborative and interactive teaching practices, along with constructive learning environments, are more effective in fostering generic skills compared to traditional lecturing methods (Virtanen & Tynjälä, 2018).

However, teaching problem-solving in higher education presents unique challenges, as it is more complex than imparting subject knowledge (Jonassen & Hung, 2008; Jonassen, 2014; Mayer & Wittrock, 2006). To address this, higher education (HE) teachers are exploring various approaches, from direct teaching to innovative classroom processes (Csapó & Funke, 2017). One of the reasons why this issue remains prevalent is that educators' views significantly vary about what constitutes problem-solving, what their roles are, or how it should be taught (Van Merriënboer, 2013; Phang et al., 2018). While fields such as medicine and engineering benefit from having a well-defined understanding of problem-solving pedagogies, specifically in Problem-Based Learning (BPL), many disciplines, including social sciences, business management, teacher training, architecture and counselling, suffer from having less clarity about different aspects of teaching problem-solving (Hallinger, 2023).

Problem-based learning has emerged as a notable inquiry-based approach aimed at fostering students' problem-solving capabilities (Norman, 2008). PBL engages students in real-world problems and encourages active learning, critical thinking, collaboration, and independent inquiry. However, the successful implementation of PBL varies significantly across different educational contexts. Factors such as institutional support, curriculum design, and teacher expertise can profoundly influence its success (Dolmans et al., 2016). Researchers have expressed concerns about the "mistranslation of PBL" and its core pedagogical philosophy (Servant-Miklos et al., 2019; Kwan, 2019). Common issues relate to using problems merely as tools to reinforce lecture content rather than as the basis for independent inquiry and knowledge construction (Dolmans et al., 2002). Failing to give students opportunities to activate prior knowledge or not giving inadequate time for individual learning. Undermining the collaborative aspects of PBL by putting students in team-based learning settings and reinforcing group work rather than collaboration. Insufficient time and resources for individual or group reflection (Kwan, 2019 & Savery, 2006).

Given these challenges, this study shifts focus from describing how PBL is practiced to exploring the underlying conceptions of problem-solving held by PBL teachers (in this study context, PBL tutors). While specific PBL practices may not be directly transferable across different educational contexts, the underlying conceptions of what it means to teach problem-solving are more likely to transcend these boundaries. By examining these conceptions, we aim to develop a framework that can assist HE teachers in understanding the diverse, complex and more complete ways in which teaching problem-solving is conceptualised. This framework will serve as a resource for developing professional development programmes or encouraging self-reflective academic practice regardless of institutional context and disciplines. While the term 'tutor' is used frequently in this article in the context of PBL, specifically within the setting of this study, where it refers to HE teachers facilitating small tutorial groups, the findings and implications are also relevant to teachers in higher education.

Literature Review

Theoretical and conceptual framework

The theoretical framework underpinning this study centres on the alignment between teachers' conceptions of teaching and their actual practices. The exploration of teaching conceptions became particularly influential as educational theorists and researchers have discovered that teachers' personal beliefs and knowledge systems influence their instructional practices (Gow et al., 1993; Lam & Kember, 2004; Kember & Kwan, 2000; Åkerlind, 2003). The most well-known framework which has been used to explain the alignment between teachers' conceptions and approaches belongs to Kember and Kwan (2000), where teaching is seen as "transmission of knowledge'' vs "teaching as learning facilitation", which has respectively been associated with "content-centred" and "learner-centred'' approaches to teaching. While PBL tutors' perspectives and approaches have been studied using different theoretical and conceptual models, tutors' conceptions have not been addressed.

In this study, the concept of "conception" is explored from a phenomenographic research perspective, which focuses on the "ways of being aware of" or "ways of understanding" a phenomenon. Unlike cognitivist approaches, which focus on beliefs, values, or traits, phenomenography defines conceptions based on awareness—how individuals perceive and experience aspects of a phenomenon (Marton & Pang, 2005). In this view, teachers' actions are not primarily shaped by their beliefs or values about teaching but by their awareness of what teaching can encompass and how it can be practiced (Åkerlind, 2024). In this paper, terms such as conception, awareness, and understanding are used interchangeably to reflect their phenomenographic meaning. This usage aligns with Åkerlind's definition of conception, which emphasizes the relational nature of awareness and understanding. "Our awareness of phenomena, or the way in which we experience them, constitutes our understanding of the phenomena, which is the meaning that they hold for us" (Åkerlind, 2024, p. 3).

By adopting this framework, the study examines how varying levels of awareness influence PBL tutors' conceptions, offering insights into the diversity and progression of their understanding. By investigating what constitutes the conceptions that make the PBL approach successful, we aim to uncover insights that are less explored, particularly demonstrating more nuanced, complete conceptions of teaching problem-solving. We believe that understanding PBL tutors' conceptions is crucial for preserving the essence of PBL when adapting it to new contexts. By exploring tutors' conceptions, we aim to facilitate more meaningful translations of PBL principles across various educational settings and provide more clarity on how problem-solving skills should be fostered in higher education institutions.

Using phenomenographic research outcomes for academic development

Phenomenographic research outcomes have a critical role in designing academic development programs and facilitating changes in teaching conceptions. Central to phenomenographic epistemology is the idea that conceptual development does not involve discarding existing understandings but rather expanding awareness to include previously unnoticed aspects of a phenomenon (Åkerlind, 2008b). The outcomes of phenomenographic research, organized into a hierarchy of complexity, allow academic developers to identify qualitatively different ways of understanding a phenomenon and prioritize where pedagogical efforts should focus on guiding teachers (as learners) toward more complex levels of understanding (Kettunen & Tynjälä, 2021, Åkerlind, 2015). This hierarchical structuring offers a practical framework for enhancing teaching conceptions by pinpointing the dimensions along which teachers' awareness needs to evolve.

From a phenomenographic perspective, conceptual development is characterized by enabling learners to discern the full range of critical aspects of a phenomenon, fostering a more comprehensive understanding. Variation theory, which complements phenomenography, informs the design of academic development by focusing on how variation in experiences helps individuals discern critical features (Marton and Booth, 1997). Specifically, the four-component method—contrast, generalization, separation, and fusion—provides a structured approach for educators to design learning activities that guide participants toward deeper and more inclusive conceptual development (Åkerlind, 2018). For instance, contrast enables learners to distinguish a phenomenon by comparing it with something else, while fusion allows the simultaneous integration of multiple critical aspects for holistic awareness.

Academic development programs play a pivotal role in reshaping HE teachers’ conceptions of teaching and learning, which are foundational to their instructional practices. Research highlights that targeted pedagogical training can bring about significant shifts in teaching approaches, fostering more learner-centred and transformative practices (Gibbs & Coffey, 2004; Ödalen et al., 2019; Hughes et al., 2023). Previous research has shown that the outcomes of phenomenographic research are actively used in planning academic development programs (Åkerlind, 2014; Booth & Ingerman, 2015; Wright & Osman, 2018). Beyond modifying conceptions, such training enhances teachers’ professional vision, helping them address misconceptions and appreciate the complexities of teaching and learning (Heinonen et al., 2023; Postareff et al., 2007). While there is consensus on the characteristics of effective teaching (Entwistle & Walker, 2002), there remains a gap in guidance for planning academic development programmes that specifically address teaching problem-solving. Addressing this gap by focusing on teachers’ conceptions of PS enables professional development programs to cultivate critical teaching skills and improve students' learning outcomes.

Conceptual framework of conceptions of teaching problem-solving (CoTPS)

Despite the existence of numerous studies on teaching problem-solving, there is still no clear conceptual framework that systematically explores the CoTPS. Previous studies have explored teaching problem-solving from single perspectives, such as how educators categorize problems (Trigwell et al., 2002), defining problem-solving strategies (Siswono et al., 2016), or only addressing the teacher's role (Hendry, 2009). Therefore, we aimed to address this conceptual gap by exploring CoTPS through three critical dimensions that have emerged after the critical analysis of literature on problem-centred instruction (Bendeliani, 2024). These dimensions are conceptions of the problem, conceptions of the problem-solving process, and conceptions of the tutor's role.

The first key feature that distinguishes problem-centered instruction from other teaching approaches is its emphasis on the nature of the problem. Various theories and models of problem-solving emphasize that the nature of the problem plays a crucial role in achieving learning goals (Jonassen, 1997; Merrill, 2002). There are numerous studies on how to design and structure problems and what constitutes a "good" problem (Biggs &Tang, 2007; Qvist, 2004). This body of research underscores the importance of the problem's nature in problem-solving instruction. For instance, well-structured problems, often used in case-based learning, have clear solutions and defined paths, promoting skills such as procedural knowledge and algorithmic thinking. In contrast, ill-structured problems, typical of PBL, are open-ended and complex, encouraging higher-order thinking skills such as analysis, synthesis, and evaluation (Jonassen & Hung 2008). By focusing on this dimension, we aim to understand PBL tutors' awareness and understanding of the role of problem in problem-solving instruction.

The second dimension that might provide critical information about tutors' understanding is the conception of the problem-solving process. The process of problem-solving in problem-centered instruction is grounded in several theories, such as information processing theory (Simon, 1981), Cognitive load theory (Sweller,1988), and Merrill's First Principles of Instruction (Merrill, 2002). The Design Theory of Problem-Solving (Jonassen, 1997) provides a structured approach to solving problems, highlighting steps such as problem identification, solution generation, testing, implementation, and reflection. Each step in this process is crucial for developing problem-solving capabilities. Although there are slight differences between different problem-centred instructional models, the main phases of problem-solving align with the cognitive process of problem-solving. Understanding how tutors perceive and conceptualize this process will provide insights into the importance of steps or the significance of the structured problem-solving process.

Finally, the role of the tutor in problem-centered instruction is a fundamental aspect that differentiates it from traditional teacher-centered instruction. Problem-centered instruction aims to enhance student autonomy and self-directed learning (Savery, 2006). Consequently, the teacher's role as a facilitator has gained considerable attention. Many studies have explored what constitutes the tutor's role in the process of facilitating tutorial groups and it remains a debatable issue in PBL research (Schmidt & Moust, 2000; Dolmans et al., 2002; Chng et al., 2011; Groves et al., 2005). Therefore, we consider this dimension crucial for our inquiry into HE teachers' conceptions of problem-solving instruction.

Aims

The aim of this qualitative research is to explore the varying ways in which teachers in Problem-Based Learning environments (PBL tutors) conceptualize key aspects of teaching problem-solving and to identify commonalities within these variations. Specifically, it seeks to understand:

1. How do PBL tutors conceptualize the role of problems in PBL?
2. How do PBL tutors conceptualize the problem-solving process in PBL?
3. How do PBL tutors conceptualize their role as facilitators in the PBL tutorial groups?

The study aims to establish a model illustrating how these conceptions relate to each other and evolve, providing insights into the hierarchical inclusiveness of these conceptions and contributing to a deeper understanding and refinement of teaching practice in problem-centred pedagogy.

Research Design

Understanding and interpreting phenomenographic research outcomes

Phenomenographic research aims to explore and map qualitatively different ways of experiencing a phenomenon, resulting in a structured representation known as the outcome space (Marton & Pong, 2005). This outcome space organizes findings into categories of description, which embody qualitatively different but interrelated ways of understanding. These categories are arranged in a hierarchical structure where more advanced ways of experiencing a phenomenon include and expand upon simpler ones. This hierarchy reflects an inclusive complexity, where each following category adds a new critical aspect of awareness while encompassing the ones from previous levels, which creates inclusively expanding levels of awareness (Stenfors-Hayes et al., 2013).

The hierarchical organization is fundamental to phenomenographic research because it illustrates how human awareness progresses (Green, 2005). Understanding is not static but develops through the discernment of additional critical aspects, which are the key features of a phenomenon that differentiate one way of experiencing it from another. This non-dualistic perspective justifies the expectation that different ways of experiencing the same phenomenon will be related because, according to phenomenography, all conceptions of a phenomenon share a connection through the object being experienced (Green & Bowden, 2009). While people may perceive the phenomenon in qualitatively different ways, their experiences are still linked by the common object—the phenomenon itself—which provides a common ground for comparison. This progression underscores how inclusivity in awareness builds collective understanding, moving beyond individual perspectives to create a broader, shared framework.

The concept of collective awareness is central to phenomenography, as the method seeks to capture the sum of variation in human experience (Bowden, 2000). This focus allows researchers to identify what could constitute a complete understanding of a phenomenon and, by that, it moves beyond identifying generic "right" and "wrong" answers (Åkerlind, 2005). In practice, this helps individuals situate their own conceptions within a broader context, enabling them to recognize gaps in their awareness and discern what is needed to develop a more comprehensive and sophisticated understanding.

Context

The study was conducted among PBL tutors at Linköping University in Sweden. In 1986, the Faculty of Medicine and Health Sciences at this university became the first faculty in Sweden to implement PBL within its medical training and healthcare programs. Apart from the medical faculty, PBL is used as a primary educational approach in several programmes across four faculties. PBL tutors at the university utilize two specific models— the PBL Wheel and the Lifebuoy (within the Faculty of Medicine and Health Sciences)—to guide students through the problem-solving process. Along with PBL tutorials, which usually take place once a week and consist of 6-7 members of students, they participate in lectures and seminar activities.

Participants

The sample consisted of 15 participants. According to the recommendation given for collecting phenomenographic data, 10-20 participants is the adequate number to achieve saturation (Åkerlind, 2005). A purposive sampling method was employed to ensure the inclusion of participants from different disciplinary backgrounds, which is crucial for study design (Han & Ellis, 2019; Stenfors-Hayes et al., 2013). Participants in this study are members of Didacticum, the university's centre for pedagogic excellence, which supports academic development; the majority of participants have taken the PBL course at least once.

Characteristics	Frequency
Gender	
Male	6
Female	9
Year of teaching experience	
< 10	1
10 to < 20	4
20 to < 30	10
Academic qualification	
Professor	5
Senior professor	1
Associate professor	6
Senior associate professor	1
Associate professor, docent	2
Academic field	
Biomedical and Clinical Sciences	5
Computer and Information Sciences	1
Behavioural Sciences and Learning	6
Health, Medicine and Caring Sciences	3

Figure 1. Profile of Participants.

Data collection

Semi-structured interviews were conducted to explore participants’ conceptions of teaching problem-solving. After a trial interview, three main questions were retained, allowing flexibility for additional follow-ups based on participants’ responses. The overarching questions included: ‘How do you define the problem-solving process?’ ‘What is your definition of a problem?’ and ‘How do you perceive your role in this process?’. Drawing on the recommendations (Åkerlind et al., 2005), follow-up questions (such as, why do you think it constitutes problem-solving, Why do you design it this way, etc.) were asked.

Method of Analysis

Given the lack of a standardised procedure for phenomenographic analysis, we experimented with various approaches to handle the data. Ultimately, we found the "whole transcript" method the most suitable. This approach, as described by Bowden (2000), involves analysing the entire interview transcript without separating chunks responding to specific questions. This method proved more effective because it preserved the context, making it easier to identify underlying conceptions.

The analysis process involved multiple iterative cycles of re-reading the data. Our data analysis steps included familiarisation, condensation, comparison, grouping, and labelling (Cope, 2004; Åkerlind et al., 2005). To make final judgments about the categories of description and determine the conceptions characterized in the interviews, we employed the framework suggested by Sjöström and Dahlgren (2002). This framework guided us in evaluating the data based on how frequently certain views were highlighted in the transcript (frequency), the position of these views within the responses, because significant aspects are often articulated early in the response, and the explicit emphasis participants placed on specific beliefs or opinions (Pregnancy).

To ensure the reliability of our results, we conducted dialogic reliability checks. Feedback was sought from two researchers who were experienced in phenomenographic analysis and had no vested interest in this project. We also presented our findings at conferences to ensure pragmatic validity.

Results

This analysis has led to the development of a hierarchical structure of conceptions of teaching problem-solving (CoTPS), where each category represents a progressively more inclusive and complex understanding of problem-solving within the PBL framework. The round model was chosen to illustrate the outcome space because it effectively demonstrates how each layer of conceptions builds upon the previous one, progressing from less complex to more comprehensive understandings of the phenomena. This aligns with the essence of phenomenography, which seeks to explore the hierarchy of understanding, moving from basic to more sophisticated conceptions (Green, 2005). The circular structure highlights the layered nature of the conceptions and shows how they collectively contribute to a holistic understanding. By visually illustrating how the first layer is less complex than subsequent layers and how each layer enhances the previous one, the round model captures the completeness growth of the conceptions. Furthermore, since this study examines conceptions of problem, problem-solving, and the role of the tutor across three dimensions, the round model facilitates the exploration of their interactions and alignments. The dotted lines connecting the dimensions reinforce their interaction and shared aspects which are discussed further in the discussion section.

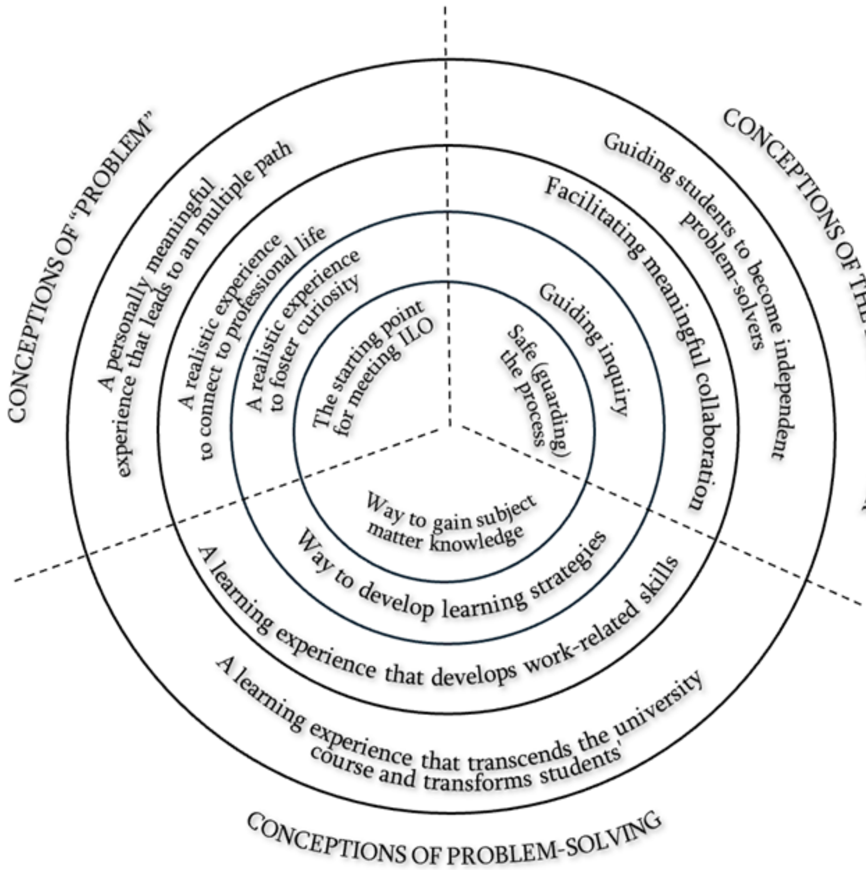

Figure 2. Outcome Space, Conceptions of Teaching Problem-Solving.

PBL tutors' conceptions of 'Problem'

Four qualitatively different conceptions of the problem have been exhibited, where the problem is seen as 1) a starting point to meet ILO 2) a realistic experience to foster curiosity 3) a realistic experience to connect to professional life 4) a personally meaningful experience that leads to a multiple path. In the appendix, you can find extended quotes where the inclusiveness of awareness is clearly illustrated.

Categories & Quotes
C1) "Well, of course, you don't give the students direct questions because they phrased their questions themselves based on the scenario. So, you can only do as much as you can. You can't make errors, so they learn exactly what they're supposed to learn. But you should aim to make a good scenario as possible. Hopefully, it will help students achieve their intended learning outcomes." (N14)
C2) "You shouldn't post the questions itself. It's important that the questions and what is required from the students are not given to them. One thing is that it should probably also be engaging, so it shouldn't be trivial. It should be something that is emotionally engaging and that some students need, that is, some trouble to engage in finding the problem (awareness 2)..." (N1)
C3) "… So, what I want with that case is that the students both should read about mourning and dying (awareness 1), but they should also try to have some self-reflection of what they think is important by death and dying because, in their future profession, they will meet people that believe in God or life after death, stuff like that because they need to do that (awareness 3)." (N4)
C4) "Sometimes, when we give them vignettes, it's like, oh, here's a vignette, and it's all about social influence (awareness 1). So, it should stimulate curiosity (awareness 2). It should be ambiguous in terms of what is to be done, but also multiple ways in which they can go with it. So, maybe one group might go off in one direction, and another group might go off in a different direction, so they should be open to different ways of solving it (awareness 4)." (N6)

Table 1. Conceptions of 'Problem', please visit the appendix for extended quotes.

The first category under this dimension sees problems as a starting point to meet the ILO, which is a fundamental but least complex view. In this conception, the problem serves as an entry point into the learning process, guiding students towards the predetermined goals of the course. According to tutors, problems should inform students about the topic of the week or semester. As one of the tutors emphasized, a problem is a means to ensure that "they learn what they are supposed to learn". Conceiving the main role of the problem as a covering ILO, might encourage academics to be more straightforward in designing the scenarios, meaning they might be too specific, or the clue of the problem might be too obvious for students.

In the second category, the problem is viewed as a realistic experience which should trigger curiosity. It is more complex than the first category because it acknowledges the importance of stimulating the intellectual curiosity of students to engage in the learning process. It adds complexity by bringing the components of curiosity, stimulus, trigger, and provocation. This category discerns the importance of the suitability of the problem with course content but extends the complexity of the first category by placing a strong emphasis on gaining students' attention. Tutors who see the value of the problem as a trigger for learning might design problems which are more provocative, puzzling, and unknown to students, given their understanding of certain concepts.

The third category sees the problem as an experience which connects students to the professional world. Here, problems are designed to show students the relevance and applicability of learning for their profession. This category of description is considered more complex because it transcends the educational purpose of the problem and shows students the importance of the knowledge they acquire for their future. Although all the problems in PBL are authentic and replicate the real world, tutors who hold this conception might value more dysfunctional, wicked problems, which are not oriented to the solution but changing the outcomes of the situations, or as one tutor describes, "creating the environment where living is possible".

The fourth and most complex category conceives the problem as a personally meaningful experience that leads to a multiple path. Several important components are included in this category. First, it shows that a problem can be multidimensional and open to having multiple solutions, or not even a solution, as the main goal of the problem, according to tutors, is not solving it but guiding learners to explore more about it. Second, it shows that it is not driven by the course content, but students are free to explore and dive into the areas they are interested in. This category emphasises personalization, ensuring that each student can engage with the problem in a way that is meaningful and relevant to them.

PBL tutors' conceptions of problem-solving

Analysing teachers' conceptions of problem-solving required a thorough examination of their responses to various follow-up questions. The question "How do you define problem-solving?" often did not reveal their full understanding of the process. Therefore, we had to look at multiple aspects of their responses, including how they view the meaningfulness of the problem-solving process, the outcomes they expect from it, and how they define knowledge within the PBL framework. This comprehensive analysis led to the development of four distinct categories, where problem-solving is seen as 1) a way to gain subject matter content knowledge 2) a way to develop learning strategies, 3) a learning experience that develops work-related skills, and 4) a learning experience that transcends the university course and transforms students' lives.

Categories & Quotes
C1) "Well, of course, you don't give the students direct questions 'cause they will phrase their questions based on the scenario. So you can only do, I mean as much as you can. You can't make errors; it is all complete for them, so they learn exactly what they're supposed to learn…" (N14)
C2) "I mean, what we try to achieve is basically for the students to look at the scenario. They should find out what they already know and what they need to know and then try to formulate distance in some good way of what they need to know so that they can read about that and then discuss it the next time (awareness 1- 2). yeah, but that's not enough. I've realised that I need to talk with my students also about why we're doing this. So in order to try to motivate them to understand. Why? Why do they do this?... (awareness 2)." (N12)
C3) "...So they have the same tutoring groups for a semester, and then they switch for the next semester. So they have a different group. And I think that it is really good for them to practice working in different group constellations with people that they would never have collaborated with if we hadn't forced them into different types of group process, how to solve conflicts and so on, is a good teaching outcome that is not necessarily about solving problems (awareness 3)." (N9)
C4) "Students are different. But I think that problem-based learning is a way of thinking. It's a style of life. It's something that you engage with, and then you learn in that way, and you operate in that way (awareness 4). I hope that you can use it in many situations in life, not only when you try to learn materials for the course (awareness 1)..." (N7)

Table 2. Conceptions of Problem-Solving, please visit the appendix for extended quotes.

In the first foundational category, the problem-solving process in PBL is viewed as a means to acquire subject matter content knowledge. The focus is on ensuring that students learn specific concepts that align with the curriculum.

The PS process is seen as an interesting way to acquire knowledge. Presumably, tutors' practice might focus on ensuring students understand and retain the subject matter through problem-solving. They might use problems that require the application of specific theories or concepts covered in the curriculum, assessing students' knowledge and understanding.

The second category of the second dimension sees the PS process as a possibility to help students develop effective learning strategies. It emphasises not only the acquisition of conceptual knowledge but also the development of academic skills such as self-reflection, learning to learn, and the ability to structure and organise their learning process. We can assume that tutors who hold this conception focus more on developing students' metacognitive strategies and encouraging self-directed learning and group work skills.

The hierarchical relationship of the conception gets more complex when PS problem-solving is conceived as closely mirroring real-life problem-solving processes. As tutors highlighted the PS process in PBL tutors should not only encourage them to read more about certain topics, but collaborate with different group members in different phases of the problem-solving process enabling them to gain work-related skills, like conflict resolution, coming to a consensus, decision -making, etc. The focus is on applying academic knowledge in practical scenarios and preparing students for professional practice by fostering critical thinking and adaptability. Tutors who value collaboration the most in the PS process might focus on the success of the group rather than the individual level, ensuring that they work together and putting more emphasis on group dynamics.

In the most complex category, problem-solving is viewed as a process that transcends the university course and transforms students' lives. It encompasses all aspects of the first three categories but extends further by emphasizing PBL as a lifelong thinking and operating process. It promotes not only content knowledge and metacognitive abilities but also personal growth and the ability to address real-world issues in both professional and personal contexts. As tutors state, the purpose of the problem-solving process in PBL should not be to complete steps but to teach students how to operate in their lives, and this is the way they will deal with problems in the workplace or in life.

PBL tutors' conceptions about their role

Before we delve into the specific categories of description, it's important to note that no tutors described their role using a single descriptor. Instead, all tutors mentioned multiple roles. Therefore, in conceptualizing their awareness, we focused on the roles they emphasized and prioritized repeatedly. This approach allowed us to capture the most salient aspects of their self-perceived responsibilities. Analysis has revealed four categories of description, where tutors' roles are seen as 1) safe (guarding) the process 2) guiding inquiry 3) facilitating meaningful collaboration, and 4) guiding students to become individual learners.

Categories & Quotes
C1) "… I'm much more like making the structure. If I notice that they need a lot of guidance and structure because some people in the group will need that, otherwise they will get paralysed…This is the structure of the day. Today, we are going to start with this, and then we will continue like this. And then I will act at the beginning, like a structure maker, like an "informator"…(awareness 1)." (N7)
C2) "… I guess, on the one hand, sort of guiding them through the stages and showing them why it's important, (awareness 1) but also sort of modelling in a way the kinds of questions they can ask. So, when I'm tutoring in a PBL group, I might ask questions and show the kinds of things I want to get them to think about and look at things in a different way (awareness 2). So, it is partly modelling, partly guiding, supporting, and encouraging." (N6)
C3) "It's a lot about just learning PBL structure and working in a group(awareness 1). A lot of the students have bad experiences with group work. I think my part is to make sure that they just don't tell each other what they have read. I read this article. I read this article. That's not okay for me. There should be a discussion. They should deepen the discussion (awareness 3). They ask questions, and if they don't ask questions, I ask questions. I want to challenge them in what they have read (awareness 2)." (N5)
C4) ".... I don't want to hear your poor version of retelling it, but I want to hear your thoughts based on what you've learned and with other people's, we can kind of create new knowledge. I hope for them back to knowledge is that even if they don't know it, even if they don't have the answer, when they get out in the work life and they see a problem they don't know the answer to, they will find a way to find the answer on their own (awareness 4)". (N9)

Table 3. Conceptions of tutors' role, please visit the appendix for extended quotes.

This foundational first category represents the most basic level of tutor involvement in the PBL process. Tutors in this role focus on establishing a safe environment where students feel secure and confident in their learning journey. The primary objective is to ensure that students understand the expectations and procedures of PBL, thereby reducing anxiety and creating a conducive learning atmosphere. Thus, the expectation is that tutors with this conception act as facilitators who provide clear guidelines, set agendas, and maintain the overall structure of the sessions.

Building on the primary role of providing structure, the second category involves tutors actively engaging students in the inquiry process. Tutors in this role stimulate critical thinking by asking probing questions, modelling reflective thinking, and encouraging students to delve deeper into problems. The focus shifts from merely following a structured process to actively exploring and understanding the problems at hand. The complexity increases as tutors now need to possess a deeper understanding of the subject matter and the ability to guide students' thinking processes without providing direct answers to scenarios. This requires a balance of knowledge, pedagogical skills, and the ability to foster an environment where students feel comfortable engaging in open-ended inquiry.

The third category adds another layer of complexity by emphasizing the importance of meaningful collaboration among students. Tutors in this role not only guide inquiry but also ensure that group interactions are productive and that students engage in deep, collaborative discussions. As was mentioned by tutors, the PBL problem-solving process not only involves reporting readings in groups but also helps students learn to work as a team, seeing the need for and power of communication and collaboration. Tutors who hold these conceptions are not only trying to guide students through PBL steps, but making them uncomfortable with questions, asking them to go back several times, asking justifications about their decisions.

And last, the most complex category comprises tutors aiming to guide students to become more individual problem-solvers. This conception is the most complex as it integrates all views about PBL tutors' roles but adds complexity by showing the understanding that facilitating is not only helping students to work well in the group or to comprehend the problem but also showing them that the skills they acquire transcends university context and makes them independent problem-solvers. Tutors who adopt these conceptions encourage students to define problems from different perspectives and not be limited to exploring multiple paths. They don't give answers, "not putting restrictions on what is to be learned", and most importantly, asking them to reflect often on how they are going through the problem-solving process, asking to evaluate their learning process, group work, how they contribute, etc.

Discussion

This study aimed to explore how tutors in a problem-based learning context conceptualise their roles in the process of facilitating PBL tutorials, the nature of problems, and the problem-solving process. The phenomenographic analysis has revealed a nuanced hierarchy of conceptions, providing insights into the complexity of these elements and their potential impact on educational practices. This section discusses findings in light of existing literature and their implications for practice. Although PBL is considered a very student-centred approach and teachers might possess all PBL competencies, previous research showed that they might differ in their ideas of PBL tutoring (Leatemia et al., 2024).

Concerning the categories of conceptions of problems, at the bottom of the hierarchical structure, they are viewed as starting points to achieve intended learning outcomes. This perspective, while not incorrect, reflects a pragmatic concern with aligning teaching practices with institutional goals and assessment requirements. Tutors often feel the pressure to ensure that curriculum objectives are met, which can sometimes seem at odds with the student-centred ideology of PBL (McAlister et al., 2013). The debate over who should formulate learning objectives—tutors or students—remains a significant issue in PBL research (Czabanowska et al., 2012). However, a more advanced conception views problems as real-life experience that triggers curiosity and also connects to professional life, resonating with Barrett (2017), who highlights the potential of PBL problems to facilitate transitions in knowledge, professional action, and identity. As the categories of description of the problem become more complex, the role of the problem perceived by the tutors becomes more sophisticated. As we can see, the function of the problem is not only to acquire knowledge about certain concepts and make students read certain books and articles, but to encourage self-exploration, to strengthen professional links, etc.

The second dimension of our study focuses on how PBL tutors conceive problem-solving. It is important to note that all participants in this research utilise the PBL methodology as practised at Linköping University, specifically the PBL Wheel. Therefore, there is no variation in the procedural steps they follow during the PBL tutorial process. Our primary interest was to understand what tutors perceive as the main value of the problem-solving process and what aspects they emphasise in their instruction. The least advanced conception views problem-solving as a means to gain subject matter knowledge. While this is undoubtedly a crucial educational goal, research suggests that PBL should not merely serve as an appealing method for covering content. Facilitating the process versus facilitating content acquisition remains a significant challenge in PBL tutoring (Azer, 2005). As conceptions evolve, tutors begin to emphasise the importance of developing learning strategies, enhancing students' work-related skills, and ultimately viewing problem-solving as a transformative learning experience that transcends the university course and significantly impacts students' lives. This advanced conception aligns with research highlighting the complex nature of the facilitation process, which requires a balance of various skills to be effective (Prodan, 2016; Groves et al., 2005).

The hierarchical categories of tutors' roles range from safeguarding the process to supporting students to become independent problem-solvers. Initially, tutors may focus on ensuring a safe and structured learning environment, which is crucial for fostering PBL group dynamics, as highlighted by Azer (2005). Previous studies have shown that the first fundamental step to ensure meaningful interaction in PBL groups and to promote deep learning is for students to be aware of their roles and how the PBL process works (Azer, 2009). However, this is not the only important conception; therefore, we intended to show how complex it is. As their understanding deepens, tutors see their role as guiding inquiry and facilitating meaningful collaboration, which is essential for developing critical thinking and self-directed learning skills (Katsara & De Witte, 2019). At the highest level, tutors view their role as supporting them to become independent problem-solvers, which involves not only guiding and supporting students but also challenging them to reflect on their beliefs, identities, and professional goals (Leatemia et al., 2024). This advanced conception underscores the importance of tutors in shaping a learning environment that promotes continuous personal and professional development, aligning with the principles of dialogic knowing in PBL (Barrett, 2017).

The outcome space developed from these categories provides a comprehensive understanding of teachers’ conceptions of teaching problem-solving. Although the categories of descriptions for each dimension have developed independently from each other, we can observe a noticeable alignment across the dimensions. Figure 1. shows that in all dimensions, first, the least complex categories focus on basic educational goals, such as seeing problems as a means to meet ILO, and gaining content knowledge; as for the teacher’s role, it is seen as a safeguard of the PBL process. The second category in each dimension emphasises creating a more stimulating and engaging learning experience for students. Here, the main role of the PBL is seen as an instructional way to suggest a more unconventional learning experience to students, as three facets of it focus on stimulating curiosity and helping students develop metacognitive learning strategies. The third category in each dimension shifts focus towards the development of practical, work-related skills. In this perspective, PBL is not only about acquiring learning strategies but also about cultivating essential workplace skills. Teachers, in this context, are seen as facilitators of collaboration, an important competency in professional settings. The most complex conceptions, represented in the fourth category of each dimension, highlight the importance of fostering independent learning experiences that promote autonomy beyond the university environment. These conceptions emphasise the development of transformative, transversal skills that students can carry into various aspects of their lives.

Limitations

While this study offers valuable insights, there are some limitations to acknowledge. This study relies on the tutor's interview analyses, which might limit the study from fully capturing how tutors implement problem-solving and tutoring strategies in practice. However, it should be noted that the approach we adopted aligns with a phenomenographic focus on conceptions ('what' aspects) rather than actions ('how?' aspects). Future studies could adopt a mixed-method approach, combining interviews with classroom observations. Furthermore, one of the limitation is the absence of a coder-checking process, which typically involves multiple researchers independently coding the same data transcripts and comparing their categories. Although some researchers view this as a potential drawback due to the possibility of subjective bias, solo research, such as doctoral papers, yields reliable and meaningful data (Åkerlind, 2005). Although it is less likely and unnecessary for different researchers to replicate the outcomes space (Cope, 2004), it would be interesting to see if similar findings emerge in different educational settings.

Application of the study

First of all, this paper highlights the value of phenomenography, as it offers a unique perspective to learn PBL tutors' awareness in a very layered and profound way, which can enrich our understanding of their professional development needs, and, at the same time, show us what are the most complete understanding one can hold regarding different aspects of teaching problem-solving in PBL context. Although this study is dedicated to the PBL context, higher education teachers whose institutions do not formally adopt PBL but are willing to incorporate problem-solving pedagogy can use it as a self-guiding tool.

The present model offers immediate utility by providing a structured framework for reflection and dialogue among PBL tutors. Individual PBL tutors can use this framework as a reflective tool to evaluate and refine their teaching practices. It enables tutors to recognize their current conceptual focus and explore pathways toward broader, more impactful perspectives. For instance, tutors who see that the only purpose of the problem is to introduce topics of the week can expand their approach by acknowledging and designing problems that connect students to the profession in a way that stimulates their curiosity and also enables them to see personal meaningfulness and multiple paths within it.

From an academic development perspective, our findings suggest that the CoTPS framework, combined with the four-component model suggested earlier (Åkerlind, 2018), can design workshops and training sessions that emphasize variation and hierarchy in understanding. For example, by applying some of the patterns of 4 components model and addressing one of the dimensions of CoTPS, academic developers can direct teachers' attention to the variation of conceptions of the problem, enabling them to identify their existing conceptions and explore distinctions (contrast). They can enable tutors to create problems that address all categories of understanding, such as meeting ILO, fostering curiosity, building professional skills and leading students to have multiple paths (fusion).

Looking ahead, as researchers, we recognize the need to collaborate with academic developers to design programs for tutors aimed at broadening their awareness of diverse aspects of teaching problem-solving. There is an opportunity to create more practical, hands-on resources that PBL tutors and higher education teachers can readily apply in their teaching practices.

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Appendix

Conceptions of Problem, extended quotes

Category 1) “Well, of course, you don't give the students direct questions because they will phrase their questions themselves based on the scenario. So, you can only do as much as you can. You can't make errors… so they learn exactly what they're supposed to learn. But you should aim to make a good scenario as possible. Hopefully, it will help students achieve their intended learning outcomes [Category 1 awareness].” (Response N14).

Category 2) “You shouldn't post the questions itself. It's important that the questions and what is required from the students are not given to them… One thing is that it should probably also be engaging, so it shouldn't be trivial. It should be something that is emotionally engaging, and that some students need, that is, some trouble to engage in finding the problem [Category 2 awareness]. Another thing, of course, is that the PBL tutorials are also kind of artificial because you know what the students are studying for that term. So, you kind of know that now it's physiology. Oh, it's someone with a problem with ‘mixed turtian’. And of course, then you think, oh, it might be that they have a problem with the blood pressure and then the students know that they should read about the kidneys…[Category 1 awareness].” (Response N1).

Category 3)“ I like cases that do not necessarily bring the most learning outcomes. I like cases that are provocative in some way, that it could be that they are wrong…[Category 2 awareness]. It's provocative because I think that psychologists still need to meet people who believe in things that they don't themselves believe in. So, what I want with that case is that the students both should read about mourning and dying [Category 1 awareness], but they should also try to have some self-reflection of what they think is important by death and dying because in their future profession, they will meet people that believe in God or life after death, stuff like that because they need to do that [Category 3 awareness].” Response (N4).

Category 4) Sometimes, when we give them vignettes, it's like, oh, here's a vignette, and it's all about social influence [Category 1 awareness]. So, it should stimulate curiosity [Category 2 awareness]. It should be ambiguous in terms of what is to be done, but also multiple ways in which they can go with it. So, maybe one group might go off in one direction, and another group might go off in a different direction, so they should be open to different ways of solving it [Category 4 awareness]. Because if it just leads you down one path and it feels very fixed, formulaic, and teacher-driven, and if it's going to be student-driven, It should be something that the students can say, no, I'm actually interested in this. Can we explore? …If I see a student and if I see them looking at a problem and thinking we can go this way, we can go that way, then I'm thinking, yeah, they've done really well here… Especially with psychology students. You want them to understand the world in different ways and see variability and flexibility and not just to see, oh, you're that kind of person [Category 3 awareness]. You're going to be like that, do you know what I mean? To see a bit more open-minded." (Response N6).

Conceptions of Problem-Solving, extended quotes

Category 1) "Well, of course, you don't give the students direct questions because they phrased their questions themselves based on the scenario. So, you can only do, I mean as much as you can. You can't make errors, it is all complete for them so they learn exactly what they're supposed to learn. But aiming to make a good scenario as possible. Hopefully, it will help students achieve their intended learning outcomes. And of course, the students also know their intended learning outcomes for the course because they have access to the syllabus, and often they also look at the intended learning outcomes when they try to formulate the questions to the scenarios." (Response N14).

Category 2) "I mean what we try to achieve is basically that the students should look at the scenario they should find out what they already know and what they need to know and then try distance from it and reflect on what they need to know so that they can read about that and then discuss it the next time [Category 1-2 awareness]. Yeah, but that's not enough. I've realised that I need to talk with my students also about why we're doing this. So, in order to try to motivate them to understand. Why? Why do they do this? [Category 2 awareness]." (Response N12).

Category 3) **"…**Students are given more freedom to structure their teaching and their learning themselves than compared to other psychology programs in Sweden [Category 2 awareness]. So, when they are done with the psychology program here, they are more self-running academics, psychologists who really do stuff by themselves without anyone telling them what to do. But then we have the idea that from working in the PBL group, students will be forced to individually read more literature than they would have done individually and they will learn more things based on that group context [Category 2 Awareness]. So, they have the same tutoring groups for a semester, and then they switch to the next semester. So, they have a different group. And I think that it is really good for them to practice working in different group constellations with people that they would never have collaborated with if we hadn't forced them into different types of group processes, how to solve conflicts and so on, is a good teaching outcome that is not necessarily about solving problems [Category 3 awareness]." (Response N9).

Category 4) “Students are different. But I think that problem-based learning is like a way of thinking. It's a style of life. It's something that you engage with, and then you learn in that way, and you operate in that way [Category 4 awareness]. I hope that you can use it in many situations in life, not only when you try to learn materials for the course [Category 1 awareness]. It will be a tool for the way you think and the way you solve problems in the future. It will be like a way of approaching problems in the future, a way of also interacting with others and trying to find solutions, not by yourself, but with the help of other people and getting richer solutions. [Category 3 awareness]. A way of learning how to formulate questions and where the questions come from because the questions are very important [Category 2 awareness]. So, if you don't have a good question, you won't get a good outcome.” (Response N7).

Conceptions of tutors’ role, extended quotes

Category 1) “I'm much more like making the structure. If I notice that they need a lot of guidance and structure because some people in the group will need that, otherwise they will get paralysed…This is the structure of the day. Today, we are going to start with this, and then we will continue like this. And then I will act at the beginning, like a structure maker, like an “informator”…[Category 1 awareness].”(Response N7).

Category 2) “I guess, on the one hand, sort of guiding them through the stages and showing them why it's important, [Category 1 awareness] but also sort of modelling in a way the kinds of questions they can ask. So, when I'm tutoring in a PBL group, I might ask questions and show the kinds of things I want to get them to think about and look at things in a different way [Category 2 Awareness]. So, it is partly modelling, partly guiding, supporting, and encouraging”. (Response N6).

Category 3) “It’s a lot about just learning PBL structure and working in a group [Category 1 awareness]. A lot of the students have bad experiences with group work. I think my part is to make sure that they just don't tell each other what they have read. I read this article. I read this article. That's not okay for me. There should be a discussion. They should deepen the discussion [Category 3 awareness]. They ask questions, and if they don't ask questions, I ask questions, I want to challenge them in what they have read [Category 2 awareness].” (Response N5).

Category 4) “ I want to kind of rock the world a bit, just nudge them and make them a bit uncomfortable by asking questions and make them feel like we have power over our own learning [Category 2 awareness]. And I think the tutor sets the tone for that because I know from my students that most PBL tutors will kind of just ask: Okay, what step are you on now? Have you forgotten anything?

How many studies have you read [Category 1 awareness]. And I'm like, I don't care. I don't care if you've read that many studies. I want you to have studied, but I want the discussion to be meaningful [Category 3 awareness]. I don't want to hear your poor version of retelling it, but I want to hear your thoughts based on what you've learned and with other people's, we can create new knowledge. I hope in the future, even if they don't know it, even if they don't have the answer, when they get out of work life and they see a problem they don't know the answer to, they will find a way to find the answer on their own [Category 4 awareness]."(Response N9).

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Problem-Based Learning (PBL)

How does it Affect the Speaking Skills of Introvert and Extrovert Students?

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Abstract

Problem-Based Learning (PBL) fosters student engagement and enhances the learning process through active problem-solving. However, limited research has explored its specific impact on the speaking skills of students with varying personality traits. This study investigates the influence of PBL on the speaking proficiency of introverted and extroverted students at Fatmawati Sukarno State Islamic University, Bengkulu. Using a comparative experimental design, 40 students were categorized as introverts or extroverts based on a validated personality questionnaire. PBL was implemented through structured group activities, including identifying real-world problems, researching solutions, brainstorming ideas, and presenting findings. These tasks targeted critical speaking skills such as fluency, confidence, organization, and clarity. Pre-test and post-test assessments of speaking performance provided quantitative data, analyzed using paired and independent t-tests. Results revealed significant

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improvements in speaking proficiency for both groups, with extroverted students showing greater gains than their introverted peers. The findings highlight the potential of PBL to improve speaking skills across personality types and underscore the importance of tailoring PBL activities to accommodate diverse learner traits. This study contributes to the literature by demonstrating the adaptability of PBL for optimizing speaking skill development in higher education contexts.

Keywords: Problem-based learning; Speaking skills; Personality traits; Introverted students; Extroverted students

Introduction

Teaching methods play a very important role in shaping the learning process by creating environments that promote academic growth and equip students with the skills needed for lifelong learning. Effective instructional approaches not only inspire learners but also enable them to achieve specific educational goals. As Jeronen et al. (2016) describe, teaching methods are structured processes facilitating knowledge exchange between educators and students, with the ultimate aim of fostering meaningful changes in learning outcomes.

Among various instructional strategies, Problem-Based Learning (PBL) has gained prominence as a dynamic approach to education. Hmelo-Silver (2004) characterizes PBL as a method that engages students in solving authentic, real-world problems, integrating knowledge across disciplines to develop critical thinking, adaptability, and informed decision-making. The emphasis on practical application makes PBL particularly relevant in English Language Learning (ELL), where developing both linguistic proficiency and real-world communication skills is paramount.

Extensive research underscores the benefits of PBL in enhancing speaking proficiency and cultivating positive attitudes toward ELL. For instance, Hasnawan (2020) found that PBL improves students' speaking skills and fosters cognitive, behavioral, and emotional engagement. However, studies like Nurhazizah et al. (2022) present mixed results, attributing limited success to contextual factors such as implementation techniques and learner participation. Despite these inconsistencies, Sutrisna and Artini (2020) highlight the value of PBL in promoting speaking proficiency and fostering a favorable attitude toward language learning.

In addition to instructional methods, individual learner differences, particularly personality traits, significantly influence language acquisition. Ellis

(1994) proposed that extroverts, with their inclination for interpersonal communication, often excel in spoken language, while introverts, known for their reflective and cognitive strengths, may perform better in structured tasks. Understanding how personality traits interact with instructional methods like PBL is crucial for designing inclusive and effective learning experiences.

Emerging studies suggest that PBL supports the development of essential social-emotional skills and fosters independence, creativity, and critical thinking. For example, Fitzgerald (2020) and Morrison et al. (2021) emphasize how PBL nurtures interpersonal and cognitive abilities. Wu et al. (2019) further examine the interplay between personality traits and communication behaviors in web-based learning environments, reinforcing the need for personalized teaching strategies.

Despite the growing body of research on PBL and its general benefits, the specific impact of PBL on speaking proficiency among learners with different personality traits—introverts and extroverts—remains underexplored. This gap limits the ability of educators and curriculum developers to design tailored interventions that maximize learning outcomes for diverse student populations. Addressing this gap, the present study investigates how PBL influences the speaking skills of introverted and extroverted students at Fatmawati Sukarno State Islamic University, Bengkulu.

The study employs a comparative experimental design to evaluate the nuanced effects of PBL on these distinct personality groups. By bridging theoretical insights and practical applications, the research seeks to advance personalized learning strategies in language education. The findings are expected to inform educators and curriculum designers, enabling them to develop more inclusive and impactful PBL interventions. The research is guided by the following question:

- How does the implementation of a Problem-Based Learning (PBL) model influence the speaking skills of students with different personality traits (introverts vs. extroverts)?

Literature review

Overview of Problem-Based Learning (PBL)

Problem-Based Learning (PBL) has emerged as a dynamic educational methodology that fosters active student engagement in meaningful problem-solving. This approach allows students to collaboratively address problems, develop mental models for understanding, and cultivate self-directed learning habits through hands-on experiences and reflective practices (Evensen & Hmelo-Silver, 2000; Norman & Schmidt, 1992; Hmelo-Silver, 2004).

The appeal of PBL lies in its alignment with educational goals that prioritize active and collaborative learning. Grounded in the belief that knowledge is constructed and co-constructed through social interactions and self-directed inquiry, PBL provides a robust framework for fostering deeper learning (Glaser & Bassok, 1989). By emphasizing the application of knowledge to real-world scenarios, PBL also encourages learners to develop problem-solving and critical thinking skills that extend beyond the classroom.

The decision to prioritize PBL in this review stems from its relevance to contemporary educational practices and its demonstrated potential to enhance learners' engagement and autonomy. Understanding PBL's theoretical foundations and practical applications is vital for contextualizing its role in improving language education and student outcomes.

Insights into Speaking Skills

Speaking skills have long been a central focus in language acquisition research, with various theoretical frameworks offering insights into their development. Behavioral Theory, for instance, posits that speaking skills are acquired through imitation and reinforcement, emphasizing the role of feedback in shaping learners' speech (Skinner, 1957). Nativist Theory, on the other hand, highlights the innate capacity for language acquisition, suggesting that speaking ability is an inherent aspect of human cognition (Chomsky, 1965; Litchfield & Lambert, 2011).

Adding to these perspectives, Semantic-Cognitive Theory stresses the importance of meaning in language development. It argues that learners acquire speaking skills by understanding word and phrase meanings, using this knowledge to construct coherent sentences (Piaget, 1981; Dasen, 1994; Wadsworth, 2004). Finally, Social-Pragmatic Theory focuses on the social and cultural dimensions of language, asserting that speaking skills emerge as learners internalize the norms and conventions of effective communication in specific contexts (Vygotsky, 1978; Tomasello, 2005).

Proficiency in speaking is a key indicator of success in language acquisition, often serving as a measure of learners' practical language abilities (Brown & Yule, 1983). This section highlights the significance of speaking skills in English as a second language (ESL) contexts, where achieving fluency is a crucial goal. The inclusion of these theories is intentional, as they provide a comprehensive foundation for examining the multifaceted nature of speaking proficiency.

Personality Concepts in Language Learning

Personality traits are increasingly recognized as influential factors in second language acquisition. Research suggests that learners' personality characteristics can either facilitate or impede language learning, shaping their strategies and outcomes (Zhang, 2008). Specifically, two contrasting hypotheses highlight the role of extroversion and introversion in language learning (Ellis, 1994).

The first hypothesis posits that extroverts excel in acquiring basic interpersonal communication skills due to their sociable nature and willingness to engage in conversations. Conversely, the second hypothesis suggests that introverts may outperform extroverts in academic language learning contexts because of their reflective and analytical approach (Richards & Schmidt, 2013). These perspectives underscore the complex interplay between personality and language learning, emphasizing the need for a nuanced understanding of individual differences.

Ehrman and Oxford (1989) provide further insights into personality-driven language acquisition strategies. Extroverts tend to favor emotive and visualization techniques, while introverts are more deliberate in their communication, carefully considering context and meaning before responding. This distinction highlights how personality traits influence learners' preferences and performance in language use.

Despite the limited research on the direct correlation between personality traits and speaking proficiency, it is reasonable to infer a connection given the social and communicative nature of speaking. This focus on personality provides a conceptual framework for examining its potential impact on learners' ability to develop and demonstrate speaking skills.

Method

Research Design

This study utilized a comparative experimental design to examine the effects of Problem-Based Learning (PBL) on the speaking skills of students with introverted and extroverted personalities. The experimental approach was chosen to establish cause-and-effect relationships, aligning with Johnson and Christensen's (2019) recommendation for studies evaluating interventions. Two groups—categorized by personality type—were exposed to the PBL model, enabling a focused analysis of its impact on speaking proficiency. This design adheres to Barrows' (1996) assertion that PBL fosters active learning and critical thinking, essential for improving communication skills.

A quantitative methodology was employed to ensure systematic measurement of outcomes and group comparisons. Creswell (2014) emphasizes the suitability of quantitative methods for generating statistically reliable conclusions in educational research. The study took place at the English Education Department of Fatmawati Sukarno State Islamic University, Bengkulu, ensuring a controlled environment for rigorous evaluation, consistent with Cohen, Manion, and Morrison's (2018) guidelines for experimental research.

Participants

The sample comprised 40 students, divided into two groups based on their scores from a self-report questionnaire measuring introversion and extroversion, adapted from Richmond and McCroskey (1998). Although self-reported data provide an accessible means of categorization, potential biases—such as social desirability effects—are acknowledged. Future studies might enhance reliability through triangulation, incorporating validated personality assessments or observational methods for cross-verification.

The sample size was consistent with Cohen, Manion, and Morrison's (2018) recommendations for maintaining validity in small-scale experimental research. Participants' demographic details, such as age and academic background, were controlled to reduce extraneous variability.

Instruments

The instruments used in this study included PBL activities and speaking tests, both designed to evaluate and enhance students' speaking skills. The PBL activities were centered around real-world, open-ended problems that were directly relevant to the course content. These activities incorporated personality-based grouping to ensure tailored engagement for students with diverse traits. The tasks involved problem identification, solution exploration, and collaborative presentations, all of which aimed to foster critical thinking and practical communication skills. Peer feedback and discussions were integral components of the process, providing opportunities for reflection and interactive learning.

The speaking tests were conducted in two phases: a pre-test and a post-test. The pre-test assessed students' baseline speaking abilities, focusing on aspects such as fluency, organization, and confidence. Students participated in structured tasks, including prepared speeches or debates, to provide a comprehensive measure of their initial skill levels. Following the intervention, the post-test evaluated improvements using the same tasks to ensure consistency. This methodology aligns with Creswell's (2014) recommendation for employing repeated measures to track changes over time. Both tests utilized rubrics with clearly defined criteria, ensuring consistent and objective evaluation throughout the study.

Procedure

The study followed a systematic procedure to ensure reliability and replicability of results. First, participant recruitment was conducted at a single institution to control for contextual variables. Students were invited to participate, and informed consent was obtained to ensure ethical compliance with institutional review board (IRB) standards.

Next, a personality assessment was administered using a questionnaire. The results of this assessment were used to categorize participants into introverted or extroverted groups, enabling the study to explore the role of personality traits in the effectiveness of PBL.

Following this, the PBL intervention took place over a designated period. Participants engaged in structured PBL activities guided by facilitators, who ensured adherence to the PBL framework and supported discussions. These activities focused on fostering critical thinking, collaboration, and communication skills through problem-solving tasks.

Finally, pre- and post-tests were conducted to evaluate the impact of the intervention. Speaking tests administered before and after the PBL activities assessed changes in participants' performance, providing measurable data on the effectiveness of the approach.

Throughout the study, ethical considerations, including confidentiality and voluntary participation, were rigorously maintained to uphold the integrity of the research.

Data Analysis

The data analysis was conducted using SPSS (Statistical Package for the Social Sciences), a reliable tool for processing and interpreting quantitative data (Field, 2018). The process involved several steps to ensure a thorough and objective evaluation of the findings.

First, categorization and scoring were carried out for the personality questionnaire. Responses were converted into Likert-scale scores ranging from 1 (strongly disagree) to 5 (strongly agree), with a maximum possible score of 70. This scoring system provided a standardized way to quantify personality traits.

Next, descriptive statistics were computed to summarize the pre- and post-test results. Measures of central tendency, including the mean and standard deviation, were calculated to provide a clear overview of students' speaking performance before and after the intervention.

To explore differences in speaking improvements between introverted and extroverted groups, comparative analysis was performed. Independent t-tests and paired sample t-tests were employed to assess statistical significance. The analysis adhered to Teddlie and Tashakkori's (2009) guidelines for ensuring meaningful and accurate comparative insights.

Additionally, frequency and percentage analysis was used to summarize the questionnaire data, offering a clear view of the personality distribution patterns among participants (Pallant, 2020).

Each analysis method was explicitly aligned with the study's objectives, ensuring that the results were relevant and contributed to addressing the research goals.

However, the study's findings should be interpreted with caution due to certain limitations. The reliance on self-reported data and the relatively small sample size may restrict the generalizability of the results. Future research could address these limitations by incorporating larger, more diverse samples and triangulated data collection methods to enhance the robustness of the findings.

Findings

The Descriptive Analysis of Pre-test and Post-test Scores in Introvert Class

This section presents the findings from a comprehensive statistical analysis of students' speaking proficiency in the Introvert class before and after the intervention. The assessment of students' speaking skills encompasses six specific dimensions: grammar, vocabulary, comprehension, fluency, pronunciation, and task performance. Students' scores were classified to determine their level of speaking competency, ranging from excellent to poor, as depicted in Chart 1. This analysis provides a nuanced understanding of the impact of the intervention on various aspects of speaking proficiency.

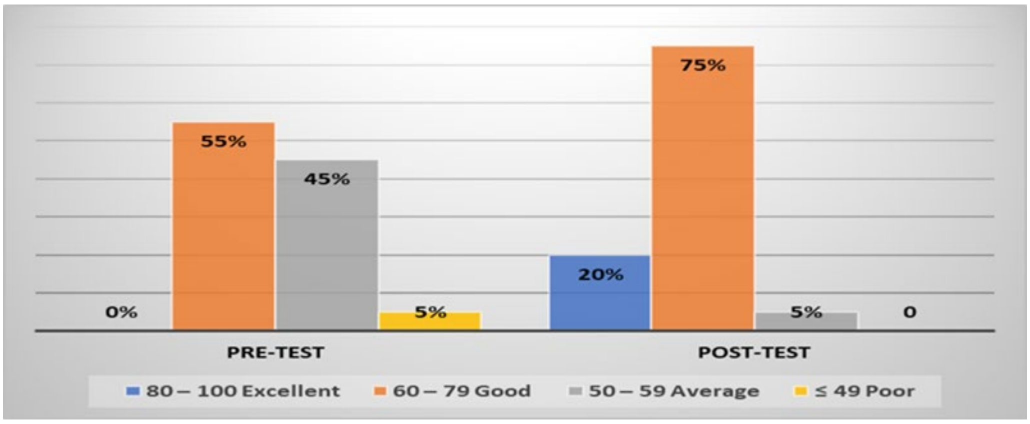

Chart 1. Pre-test and post-test scores in Introvert group.

As illustrated in Chart 1, the enhancement in speaking proficiency among introverted students becomes evident following the integration of PBL. In the pre-test, 1 student (5%) was classified as poor, 9 students (45%) as average, and 11 students (55%) as good. In contrast, after the intervention, the distribution shifted to 1 student (5%) in the average category, 15 students (75%) in the good category, and 4 students (20%) in the excellent category. This shift provides valuable insights into the speaking abilities of students, clearly demonstrating a significant improvement in speaking skills within the introvert class following instruction using the PBL model.

The Descriptive Analysis of Pre-test and Post-test Scores in Extrovert Class

The following illustration presents the results of both the pre-test and post-test assessments for students in the extrovert class. Subsequently, the researcher categorized the scores to assess the proficiency levels of students in speaking, employing criteria spanning from excellent to poor, as detailed in Chart 2.

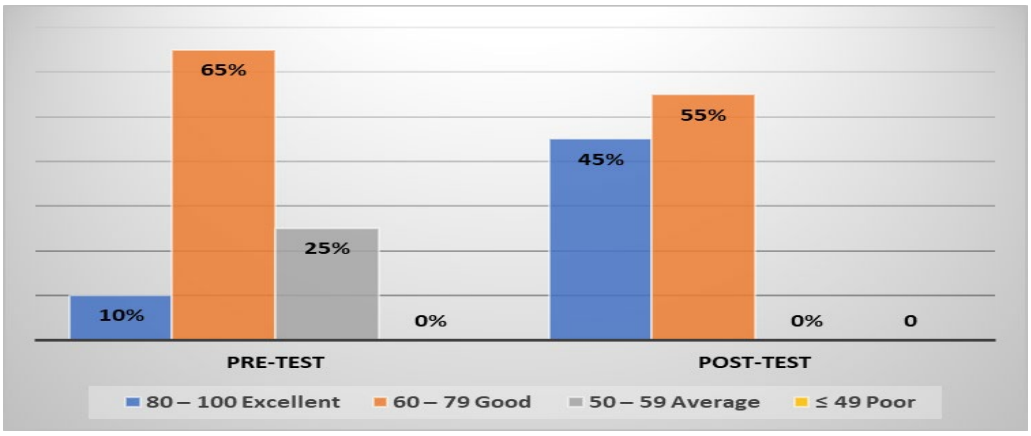

Chart 2. Pre-test and post-test scores in Extrovert group.

As depicted in Chart 2, there is a noticeable enhancement in the speaking proficiency of students in the extrovert group following the implementation of PBL. In the pre-test, 5 students (25%) were categorized as average, 13 students (65%) as good, and 2 students (10%) as excellent. In contrast, in the post-test, the distribution shifted to 11 students (55%) in the good category and 9 students (45%) in the excellent category. This distribution offers valuable insights into the speaking abilities of students, clearly demonstrating a significant improvement in speaking skills within the extrovert class following instruction using the PBL model.

The Comparison Descriptive Analysis of Pre-test and Post-test Scores in Introvert Class and Extrovert Class

The table below presents a comprehensive descriptive analysis of the average speaking ability scores among students in both the Extrovert and Introvert groups before and after receiving instruction through the Problem-Based Learning (PBL) model. It delineates the average scores of students in the pre-test and post-test, categorized by their introverted and extroverted traits.

	Pre-test		Post-test	
Score	**Introvert**	**Extrovert**	**Introvert**	**Extrovert**
SUM	20	20	20	20
MEAN	61.6	65.6	72.9	78.2
SD	8.75	9.65	9.11	12.01
MAX	77	83	91	98
MIN	47	50	59	60

Table 1. Average Scores of Students in the Pre-Test and Post-Test.

The data presented in the table highlights the average scores of both introverted and extroverted students during the pre-test and post-test phases, revealing a notable improvement in scores for both groups. Specifically, the average score for introverted students increased from 61.6 to 72.9, while for extroverted students, it rose from 65.6 to 78.2.

Overall, both introverted and extroverted students demonstrated significant score improvements from the pre-test to the post-test. This rise underscores the efficacy of the Problem-Based Learning (PBL) model in fostering learning and enhancing speaking skills across both personality types. Moreover, the consistent higher scores achieved by extroverted students in both tests suggest a potential area for further investigation. In conclusion, these findings affirm that the PBL approach has effectively contributed to enhancing student performance in speaking proficiency.

The Statistical Analysis of Pre-Test and Post-Test Scores in Introvert and Extrovert Group

The t-test is a statistical tool used to assess whether there is a significant difference between the means of two groups. Before conducting a t-test, it is essential to verify if the data meets specific assumptions, primarily focusing on normality and homogeneity of variance. Normality pertains to the assumption that the data follows a normal distribution, ensuring the accuracy of t-test results. If the data deviates from normality, the outcomes of the t-test may be compromised. Similarly, homogeneity of variance assumes that the variances within the compared groups are equal; discrepancies here could also impact the reliability of t-test results. Thus, checking for normality and homogeneity of variance is crucial prior to conducting a t-test to uphold the integrity of the findings.

Table 2 below outlines the results of the normality tests conducted on the speaking proficiency of students in both the introvert and extrovert groups. The Kolmogorov-Smirnov test, employed in this study, assesses whether sample data conform to a normal distribution. This analysis ensures that the subsequent statistical tests are conducted appropriately and reliably reflect the characteristics of the data.

	Students	**Kolmogorov-Smirnova**			**Shapiro-Wilk**		
	Personality	Statistic	df	Sig.	Statistic	df	Sig.
Post-test	Introvert	.093	20	.200*	.972	20	.797
	Extrovert	.152	20	.200*	.933	20	.178
*. This is a lower bound of the true significance.							
a. Lilliefors Significance Correction							

Table 2. Test of normality.

Based on the Kolmogorov-Smirnov test presented in Table 2, the significance values for all variables are below the alpha level of 0.05 (5%), indicating that all variables exhibit a normal distribution. Therefore, it can be inferred that both the introvert and extrovert groups of students conform to normal distribution assumptions.

In summary, Table 2 provides the outcomes of statistical tests assessing the normality of the introvert and extrovert groups. The results strongly suggest that both groups adhere to a normal distribution.

Table 3 below presents the findings from the homogeneity test conducted on the speaking proficiency of students in both the introvert and extrovert groups. The Levene test, utilized in this analysis, examines whether these groups exhibit equal variances.

Levene Statistic	**df2**	**df2**	**Sig.**
2.153	1	38	.151

Table 3. Test of Homogeneity of Variance.

According to Levene's test results shown in Table 3, both the Extrovert and Introvert groups of students, following instruction with the PBL model, exhibit a significance value (sig) of 0.151. Comparing this sig value with the alpha level (α) of 0.05 reveals that the sig value exceeds α = 0.05. This indicates that the variance in speaking ability data among students in both groups—Extrovert and Introvert—is consistent and homogeneous.

Having conducted these prerequisite tests and confirmed adherence to the requirements for conducting a t-test, the next step involves performing the t-test to evaluate mean differences. The results of the t-test for mean differences are detailed in Table 4 below.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Post-test	Equal variances assumed	2.153	.151	1.557	38	.001	5.250	3.372	1.576	12.076
	Equal variances not assumed			1.557	35.435	.001	5.250	3.372	1.592	12.092

Table 4. Independent Sample Test

The table presented above illustrates the outcomes of a t-test conducted on the average post-test speaking ability scores of both Extrovert and Introvert student groups, following instruction with the PBL model. This table provides two significant values for the average difference test, one assuming equal variances and the other not assuming equal variances. Based on preliminary test results indicating consistent variance in speaking ability scores between the Extrovert and Introvert groups, the significance value in this average difference test is considered assuming equal variances.

Referring to the t-test results, the significance value for the two-tailed test is 0.001. Comparing this significance value with the α value of 0.05 reveals that sig. (2-tailed) = 0.001 is less than $\alpha = 0.05$. This indicates a significant difference in the speaking abilities of students in the Extrovert and Introvert groups, tested at a significance level of $\alpha = 0.05$. In simpler terms, following instruction using the PBL model, the speaking abilities of Extrovert and Introvert student groups exhibit a statistically significant difference at the $\alpha = 0.05$ significance level.

Discussion, Conclusions, and Suggestions

Discussion

The analysis reveals a significant improvement in students' speaking skills across both introverted and extroverted groups after the implementation of Problem-Based Learning (PBL). This finding underscores the effectiveness of PBL in enhancing speaking competence, aligning with Barrows' (1996) assertion that PBL promotes active engagement and critical thinking—essential components for developing communication skills. Furthermore, PBL encourages self-directed inquiry, as highlighted by Schmidt, Loyens, Van Gog, and Paas (2007), enabling students to apply their knowledge in practical contexts.

One of the most notable outcomes of this study is the broader educational impact of PBL, regardless of students' personality traits. For instance, PBL fosters long-term knowledge retention by engaging students in active problem-solving, as supported by Hmelo-Silver (2004). This method shifts teaching practices away from rote memorization toward dynamic and meaningful interactions, equipping students with skills relevant to real-world scenarios. According to Savery and Duffy (1995), PBL also nurtures essential communication and negotiation skills, while Wood (2003) emphasizes its role in promoting collaboration and social interaction. These attributes are critical for students' academic and professional success, as noted by Norman and

Schmidt (1992), who advocate for PBL as a mechanism to cultivate critical thinking and problem-solving abilities.

The study sheds light on how personality traits influence the effectiveness of PBL. Introverted students, who typically prefer solitary tasks and observation (Richards & Schmidt, 2013), benefited from the collaborative and interactive nature of PBL. This engagement aligns with Jonassen's (1999) theory that PBL motivates diverse learners by fostering participation and motivation. For extroverted students, PBL provided ample opportunities for social interaction, enhancing their speaking proficiency. Cain (2012) notes that extroverts' natural tendency toward communication often facilitates language acquisition, which may explain their superior performance.

Conclusions

This study concludes that PBL is a highly effective pedagogical strategy for improving speaking skills in both introverted and extroverted students. The significant improvement in post-test scores for both groups highlight PBL's impact on fostering critical thinking, reasoning, communication, and self-assessment skills. Extroverted students consistently outperformed their introverted counterparts, suggesting that PBL might align more closely with their natural inclinations toward social interaction.

The research contributes to the growing body of evidence supporting PBL as a dynamic and effective educational approach. By addressing the diverse needs of learners, PBL equips students with practical skills and knowledge applicable beyond the classroom. The study also underscores the potential for PBL to bridge the gap between different personality types, fostering a more inclusive and participatory learning environment.

Suggestions

To enhance the effectiveness of Problem-Based Learning (PBL), several suggestions can be made. First, pedagogical strategies for introverted students should be tailored to better accommodate their learning preferences. Incorporating structured reflection periods or forming smaller collaborative groups could create a more comfortable environment for introverted learners. These adjustments would enable them to participate more actively and benefit from the interactive aspects of PBL.

Future research directions could focus on exploring specific modifications to the PBL framework to address the unique challenges faced by introverted students. Investigating the long-term impacts of PBL on speaking skills and examining its application across various educational contexts would provide valuable insights. Such studies could help refine PBL approaches to maximize their effectiveness for a broader range of learners.

From a practical perspective, educators are encouraged to adopt PBL as a core instructional strategy, given its ability to foster critical thinking and communication skills. To support this transition, professional development opportunities for teachers on designing and implementing effective PBL activities should be prioritized. This training would ensure educators are equipped with the tools and knowledge to maximize the benefits of PBL in their classrooms.

Despite its demonstrated effectiveness, the study acknowledges certain limitations. The findings are based on a relatively small sample size and a single institutional context, which may limit their generalizability. Future research should aim to expand the participant pool and explore diverse educational settings to strengthen the validity and applicability of the results.

In conclusion, PBL has significant transformative potential for language education, particularly in enhancing speaking skills and fostering active learning. Its adaptability makes it a valuable tool for addressing the needs of diverse learners. By incorporating tailored strategies, pursuing further research, and providing practical support for educators, PBL can contribute to more effective and inclusive teaching practices.

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Conceptualizing Academics Experiences in Adopting Project-based Learning in Maritime Higher Education

An Analysis through Activity Theory

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Abstract

This study examines how academics experience the adoption of project-based learning (PBL) in maritime higher education, analyzed through Engeström's Activity Theory. While PBL has shown effectiveness in higher education, little research addresses the contradictions that arise in specific teaching and learning contexts. Using a qualitative approach, semi-structured interviews with 16 faculty members in a UAE maritime institute revealed key tensions: differing perspectives between academics and practitioners, inconsistent use of technological tools, and the absence of standardized progression rules for student projects. Faculty discussions informed recommendations such as targeted professional development, shared e-resources, and a phased PBL framework. The findings underline the need for inclusive dialogue, structured flexibility, and academic leadership in optimizing PBL implementation. This study offers a theoretically grounded and contextually novel analysis that

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informs curriculum design, stakeholder collaboration, and policy development, contributing to both academic understanding and the enhancement of professional practice in maritime higher education.

Keywords: Project-based Learning; Activity Theory; Teaching and Learning; Maritime Education

Introduction

Higher education is undergoing a profound transformation due to evolving industry demands, shifting stakeholder expectations, and an increasing focus on skill-based education. Traditionally, universities have sought to develop both hard skills, such as cognitive knowledge and professional expertise, and soft skills, including problem-solving, teamwork, and adaptability (Guo et al., 2020). However, these efforts have intensified in response to contemporary challenges, particularly the pandemic, which accelerated the transition to technology-enabled learning (Gupta, 2022). This shift underscores the urgency for higher education institutions to adopt innovative pedagogical strategies.

A key challenge is fostering students' holistic development, encompassing creativity, critical thinking, communication, collaboration, and independent learning (Gupta, 2022). Traditional teacher-centered approaches, where instructors primarily transmit knowledge and students passively receive it, often hinder these objectives (Guo et al., 2020). In contrast, research suggests that learner-centered and active learning methods enhance critical thinking, knowledge retention, motivation, interpersonal skills, and academic performance (Davenport, 2018). Consequently, a shift toward student-centered pedagogy is essential.

At the core of these pedagogical innovations lies collaborative learning, which fosters social interaction, teamwork, and shared knowledge construction. Contemporary educational research emphasizes the importance of interactive, participatory learning experiences (Parker et al., 2022). When students perceive their contributions as valuable, they participate more actively, leading to deeper learning (Adesina et al., 2022).

One prominent approach is Project-Based Learning (PBL), which has gained traction as a means to create sustainable and effective teaching models. PBL aims to engage students in real-world problem-solving and knowledge construction within authentic professional contexts (Gupta, 2022; Guo et al., 2020). Rooted in Dewey's advocacy for inquiry-based education (Dewey &

Dworkin, 1959), PBL prioritizes learners' active engagement in projects that involve driving questions, investigations, and teamwork (Krajcik, 2015).

PBL is an inquiry-driven instructional approach. Krajcik and Shin (2014) identified its six defining characteristics: a driving question, a focus on learning objectives, active student participation, collaboration, scaffolding technologies, and artifact creation. The production of artifacts that address authentic challenges differentiates PBL from other student-centered pedagogies, such as problem-based learning (Helle et al., 2006). Through PBL, students develop interdisciplinary knowledge, problem-solving abilities, critical thinking skills, and collaborative competencies (Meng et al., 2023; Hadgraft & Kolmos, 2020). Research on PBL has spanned various disciplines, particularly engineering education. Studies have explored its integration with industry engagement in the UK (Ruikar & Demian, 2013), its application in electronic engineering in Spain (Hassan et al., 2008), and its role in project-led education in Portugal (Fernandes et al., 2013). In maritime higher education, PBL has been studied as a means of enhancing training and competency development (Fedila, 2007; Gutiérrez et al., 2016).

Despite its growing adoption, PBL presents several challenges. Studies have highlighted difficulties in assessing its impact on academic attainment (Helle et al., 2006) and a lack of rigorous evaluations of learning outcomes (Guo et al., 2020). Some researchers argue that PBL’s effectiveness compared to traditional teaching remains inconclusive (Markham et al., 2003; Powell & Wimmer, 2016).

This qualitative case study aims to analyze faculty experiences with PBL at a UAE maritime institute. The study adopts a realist/interpretivist perspective to address the following research questions:

- RQ1. What are the key areas of contradiction between the different components of the PBL activity system at the investigated institute?
- RQ2. How can these tensions be used to inform the development of the PBL environment?

Based on faculty perspectives, the findings describe the core aspects of the Project-Based Learning activity, which collectively revealed a system under tension; the subsequent discussion analyzes three key contradictions that emerged from this activity system—namely, the misalignment between academic and professional perspectives, inconsistent use and support of technological tools, and critical gaps in institutional rules and support structures. By treating these tensions not as failures but as catalysts for change, the analysis then articulates how these very contradictions were leveraged to inform concrete recommendations for the effective implementation of PBL, focusing on structured stakeholder collaboration, targeted resource development, and coherent policy frameworks tailored to the maritime education context.

The significance of this study lies in its ability to contribute meaningfully across theoretical, contextual, practical, and policy domains. First, by applying Engeström's Activity Theory to the investigation of project-based learning (PBL), the study advances theoretical understanding of how pedagogical innovation unfolds within complex institutional systems. As will be examined in more detail in a subsequent discussion of this study, Activity Theory offers a dynamic framework for analyzing the interrelations between tools, rules, community, and division of labour, and how contradictions among these elements shape teaching and learning. This application reinforces the theory's relevance to higher education research and extends its use into the domain of maritime pedagogy, where it has been underutilized.

Second, the study addresses an established academic issue—faculty engagement with student-centered pedagogies—within a novel and under-researched context: maritime higher education in the Gulf region. This setting presents unique structural and cultural conditions, including regulatory demands, industry alignment, and evolving technological infrastructures. By situating the inquiry in this context, the study generates insights that are both locally grounded and globally relevant, offering fresh perspectives on how PBL is interpreted and enacted by educators working within specialized professional environments.

Third, the study's design supports the enhancement of professional practice by providing a research-based foundation for improving teaching strategies and institutional support mechanisms. Through its focus on faculty experiences, it identifies systemic factors that influence the adoption and sustainability of PBL. These insights can inform the development of targeted professional development programs, instructional design improvements, and collaborative practices that better align academic goals with real-world competencies — particularly important in fields like maritime education where professional readiness is paramount.

Finally, the study contributes to policy content and approaches to policy-making by revealing how institutional structures and regulatory frameworks interact with pedagogical innovation. The findings can guide educational leaders and policymakers in refining institutional policies that support flexible, context-sensitive implementation of PBL. This includes considerations around assessment standards, resource allocation, and stakeholder engagement. In doing so, the study offers a model for evidence-informed policy development that is responsive to both educational and industry needs.

Theoretical framework

Activity Theory (AT) is a theoretical framework derived from the cultural-historical school of psychology, primarily associated with Lev Vygotsky, Alexei Leont'ev, and Yrjö Engeström. It offers a comprehensive approach to understanding the complex interactions in human activities that are mediated by tools and influenced by social and cultural contexts (Vaganova et al., 2020; Roth & Lee, 2007). AT posits that individuals are perpetually involved in a system of activity directed toward an object or goal, with learning and development emerging through these mediated interactions. This perspective highlights that individuals do not function in isolation but rather within larger systemic structures that shape their practices (Roth & Lee, 2007).

A critical aspect of Activity Theory is its conceptual model, which includes the components of subject, object, tools, community, rules, and division of labor (Figure 1). This model enables researchers and educators to assess how cultural and institutional contexts affect learning processes and organize activities.

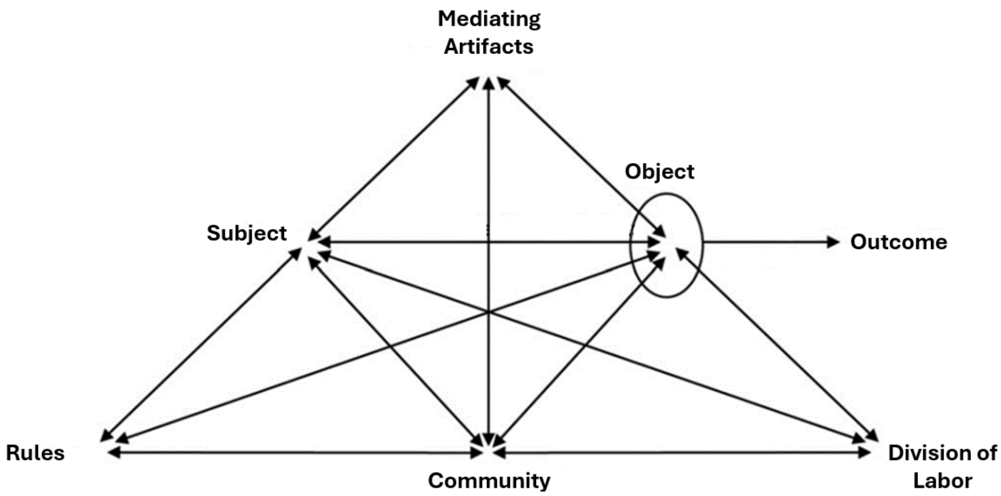


Figure 1. Engeströms (2001) extended activity system model, depicting the six interacting components of a collective activity.

In an analytical setting, the "subject" is the person or group whose agency forms the vantage point of the study, such as learners or instructors. Activities are distinguished by their "object" – the motive or purpose that gives the activity meaning and directs its transformation into an outcome. This relationship between subject and object is mediated by "tools", which include any instruments used in the transformation process. The activity is also shaped by its "community" (the people or groups involved), explicit and implicit "rules," and the "division of labour" that organizes how work is distributed. These components interact dynamically, constantly influencing one another as the activity evolves. In this study, the subjects are faculty members at a maritime higher education institute in the UAE, and the object is their motive for adopting PBL, all situated within a system mediated by tools, rules, community structures, and divisions of labour.

Contradictions naturally arise within an activity system when its elements become misaligned, often due to external influences. These tensions are experienced as problems that individuals strive to resolve, serving as catalysts for change and development within the activity (Ashwin, 2012; Issroff & Scanlon, 2002). The framework asserts that learning encompasses the reshaping of practices and collective understanding through ongoing interactions (Vianna & Stetsenko, 2011).

In applying Activity Theory to pedagogy in higher education, it serves as a relevant framework for several reasons. First, it provides robust tools for analyzing and redesigning teaching practices that are socially situated and collaborative. Such analysis is essential in higher education, where diverse stakeholders, including students and faculty, interact with various tools—from educational technologies to institutional policies—shaping their learning experiences (Scanlon & Issroff, 2005; Isssroff & Scanlon, 2002).

Moreover, Activity Theory accentuates the need for careful consideration of educational contexts, allowing educators to reflect on their pedagogical strategies and identify potential barriers affecting learning (Woulfin, 2016). Reflection is crucial in higher education, given the diverse student populations and disciplinary contexts educators typically encounter. For example, AT has been utilized to investigate how technology influences student engagement and learning outcomes, demonstrating its applicability in modern educational settings (Scanlon & Issroff, 2005; Isssroff & Scanlon, 2002).

Additionally, the emphasis of Activity Theory on systemic relationships and contradictions within activity systems can help educators comprehend the complexities of educational change, fostering a proactive stance toward collaborative learning. This approach encourages the implementation of culturally sustaining pedagogies that recognize and address the varying needs of students (Hirsh, 2020). By acknowledging the historical and contextual factors shaping educational practices, educators can create inclusive curricula and teaching methods aligned with students' real-life experiences and social realities (Vaganova et al., 2020; Roth & Lee, 2007).

The appropriateness of Activity Theory as the lens for examining project-based learning environments, particularly in a maritime higher education institution in the Gulf Area, stems from its integrative and contextual nature. The theory enables researchers to analyze how various elements interact to produce specific pedagogical outcomes in a culturally rich and complex educational setting. Given the distinctive characteristics of maritime education, including practical training components and collaborative learning requirements, Activity Theory offers a nuanced understanding of the challenges and opportunities within the PBL framework. This perspective allows for insights into how faculty members perceive and implement project-based methodologies, ultimately contributing to the development of more effective teaching practices and enhancing student learning experiences in the maritime domain. By employing Activity Theory, this study aims to effectively explore the entirety of the educational ecosystem, fostering a deeper understanding of the factors that influence learning and engagement in maritime studies.

Materials and methods

Study context

The study was conducted at a young higher education institute, established in 2019. It offers three bachelor's programs: Maritime Transport, Marine Engineering Technology, and Maritime Logistics and Supply Chain Management. The institute's pedagogical model blends traditional instructor-guided courses with a sequence of mandatory student-led projects across all four years of each program.

This study applies Engeström's Activity Theory. The faculty members are the "subjects." Their main motives for adopting PBL represent the "object." This relationship is mediated by various factors: technological and evaluation tools, institutional and maritime industry rules, the broader community of stakeholders, and the division of labour concerning student autonomy. A translation of this activity system into the study's context is provided in Figure 2.

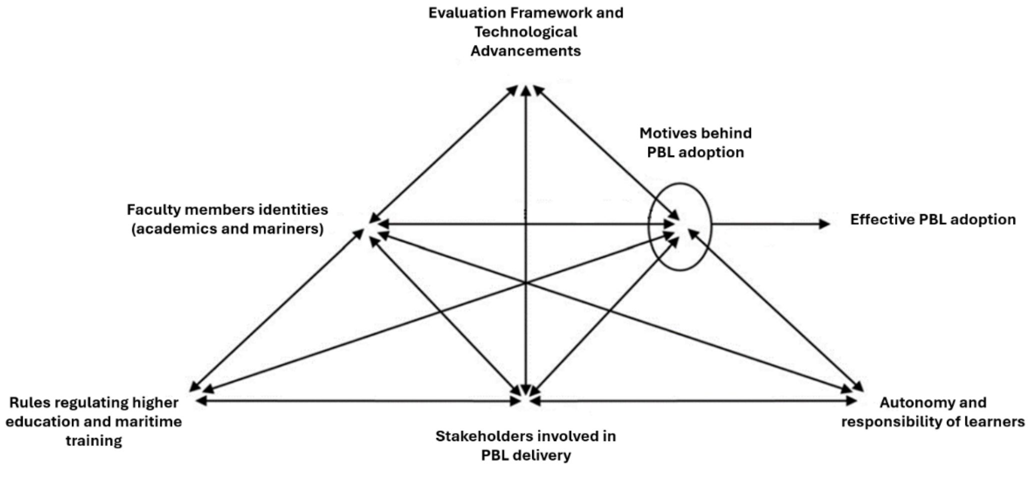


Figure 2. The translated activity system for this study, mapping faculty subjects, their object for adopting PBL, and the mediating tools, rules, community, and division of labour.

Data collection and analysis

Data were collected through semi-structured interviews with 16 faculty members. The interviews aimed to (1) identify key aspects and contradictions within the PBL activity system and (2) explore potential actions to address those contradictions. All interviews were audio-recorded with prior written consent from participants.

The data analysis followed a systematic process influenced by the methodology of Campos and Pinto (2016), which is rooted in Engeström's activity theory. The process consisted of several stages:

1. Transcription and Familiarization: Interview recordings were transcribed verbatim and repeatedly reviewed to gain a deep familiarity with the data.
2. Coding: Transcripts were imported into qualitative data analysis software for coding. An initial set of codes was developed deductively based on the components of Engeström's activity system (e.g., tools, rules, community). Subsequently, inductive coding was applied to identify emergent themes not captured by the initial framework.
3. Theme Development and Validation: Coded data were analyzed to identify recurring patterns and contradictions. To enhance reliability, a second coder familiar with activity theory reviewed a subset of transcripts (approximately 25%); any discrepancies in coding were discussed and resolved to ensure consistency. These patterns were then organized into coherent themes that described the key tensions within the PBL activity system.
4. Interpretation and Contextualization: The finalized themes were interpreted through the lens of activity theory to articulate the systemic contradictions. The findings were continually contextualized within the specific setting of the maritime institute to ensure their validity.

This structured approach ensured a rigorous analysis that directly addressed the study's aim of diagnosing contradictions to inform PBL development.

The Sample Selected

Participants were selected using a snowball sampling technique, which was effective for reaching faculty deeply embedded in the institute's PBL network. Initial participants were identified based on their central roles in PBL delivery and were asked to recommend colleagues with relevant experience. Recruitment continued until thematic saturation was reached, meaning new interviews ceased to yield novel insights into the core research questions concerning systemic contradictions. A sample of 16 participants was sufficient to achieve this saturation, providing a comprehensive range of perspectives across academic ranks, programs, and experience levels (see Table 1).

Rank (Pseudonym)	**no**	**%**
PhD (DR1, DR2, etc.)	6	38
Master Mariner (MM1, MM2, etc.)	5	31
Chief Engineer (CE1, CE2, etc.)	5	31
Gender	**no**	**%**
male	12	75
female	4	25
Age	**no**	**%**
30-39	2	13
40-49	12	75
50-55	2	13
Program	**no**	**%**
Maritime Transport	6	38
Marine Engineering Technology	5	31
Maritime Logistics & Supply Chain Management	5	31
Ethnicity	**no**	**%**
Arab	7	44
European	6	38
South Asian	3	19
Years of Experience with PBL	**no**	**%**
<3	1	6
3-6	6	38
7-10	5	31
>10	4	25

Table 1. Overview of the study participants.

Results

This section describes the key aspects of the PBL teaching activity as perceived by the participants of this study.

The subject of the PBL activity system

The findings revealed two distinct forms of faculty identities within the institute, each with divergent perspectives on the PBL model. The first group consists of academicians who hold PhD degrees and come from traditional university backgrounds. These faculty members are highly supportive of the

PBL model, viewing it as a transformative approach to student learning. As DR2 noted:

> "PBL encourages students to engage in deep learning, allowing them to grasp complex concepts through inquiry-based methods. This approach fundamentally changes how they think, analyse, and interpret reality, which is crucial for their overall intellectual development."

In contrast, the second group comprises master mariners and chief marine engineers who bring extensive maritime experience to their teaching roles. This group does not hold terminal degrees but possesses Certificates of Competence (COC), certifying their ability to perform specific roles on maritime vessels. Their scepticism towards the PBL model stems from their belief in a curriculum closely aligned with the COC requirements, focusing on practical skills and competencies necessary for maritime professions. MM3 expressed this viewpoint, stating:

> "Our primary goal should be to ensure students meet the Standards of Training and Certification for Watchkeepers (STCW). The PBL model, with its focus on inquiry and deep learning, doesn't necessarily prepare students for the specific tasks and responsibilities they'll face on board ships."

The object of the PBL activity system

In examining the object component of the faculty activity system, it became evident that there were two distinct key motives driving the faculty's engagement with the PBL model. The first motive, predominantly adopted by the academicians, was centered around producing an enhanced, inquiry-based learning experience for students. Faculty members with this focus believed that the PBL model could foster high-level problem-solving and critical thinking skills, offering educational benefits that traditional courses could not match. DR5 articulated this stance, stating:

> "Our goal with PBL is to cultivate a learning environment where students can engage deeply with the material. By tackling real-world problems, they develop critical thinking and problem-solving abilities that are crucial for their future careers."

Conversely, the second motive, held by the master mariners and chief engineers, was primarily driven by a need to comply with the college's requirements for adopting the PBL model. This group viewed the PBL approach more as an institutional mandate than an educational enhancement. As such, their primary focus was on fulfilling these requirements rather than on the potential pedagogical benefits of PBL. CE2 expressed this perspective, saying:

> "While we recognize the need to implement PBL as part of the college's curriculum, our main concern is ensuring it aligns with the practical training standards required by the industry. Compliance with PBL requirements is essential, but it shouldn't overshadow the fundamental competencies our students need to master."

The artifacts of the PBL activity system

The discussion on artifacts revealed a consensus among most faculty members, irrespective of their identities or backgrounds, regarding the inadequacies in supporting guidelines and documentation for PBL courses. Faculty members consistently highlighted the absence of clear, standardized guidelines and documents, which are crucial for ensuring a unified and coherent approach to adopting and implementing PBL methodologies. DR4 remarked:

> "There's a significant gap in the resources provided to us. Without comprehensive guidelines, it's challenging to ensure we're all moving in the same direction when it comes to PBL delivery."

Additionally, the interviews uncovered a widespread lack of awareness among faculty members concerning the available software and hardware on campus that could support and enhance their PBL activities. Many faculty expressed that they were either unaware of the technological resources at their disposal or uncertain about how to effectively integrate these tools into their PBL courses. This lack of awareness further complicates the implementation of PBL, as faculty members are unable to leverage potentially beneficial technologies that could enrich the learning experience. DR1 highlighted this issue, saying:

> "I often hear about various tools and technologies that could benefit our PBL courses, but there's no clear communication or training on what's available and how we can use it effectively."

The rules of the PBL activity system

In general, the academicians believed that all curriculum changes should primarily reference the standards set by the Commission for Academic Accreditation (CAA) of the Ministry of Education, which is the main regulator of higher education and assurer of academic quality in the UAE. They argued that adherence to these standards ensures the academic rigor and quality necessary for a comprehensive educational experience. As DR3 stated:

> "Aligning our curriculum with the CAA standards is crucial. It ensures that our educational programs maintain high academic quality and meet the national requirements for higher education."

In contrast, several master mariners and chief marine engineers insisted that the STCW requirements should be the focal point for curriculum design. They emphasized that without meeting these requirements, students would be unable to obtain their Certificates of Competence (COC) through the Ministry of Energy and Infrastructure, which oversees maritime teaching and training in the UAE. CE4 highlighted this point, saying:

> "Our priority must be the STCW standards. If our students don't meet these requirements, they won't be able to obtain their COC, regardless of their academic achievements. This is essential for their future careers in the maritime industry."

The community of the PBL activity system

The 'community' element of the faculty activity system also revealed differing perspectives regarding the involvement of research assistants in PBL delivery. Academicians believed that they should be the primary instructors for PBL courses, assuming the role of supervisors to ensure the quality and effectiveness of the learning experience. They argued that research assistants might lack the necessary teaching experience and pedagogical skills to oversee such courses effectively. DR6 explained:

> "As experienced educators, we should lead the PBL courses to maintain high instructional standards. Research assistants, while valuable, may not have the requisite teaching experience to manage these complex learning environments."

On the other hand, the team of practitioners, including master mariners and chief engineers, advocated for giving research assistants key responsibility for delivering PBL courses. They believed this approach would allow practitioners to focus on delivering core maritime and engineering courses, which require the expertise of individuals holding Certificates of Competence (COC) as mandated by the Standards of Training, Certification, and Watchkeeping (STCW) conventions. CE5 expressed this view, stating:

> "Research assistants should take on the PBL courses, freeing us to concentrate on the essential maritime and engineering subjects that cannot be taught by anyone without the appropriate COC. This division of labour ensures that all courses are delivered by those best qualified to teach them. Hiring me to teach such courses is like installing a twin-turbo V8 on a Fiat. It is an epic misfit."

The division of labour in the PBL activity system

The 'division of labour' within the faculty activity system presented a notable divergence in the delivery of PBL courses, reflecting a spectrum between faculty-centered and student-centered activities. Discussions with some faculty members revealed that PBL courses are often delivered similarly to traditional courses, with faculty making the majority of key decisions regarding the selection of topics and the methods of investigation. These faculty members tend to maintain control over the course structure, guiding students closely through predefined pathways. DR1 noted:

> “While we incorporate PBL elements, we still find it necessary to steer the topics and methodologies to ensure that the learning outcomes align with our academic standards and objectives. You must understand the calibre of students you are dealing with.”

In contrast, other groups of faculty members demonstrated a deep understanding of and commitment to student empowerment within PBL courses. They recognized these courses as excellent opportunities to instil autonomy, accountability, self-learning, reflection, and life-long learning skills in students. These faculty members advocate for a more student-centered approach, where students have significant input into the selection of topics and the ways in which they will be explored, thereby fostering a sense of ownership and active engagement in their learning process. DR4 expressed this perspective, stating:

> “PBL courses are designed to be student-driven. By allowing students to choose their topics and determine their investigative approaches, we help them develop crucial skills like autonomy, critical thinking, and life-long learning, which are essential for their professional and personal growth.”

Discussion

This section discusses the key contradictions within the PBL teaching activity and how they were used to inform its effective implementation at the institute. Our analysis identified three central contradictions, visualized as tensions within the activity system triangles (Figures 3-5). These are not isolated issues but interconnected tensions that collectively hinder PBL implementation.

Identifying the key contradictions within the PBL teaching environment

The subject-object-artifact contradiction

The first contradiction lies between faculty identities (subject), their motives (object), and the lack of a unified evaluation framework (artifact) (Figure 3). This tension reflects a fundamental divide in educational philosophy. Academicians, aligned with constructivist pedagogy (Krajcik & Shin, 2014), saw PBL's object as fostering deep learning. Practitioners, bound by the need for industry compliance, viewed the object as meeting certification requirements. This divergence created a dual-purpose system. Without a shared artifact—a standardized framework to evaluate PBL's effectiveness—these groups lacked a common ground to reconcile their goals, leading to inconsistent implementation. This finding echoes Gibbes and Carson (2014), who identified similar tensions between pedagogical innovation and institutional compliance.

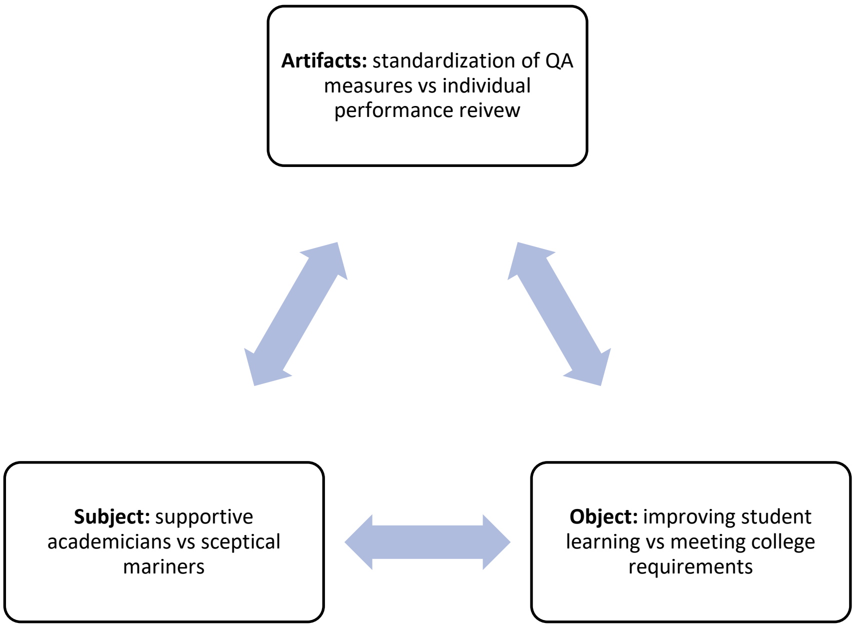
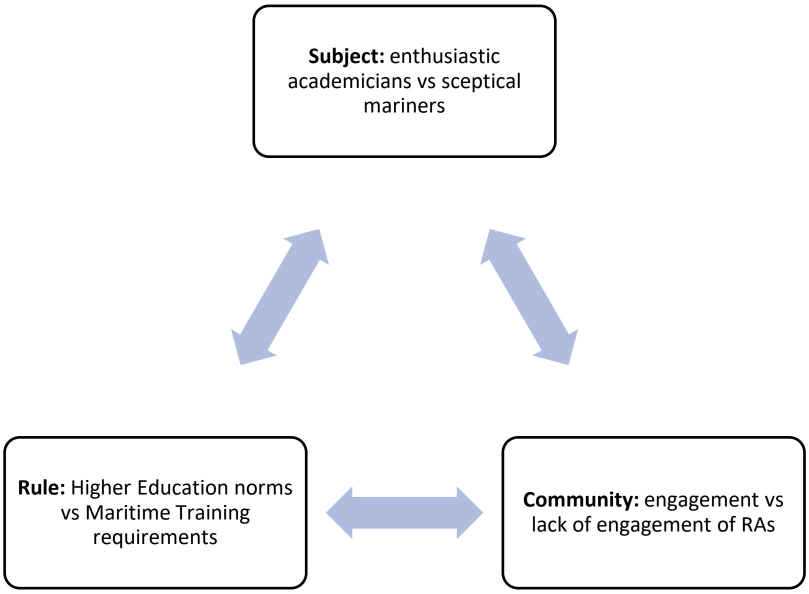


Figure 3: The primary contradiction within the subject-object-artifact relationship of the PBL activity system, highlighting tensions between faculty identities, motives, and evaluation tools.

The subject-rules-community contradiction

The second contradiction involves faculty identities (subject), conflicting regulatory frameworks (rules), and the inconsistent role of research assistants (community) (Figure 4). Academicians operated under the rules of the national academic accreditor (CAA), while practitioners adhered to international maritime conventions (STCW). This regulatory misalignment shaped their view of the community. Practitioners, prioritizing STCW-mandated teaching, argued research assistants should deliver PBL. Academicians believed their pedagogical expertise was essential for quality assurance. This finding extends the work of Issroff and Scanlon (2002) on how contradictions arise from external influences. Here, two external regulatory bodies created internal tensions



regarding roles and responsibilities.

Figure 4. The secondary contradiction within the subject-rules-community relationship, illustrating tensions between faculty identities, regulatory frameworks, and the role of research assistants.

The tools-rules-division of labour contradiction

The third contradiction emerged between technological tools, ambiguous progression rules, and an inconsistent division of labour (Figure 5). A core principle of PBL is that projects should scaffold in complexity (Krajcik, 2015). However, no clear rules defined this progression. Consequently, project difficulty often remained static, preventing the division of labour from shifting meaningfully from teacher-centered to student-centered. Technology use was also fragmented. Some faculty used advanced software to empower students; others underutilized these tools. This inconsistency prevented students from progressively developing autonomy, a key intended outcome of PBL (Hadgraft & Kolmos, 2020).

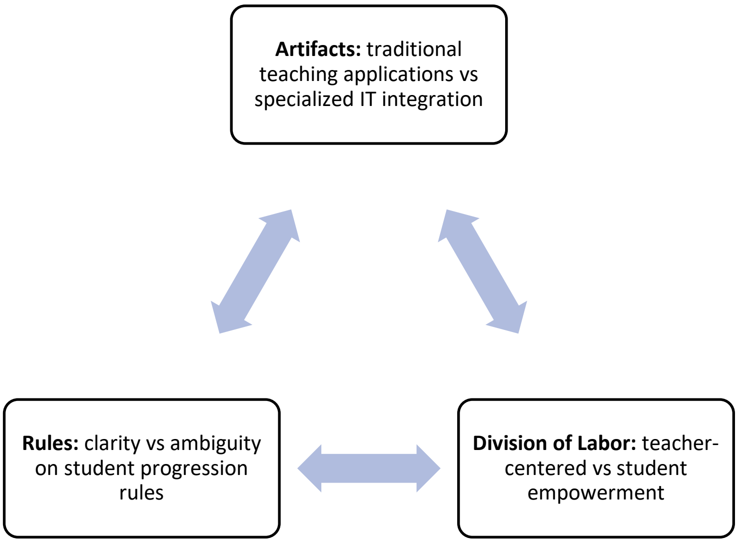


Figure 5. The tertiary contradiction within the tools-rules-division of labour relationship, showing tensions between technological tools, progression guidelines, and the distribution of teaching responsibilities.

Informing PBL Development Through Contradictions

Following Engeström (2001), we treated these contradictions not as failures but as catalysts for change. Faculty discussions translated these tensions into concrete improvement strategies.

Addressing the subject-object-artifact contradiction

Faculty discussions led to adopting the Kirkpatrick (2009) model to establish a common evaluation framework (Table 2). This addressed concerns raised in prior reviews about weak measurement tools in PBL (Guo et al., 2020). By combining reaction, learning, behavior, and results measures—such as CLO feedback, pre/post-tests, and alumni surveys—the model provides a structured yet flexible way to capture PBL outcomes across academic and professional domains.

Level	Description/Scope	Proposed Institutional Evaluation Tools
Reaction	Whether learners find the training engaging, favourable, and relevant to their jobs. Includes feedback on CLOs, course material, content relevance, and instructor knowledge.	Student Satisfaction with Course Course Evaluation Report by Faculty Student Reflection

Learning	Whether learners acquire the intended knowledge, skills, and competencies. Covers horizontal (PM skills) and vertical (subject knowledge) learning.	Pre- and post-assessments Presentation/discussion; rubrics covering horizontal (external e.g., leadership team, IAC representative) and vertical learning (internal e.g., faculty panel).
Behaviour	Whether participants were truly impacted by the learning and if they're applying what they learn.	Alumni Survey Employer Satisfaction Graduate Survey
Results	Measuring learning against high level pre-defined performance indicators	# projects achieving awards # projects endorsed by the industry #projects evolving into research/ innovations

Table 2. Implementation of the Kirkpatrick (2009) model of evaluation in the study context.

Addressing the subject-rules-community contradiction

To bridge regulatory and role-related divides, the institute introduced professional development sessions on PBL pedagogy, a shared e-resource repository, and peer mentorship. These initiatives align with earlier calls for faculty training and shared resources to reduce variability in PBL delivery (Mettas & Constantinou, 2006; Frank & Barzilai, 2004). Integrating technologies like AUTOCAD and MATLAB also addressed the need to connect PBL with authentic industry practices (Gutiérrez et al., 2016). Collectively, these measures foster a more cohesive teaching community while balancing STCW compliance with broader learning objectives.

Addressing the tools-rules-division of labour contradiction

A phased PBL framework adapted from Morgan (1983) clarified student progression (Figure 6). Year 1 introduced small-scale projects with basic tools; Year 2 expanded into interdisciplinary projects with advanced software; Year 4 culminated in comprehensive, industry-aligned projects. This phased model ensured scaffolding, consistent technology integration, and gradual student autonomy. Comparable staged approaches have proven effective in other professional fields (Fernandes et al., 2013).

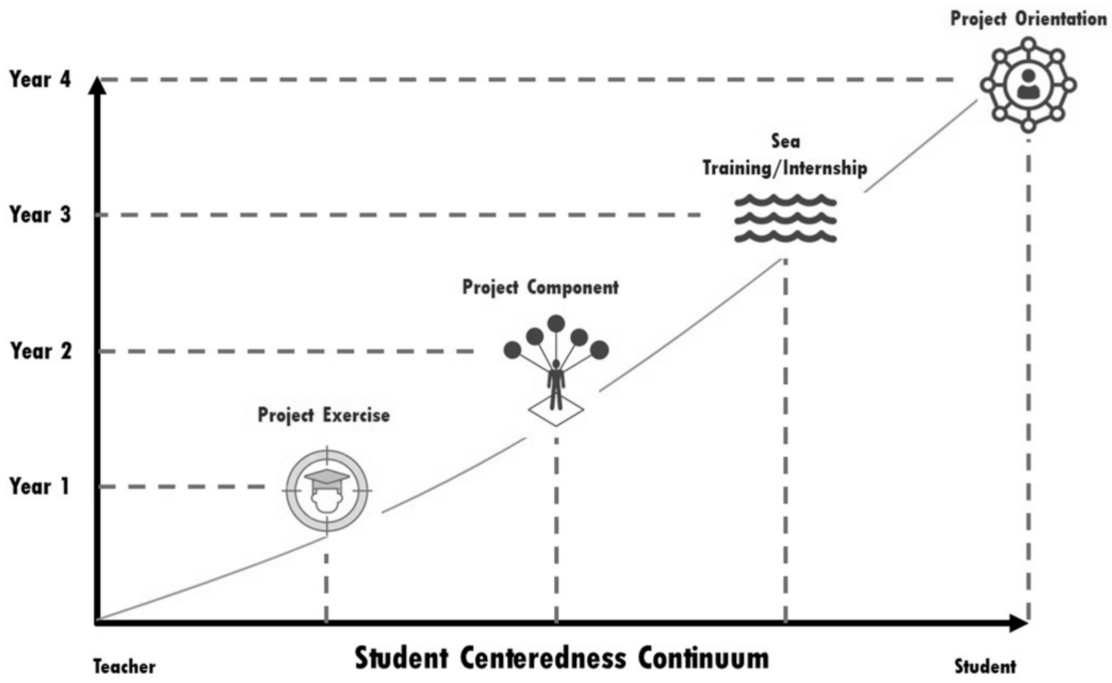


Figure 6. The application of Morgan's (1983) progressive model of PBL, outlining the phased transition of project complexity and student autonomy from Year 1 to Year 4.

Figure 7 illustrates the three main contradictions identified in this study (dashed triangles) and the corresponding action plans developed to address these challenges.

In summary, this study advances the application of Activity Theory in higher education research. It demonstrates how the theory can diagnose implementation challenges not as individual resistances but as systemic contradictions between interacting components of an activity system. The findings extend previous work by Gibbes and Carson (2014) by identifying a unique set of contradictions arising from the clash between professional vocational training and academic higher education standards within a maritime context.

Furthermore, this research contributes a practical blueprint for leveraging Activity Theory. It shows how identified contradictions can be systematically translated into actionable design principles—such as structured evaluation frameworks, targeted professional development, and phased pedagogical models—to reconfigure an activity system. This process moves beyond theoretical diagnosis to intervention, offering a replicable approach for other institutions navigating complex pedagogical changes.

By explicitly addressing these systemic tensions, the proposed strategies aim to transform contradictions into drivers of development, ultimately creating a more coherent and effective PBL environment for maritime education.

While the findings and proposed strategies offer a framework for addressing PBL contradictions, several limitations to this study must be acknowledged. Its reliance on semi-structured interviews with 16 faculty members, while providing depth, may introduce potential biases inherent in self-reported data. Furthermore, the exclusive focus on faculty perspectives omits the critical student viewpoint, which is an equally vital component of the PBL activity system. Grouping faculty with divergent motives into a single activity system, though analytically useful, may also oversimplify nuanced differences in how these distinct groups implement PBL. Finally, the study's context is confined to a single maritime institute in the UAE, which may limit the direct transferability of the findings to other higher education contexts or geographical regions without further investigation.

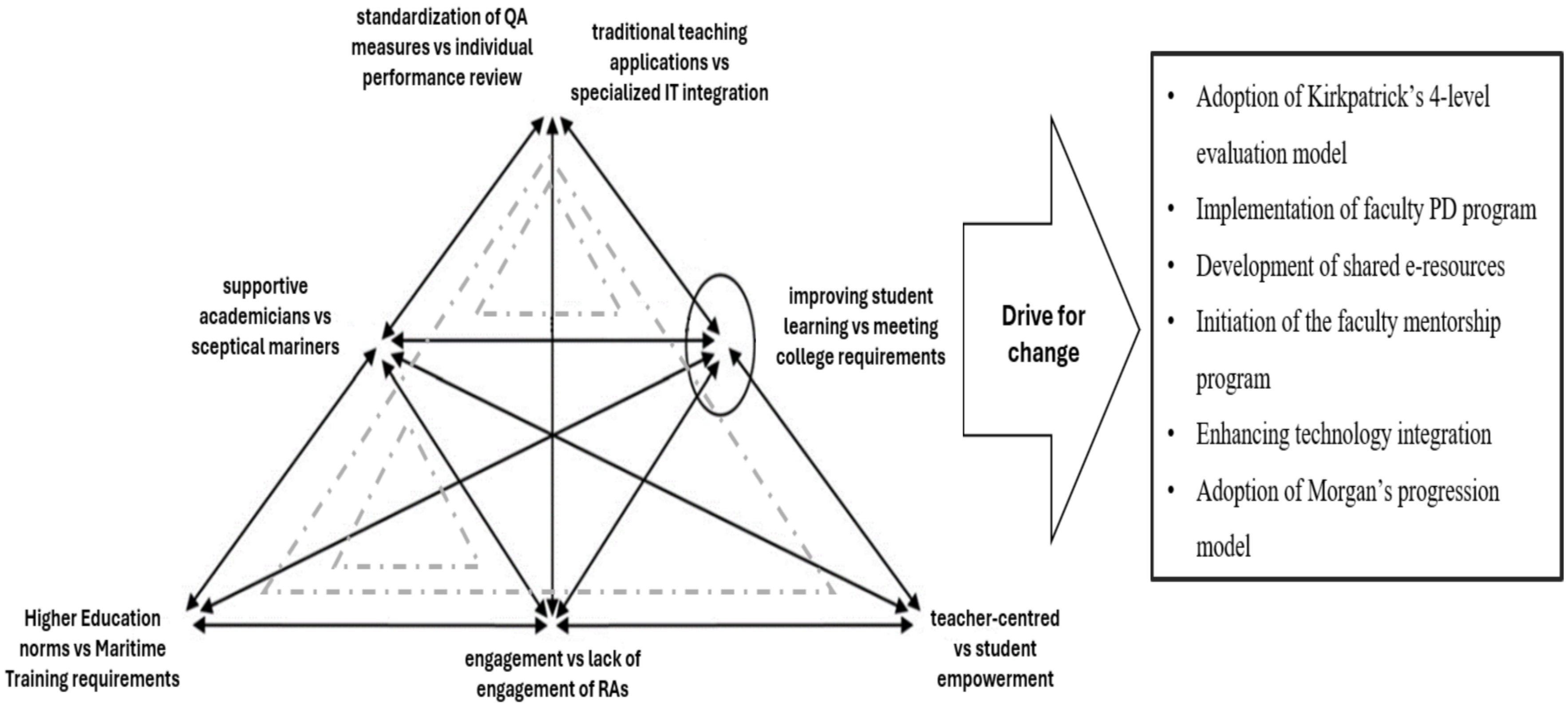


Figure 7. A synthesis of the three key contradictions identified in the faculty activity system and the corresponding strategic initiatives designed to address them.

Conclusion

Reflecting on this study provides valuable lessons that extend beyond its immediate findings. The most profound lesson was the critical importance of acknowledging and addressing diverse faculty identities. The distinct perspectives of academics and practitioners revealed a fundamental tension, suggesting that mitigation requires deliberate, inclusive dialogue. This insight underscores the necessity of creating an environment where educational ideals and industry requirements are viewed as complementary, not mutually exclusive.

A further lesson involves the necessity for a standardized yet flexible PBL framework. The inconsistencies in tool usage and unclear progression rules highlighted the need for structured guidance that remains adaptable to different disciplines. This balance is crucial for fostering innovation without compromising the quality of student learning.

The discussions with faculty emphasized the value of collective input. The proposed strategies—such as targeted professional development, shared e-resources, and mentorship programs—reflect a broader principle: an educational system's strength lies in its community. Encouraging collaboration and peer support leads to a more cohesive PBL implementation.

The study also highlighted the role of leadership in resolving systemic contradictions. Strong academic leadership is essential to articulate a unified vision for PBL and to provide the necessary support and training for faculty.
In summary, this study suggests that successful PBL implementation requires an approach that values faculty diversity, promotes structured flexibility, leverages community, and relies on effective leadership.

The recommendations from this study, while contextual, offer a transferable framework for other institutions. For educators and administrators seeking to implement similar changes, the following actionable steps are proposed:

- For Faculty Development: Instead of generic workshops, institutions can implement differentiated training sessions. Separate tracks could be developed for faculty with industry-heavy backgrounds (focusing on pedagogical theory and PBL's long-term benefits) and for research-focused academics (focusing on industry standards and competency-based outcomes). This tailored approach addresses the identity-based contradictions directly.
- For Standardizing Flexibility: Administrators can adopt a "framework with examples" model for PBL progression. A central policy could

define core principles (e.g., projects must increase in complexity and student autonomy year-on-year), supplemented by a digital repository of annotated project examples from different disciplines. This provides clear rules (standardization) while allowing for disciplinary adaptation (flexibility).

- For Leveraging Community: A practical first step is to formalize a "PBL mentorship program", pairing PBL-skeptical faculty with experienced PBL advocates within the same disciplinary field. This builds community and provides practical, relatable support, moving beyond top-down mandates.
- For Leadership: Leadership should focus on creating bridging objects. For example, forming a joint committee comprising academic leaders and industry-experienced practitioners to co-design key PBL evaluation metrics that satisfy both academic accreditation and professional certification standards can align conflicting priorities.

Looking forward, future studies could explore the student perspective on these tensions. Longitudinal research is also needed to assess the sustained impact of such strategic changes on career readiness. Examining the effectiveness of these implementation strategies in different educational contexts will further refine their applicability.

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Conflict of Interest

The author reports there are no competing interests to declare.

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Navigating the Transition

Problem-Based Learning as Technical Writing Pedagogy

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Abstract

This article reports on an IRB approved multi-semester qualitative study investigating student experiences during the challenging transition to Problem-Based Learning (PBL) in a technical writing (TW) course. The primary purpose of this research is to evaluate the effectiveness of specific strategies utilized to facilitate this transition and to develop practical principles for instructors implementing PBL. Transitional strategies include: a structured, recursive PBL framework (based on Hmelo-Silver's cycle), a four-day cyclical schedule, incremental assignments, and a questioning strategy deriving answers from the problem description. Utilizing thematic analysis of student interviews, reflections, and researcher field notes, this research identifies initial student frustration and uncertainty largely stemming from a perceived lack of direct instruction and concerns regarding assessment standards. While these transitional strategies produced some benefits, they did not eliminate student frustration and uncertainty. However, findings also reveal that strategically implemented, collaboratively created checklists (functioning as contract grading) and required peer reviews provided crucial support, mitigating

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anxieties and fostering deeper engagement. Furthermore, PBL encouraged creative expression in assignments and facilitated functional, contextualized discussions of grammar and mechanics. This research offers practical principles for TW instructors seeking to ease student transition into PBL, thereby maximizing its potential pedagogical benefits.

Keywords: Problem-Based Learning; Technical Writing; Pedagogy; Student Transition; Assessment; Contract Grading; Qualitative Research

Introduction

This article reports on a multi-semester study using PBL as TW pedagogy. In particular, I focus my attention on the transition that occurred as my students and I adjusted to the new pedagogy. I employ multiple strategies to facilitate this transition (discussed below). My goal with this research is to report on how students articulate their transition into PBL pedagogy. I aim for these analyses to highlight general principles that future instructors can use to reduce the challenges technical writing students face when transitioning into PBL and to help access the potential it promises.

My findings are both consistent with previous research on PBL and add nuance to them. While students initially experienced frustration and uncertainty during their transition to PBL due to a perceived lack of direct instruction and concerns about meeting assessment standards, this research reveals that a collaboratively created checklist used as a form of contract grading (Inoue, 2004; Litterio 2016), as well as required peer reviews provided valuable support for students, fostering engagement and likely mitigating anxieties. In addition, PBL cultivated a positive pedagogical impact for learning technical writing where students came to view their assignments as opportunities for creativity and personal expression. Lastly, this research finds that PBL facilitated functional and contextualized discussions of grammar and mechanics by connecting them directly to their problem-solving utility.

Literature review

A survey of relevant literature quickly finds competing definitions for technical writing (Allen, 1990; Brasher, 2020). What scholars do find consensus on is that technical writing (TW) is not like other kinds of writing. Dissimilar from academic or creative writing, technical writing's primary purpose is not often the author's personal expression. Rather, TW prioritizes the communication of technical information. Technical writing is pragmatic, its purpose is to communicate knowledge that readers need for accomplishing goals or solving problems (Spring, 1997; Atkinson and Corbitt, 2021, p. 6). TW is so driven by this purpose that it encompasses innumerable genres and modalities, because the form it takes is dependent on what's most effective for helping its readers (Atkinson and Corbitt, 2021, p. 27).

From this perspective, teaching TW necessarily involves helping students see the indelible link between communicative effectiveness and the context in which that communication occurs. Rather than focusing on rote skills or mechanics divorced from their application, technical writing educators have long agreed that students benefit from studying how audience and purpose influence the effectiveness of one's communicative choices (Miller, 1979; Bridgeford et al., 2004; Williams et al., p. 247). There is far less agreement, however, on what pedagogy is best for fostering this fundamental knowledge.

Such a pedagogy would help students focus their attention on how language functions in context and to organize/design their language toward accomplishing goals within those contexts. One method that educators rely on is Task-Based Learning (TBL). Task-Based Learning occurs when assignments indicate what writing task students need to complete and then lessons are designed to assist students with completing the required task. In this case, Powers explains, "lessons are constructed according to the language required to perform specific tasks rather than according to the aspects of language such as structures and vocabulary" (2008, p. 73). Ellis (2017) writes that proponents of TBL aim to promote "interactionally authentic contexts (p. 113) …where learners can draw upon their existing linguistic resources (p. 111) where then, as Powers adds, it is assumed "that students will learn… through induction as they focus on task completion" (2008, p. 73).

A particular kind of TBL regularly found in technical writing classrooms are often referred to as genre-based approaches (GBAs). GBAs emphasize teaching language by focusing on particular genres and their use in specific contexts. At the heart of GBAs, Nordin explains, "is the view that writing pedagogies should offer students explicit and systematic explanations of the ways language functions in social contexts" (2006, p. 78; Hyland, 2003, p. 18). Kim adds that, "in the genre approach… the knowledge of language is intimately attached to a social purpose, and more focus is on the viewpoint of the reader rather than the writer" (2006, p. 35), indicating also that instructors should work to help students connect a genre's structural features with their communicative purposes (p. 34).

The increased attention to social context and its impact on communicative effectiveness is an important step in the right direction, but Genre-Based Approaches have some notable critiques. Pennell and Miles put it well when they explained that "many genre-based approaches tend to rely on situations or cases for the context within which students employ a particular genre, such as a memo or business letter" (2009, p. 384). Students focus on the task of recreating genres by using detailed contextual information that the instructor provides to guide their choices (Pennell and Miles, 2009, p. 385). Nevertheless, Pennell and Miles explain, there is a tendency for genre-based approaches to rely on context only as background for writing assignments (2009, p. 384). In such classrooms, Pennell and Miles argue, "students do not see how genres and documents emerge from a particular problem and situation" because they are given "the answer up front" (2009, p. 384). Instead of having students produce genres or documents *in response* to a situation, the genres students create are predetermined and only applied to a situation (p. 385; Derewianka, 2003, p. 139). Such a pedagogy, Takahashi explains, can "leave students feeling dependent on instructors" rather than pushing them to think for themselves (2008, p. S31).

Problem-Based Learning (PBL) is theorized to have affordances that respond directly to the above critiques, and as Diamond (2019) asserts it, is readily applied to teaching technical writing (p. 160). "The crucial difference," Pennell and Miles maintain, that PBL offers is in the "pedagogical sequence" (2009, p. 384). Where GBA provide students with the genre (task) and the essential concepts students need to create that genre, De Graaf and Kolmos explain that PBL identifies a problem as the "starting point of the learning process" (2003, p. 658; Rosinski and Peeples, 2012, p. 10). The specific PBL framework employed in this study is based on the recursive problem-solving stages articulated by Hmelo-Silver (2004), which moves students through identifying the problem, generating hypotheses, identifying knowledge deficiencies and application of new knowledge before reflecting on the abstract knowledge gained and evaluating their work (p. 237). This cyclical approach and its theoretical underpinnings are the structural foundation for the four-day schedule implemented in the course (discussed in detail in the Course and Institutional Description section below). Students are assigned unstructured problems—challenges that don't have a clear or predetermined solution—and their submitted responses to those problems are what instructors assess. This "pedagogical sequence" is an important part of why PBL is a good choice for teaching writing. Rosinski and Peeples (2012) explain that students learn "new content, skills, and methods…through the process of investigating and addressing the problem, rather than being supplied, studied, and/or practiced prior to engagement with the problem" (p. 10). Without a ready solution, students must learn to rely on their creative thinking skills to invent effective responses (Ersoy and Başer, 2014) as well as on collaboration with others to create solutions not possible alone (Barber and King, 2016, 242; Hmelo-Silver, 2004, p. 246). Instructors take on a supportive role as they work with students to help them create their own solutions (Hmelo-Silver, 2004, pp. 244-245; Haith-Cooper, 2000). PBL shifts student roles away from passively receiving information and encourages them instead to become the initiators of their own learning, acting as inquirers and problem solvers during the learning process (Hung et al., 2008, p. 493; Stentoft, 2017, p. 55). Kumar and Refaei explain that a well-crafted real-world problem gives students chances to write for diverse audiences using new forms of communication (2017, p. 2). They also say that PBL allowed students to apply what they were learning in the classroom to contexts beyond the classroom immediately and in a relevant way (Kumar and Refaei, 2013, p. 67).

I am thus not alone when I began to see PBL as an opportunity to foster effective TW skills in my students. Yet, though the nontraditional components of PBL present exciting pedagogical opportunities, PBL also carries with it significant challenges. Students' entry into higher education often requires a literacy transition, where they adapt to the demands of academic discourse and different study habits (Armstrong and Newman, 2011 p.6). However, the shift into active engagement with ill-structured problem-solving that is required by PBL represents an additional, intensive transition, building on or sometimes frustrating the academic skills gained in the first. Barron and Darling-Hammond (2008) explain that PBL can be "challenging to implement" because it requires "simultaneous changes in curriculum, instruction, and assessment practices—changes that are often new to teachers, as well as students" (p. 12; Barron et. al. 1998, p. 271). Such a transition should be seen as part of a larger literacy transition students undergo as they learn to be effective in the college environment in ways that differ from high school. As Hung et al. maintain, PBL differs substantially from conventional teaching methods, and these distinctions necessarily impact the roles and responsibilities of both instructors and students throughout the course (2008, p. 493). They emphasize that both students and instructors face significant difficulties when moving from traditional teaching approaches to PBL (Hung et al., 2008, p. 493). Students must not only redefine their responsibilities in the learning environment but also adjust their study habits (p. 493). Educators "reposition their roles in teaching from a knowledge/information transmitter to a learning/thinking process facilitator" (Hung et al., 2008, p. 493; see also Maudsley, 1999; Hmelo-Silver 2004). This upending of traditional roles for students and instructors has been linked to uncertainty and frustration that students experience while transitioning into PBL (Hung, Jonassen, and Liu, 2008, p. 493). PBL also displaces traditional assessment practices that instructors have long relied on and to which students are accustomed (Barber and King, 2016, Nendaz and Tekian, 1999, p. 233). Indeed, part of the uncertainty and frustration students face when transitioning into PBL has been linked to concerns about how their work will be assessed (Moro and McLean, 2017, p. 356; Woods, 1996, p. 93). The difficult transition students endure is thus an obstacle to the pedagogical successes PBL can achieve. To facilitate the transition to PBL is thus to increase access to the pedagogical benefits it promises. The following section describes the context of the study, detailing the course design, institutional setting, and the three primary strategies used to facilitate students' transition into Problem-Based Learning.

Course and institutional description

This course was taught at a public historically black land-grant university located in large city in the Southern United States. Offered through the English Department, it has an ENGL course abbreviation. TW attracts students from a wide range of academic backgrounds due to its open enrollment policy but is notably represented by Criminal Justice and Social Work because TW is required for these majors.

As mentioned above, I designed the class to assist students' transition into PBL. I use three primary strategies for accomplishing this goal. First, I sought to stretch the transition across much of the semester such that earlier assignments took more familiar forms but still included elements of PBL that would steadily increase across the semester. Second, we utilized the same schedule throughout the semester to help students understand and step into their new classroom roles. Third, I incrementally implemented contract grading in the form of checklists that students and I created.

First, I sought to stretch the transition by fitting assignments into three separate categories. The first set of assignments were primarily Task-Based and asked students to create reports, for example exploring basic principles of usability and their relation to effective TW. Students are provided with assignment descriptions including checklists that identify and explain important aspects of the assignment. The second category of assignments was genre-based and included several important developments designed to prepare students for the final PBL assignments. I ask students to create a particular gerne but all discussion and preparation centers around the problem our assigned genre will solve. For example, students are not only asked to complete a written how-to but are also presented with a detailed explanation about who it is for and why it is needed. One important development is that when students ask questions, we use the problem description as the primary resource for determining an answer. That is, when students ask questions, rather than immediately providing straightforward answers, I would explain that the information needed to develop *their own answers* is in the problem description. Then, we would collectively examine the problem description, pinpointing useful information and brainstorming potential answers. My aim was for students to move away from thinking of the problem as having a single right answer and to highlight the importance of understanding the problem and its context for developing their own answers. Questions of tone, for example, were met with, for example, detailed descriptions of audience and genre expectations. Further, as all answers were emergent through discussion of the problem, my aim was also to avoid examination of grammar or mechanics separated from their pragmatic capacity. In addition, focusing our efforts on the problem offers an excellent opportunity to begin decentering myself as the only knowledge authority. In particular, I maintain that there are infinite ways to respond to any problem and that mine is only one. In this way, I aim for students to see how their written genre became communicatively effective through understanding how it will be used and by whom, but also to see their own rhetorical skills as the vehicle to their success.

The second category of assignments is when we begin cocreating the checklists. Our initial discussion of each assignment included examining the problem description and creating a working technical document identifying what we all agree an effective response should include. I make clear that these checklists identify both what an effective solution needs and the primary criteria for grading their assignments (a more thorough discussion of the checklist provided below).

The final category of assignments includes the last two in the semester, both of which present students with only a detailed description of the problem. These problems are designed to situate students as experts. For example, the second to last assignment identifies that next semester's incoming students would greatly benefit from a text explaining how to complete one of the genre-based assignments. Such a text could identify where mistakes are likely and explain how to deal with them if encountered. Current students write about an assignment they have already completed and to an audience with which they can claim greater familiarity than I, having been in their shoes only weeks earlier.

The final assignment asks students to think about their work after graduation. The problem description informs students that there is a benefit to their future colleagues and supervisors knowing about, and seeing an example of, their skills as a technical writer. The assignment description explains: "They will not know what assignments you completed nor how they strengthened your TW skills in particular ways. A single document can solve this problem." Their final, I specify, calls for them to identify and explain what they learned as well as to showcase that learning. My aim was for students to think of their own experiences, efforts and professional goals as the substance of their writing, something about which they are experts.

The second strategy I utilized to smooth the transition into PBL is with scheduling. Throughout the semester, I utilized a weekly schedule inspired by the problem-based learning cycle identified by Hmelo-Silver (2004, p. 237). These steps include identify the problem/scenario, generate hypotheses, identify knowledge deficiencies, apply new knowledge and finally abstraction where "students reflect on the abstract knowledge gained" and evaluate their work (2004, p. 237). In fact, it was this series of steps that initially caught my attention. I was immediately struck by how similar Hmelo-Silver's steps were to the conventional writing process steps which are often identified as prewriting, research, drafting, and revision. I realized the class could be scheduled to engage in steps that fulfilled both criteria.

Our schedule worked on a four-day cycle. On day one, students write a reflection about the previous assignment where students abstract the knowledge gained from, and evaluate the quality of, their work. I then introduce the new assignment/problem. We practice close reading strategies as we slowly go over the description. This work fulfills the 'identify the problem/scenario stage' of Hmelo-Silver's PBL cycle. Part of our efforts are directed toward creating an initial draft of a checklist students can rely on as criteria for completing the assignment, which also functions as an initial attempt at generating hypotheses. For early iterations, I bring a document up on the projector and then I add/revise it using students' own words. Later versions might open editing access and ask students to write on the document. On day two we review the problem description and revise the checklist. This activity explicitly addresses the identify knowledge deficiencies and the planning required for the apply new knowledge stages. We aim for a single technical document identifying what we all agree an effective response should include, with special attention paid to content requirements, genre expectations and audience/purpose considerations. For each entry on the checklist, we write brief descriptions for why the entry is needed as well as how to effectively fulfill the requirement (additional description below). On day three, students are asked to write out ideas and examples for how they will respond to the problem before sharing them, first in small groups and then with the class for feedback. Students are asked to complete a draft of their assignment and bring it to the next class. This work serves as the primary apply new knowledge stage. Day four is a graded peer review where students work in small groups to identify and remedy any shortcomings (additional detail provided below). This collaborative review functions as a final evaluation, setting up for reflection at the beginning of next class. Students were provided with a list of questions to assist in their peer reviewing. Early classes involved identifying and modeling effective peer review strategies, with students taking increasing control as the semester progresses. Our next class begins the cycle again. My hope was that this cycle would facilitate students' transition into PBL because, even though the assignments and their role in classroom practices became less familiar as we shifted from Task to Problem-Based Learning, the schedule did not, and so students could rely on the classroom experience to which they were familiar to facilitate the uptake if their new roles.

Cocreating the checklist and using it as a form of contract grading is the third and final strategy, I employed to facilitate students' transition into PBL. As Littero explains, Contract grading is generally recognized as a method of negotiation between students and faculty regarding their course performance and has been utilized in various ways in writing classrooms since it first appeared in the 1970s (2016, p. 1). Like Inoue (2004), I worked from the "hermeneutic dialectic circle" offered by Guba and Lincoln (1989, pp. 44-45) where each stakeholder offers input into the evaluation. In this "round-robin style" we engaged in a "recursive negotiation and consensus making" that resulted in the communal production of a technical document identifying what students needed to include in their assignments to achieve educational success (Inoue, 2004, p. 222). Students were not required to speak. My hope was that access to a thorough co-created checklist identifying what each assignment called for would quell assessment related anxiety because students would have access to, and some control over, specific assignment requirements they could work towards. Further, I hoped that the sum of these strategies offered a smoother transition into PBL and thus greater access to the educational benefits it promises.

Methodology

This IRB approved qualitative research utilizes thematic analysis to investigate how students articulate their transition into PBL. Denzin and Lincoln explain that qualitative researchers investigate subjects in their natural environments, seeking to understand or interpret phenomena based on the meanings individuals ascribe to them (2011, p. 3). A thematic analysis is thus particularly well-suited to report on how students articulate their transition into PBL because it aims to summarize the value participants perceive and is primarily focused on generating a descriptive account of the participants' understanding (Lochmiller, 2021, p. 2029). A thematic analysis begins with coding, where researchers pour over data to identify units of language to which codes are attached. Saldaña defines a code as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2013, p. 3). Thematic researchers code their data and then look for patterns across those codes. Lochmiller (2021) adds that categories represent emergent patterns that the analyst gathers together to create thematic statements (p. 2032; Saldaña, 2015). It is these thematic statements that will explain what the underlying data suggests and illuminate how my students interpret their transition into PBL learning (Lochmiller, 2021, p. 2032).

The study utilized triangulation across three primary data sources that were gathered across one school year and two separate course sections. Data sources include semi-structured interviews with students, student reflective writing, and researcher field notes.

Participants and data gathering

The researcher interviewed a total of four students (two after the first semester and two after the second). Participants were recruited through a general invitation extended to all students across both sections, resulting in a convenience sample of volunteers. The initial interview questions were revised before each participant to account for any new information learned as well as altered questions to better fit participants, sometimes referred to as semi-structured interviewing (Drever).

The written reflections students completed after each major assignment served as a fruitful source of data. Across the two sections (18 and 20 students, respectively), approximately 229 student reflections were collected from six major assignments. Each reflection asked students to respond to different prompts, such as asking students to summarize, assess and identify ways to improve upon their work or to consider what they learned, how they learned it and to speculate on how they might rely on that learning in the future. Student reflective writing has been utilized in PBL design before (Chiriac, 2024; Johansson and Svensson, 2019). The reflections served dual purposes. First, as Hmelo-Silver reminds us, "reflecting on the relationship between problem solving and learning is a critical component of PBL" (2004, p. 247). Reflection can help students understand the relationship between their problem-solving efforts and the knowledge gained from those efforts, a meta insight one can rely on to achieve future learning goals (Hmelo-Silver, 2004, p. 247; See also: Gardner and Korth, 1997, p. 52). Second, the student reflections offered key insight into students' thinking that served this research well. The researcher began making field notes before the teaching started and continued after the year was over. The researcher documented any statement providing insight into students' experience transitioning into PBL. The researcher would make quick notes during class and write them out more thoroughly after class while the events were still fresh in memory. These notes include reflexive journaling (Ortlipp, 2008) as well as extemporaneous statements made by students, both of which highlight student experience and served as an important source of data.

Data Gathering and Sources	Interviews and Iterative Coding Cycles (dedoose.com assisted)	Rigor and Verification
Source 1: Interviews • 4 student volunteers (semi-structured)	**Interviews 1 and 2** • Questions derived from student written reflections and field note data	**Verification 1** • Triangulation across all data sources. Themes emerge across all data sources
Source 2: Student Written Reflections • ~228 total documents. (1 reflection for each 6 assignments, 2 sections)	**Coding Cycle 1** • Descriptive coding to create initial codebook • Codebook refinement: Organization, Revision, Combination/Splitting	**Verification 2** • Audit trail: saving codebook versions and subsequent review of code evolution in relation to data gathered and peer feedback
Source 3: Field Notes • Reflexive Journaling • Documentation of extemporaneous statements from students	**Interviews 3 and 4** • Questions revised using data from interviews 1 and 2 and student written reflections	**Verification 3** • Member checking: Questions/Follow Up Questions for Interviews 2-4 derived from previous data already gathered and serve as verification
	Coding Cycle 2 • Apply refined codebook to interviews 3 and 4 • Group codes into categories and ultimately into themes	**Verification 4** • Peer debriefing (Work-In-Progress conference presentation with feedback)

Figure 1. Data Sources, Coding Cycles and Verification.

Data analysis, coding cycles and rigor

The data was analyzed after each set of interviews, all of which occurred at the end of each semester. Coding and analysis were facilitated using Dedoose.com. The researcher relied on the reflection data to create the first set of interview questions and an initial list of codes. For the researcher, descriptive coding seemed most productive. In an effort to uphold the authenticity of the participants' statements, the researcher sought to do as little interpretation as possible while constructing meaning (Miles and Huberman, 1994, p. 57). Instead, the researcher simply assigned a class of phenomena to a segment of text (p. 57). The coding process began with a slow review of the first interview transcript, generating new descriptive codes along the way (e.g., "Frustration/anxiety related to Assessment" or "Checklist/Contract Grading"). After examining the whole transcript, the researcher reviewed the list of codes generated (codebook) to organize, revise, and reflect on them. The researcher revised the codebook by changing wording, combining codes, and breaking codes into smaller conceptual pieces. The codebook generated from the first interview was used to code the second interview. Using data from the second interview, the researcher again revised the codebook. After each interview, the researcher would then code the available field note data using the updated codebook to confirm and elaborate on the emerging categories. This iterative revision process allowed the researcher to refine and develop the codes generated. Categories, and ultimately themes, were defined by the recurrence and conceptual grouping of codes across all data sources.

The study established rigor through triangulation across all data sources. For example, the interviews served as a method of verifying data. The researcher asked the same question, but included follow-up questions in direct response to data received from other participants or reflection data. The reflections were also helpful with data confirming as questions were posed in response to data received. In addition, the researcher maintained an audit trail by saving each codebook before revision so that the progress could be reviewed. Lastly, the researcher presented work-in-progress findings at a conference and received feedback from peers to enhance the credibility of the findings.

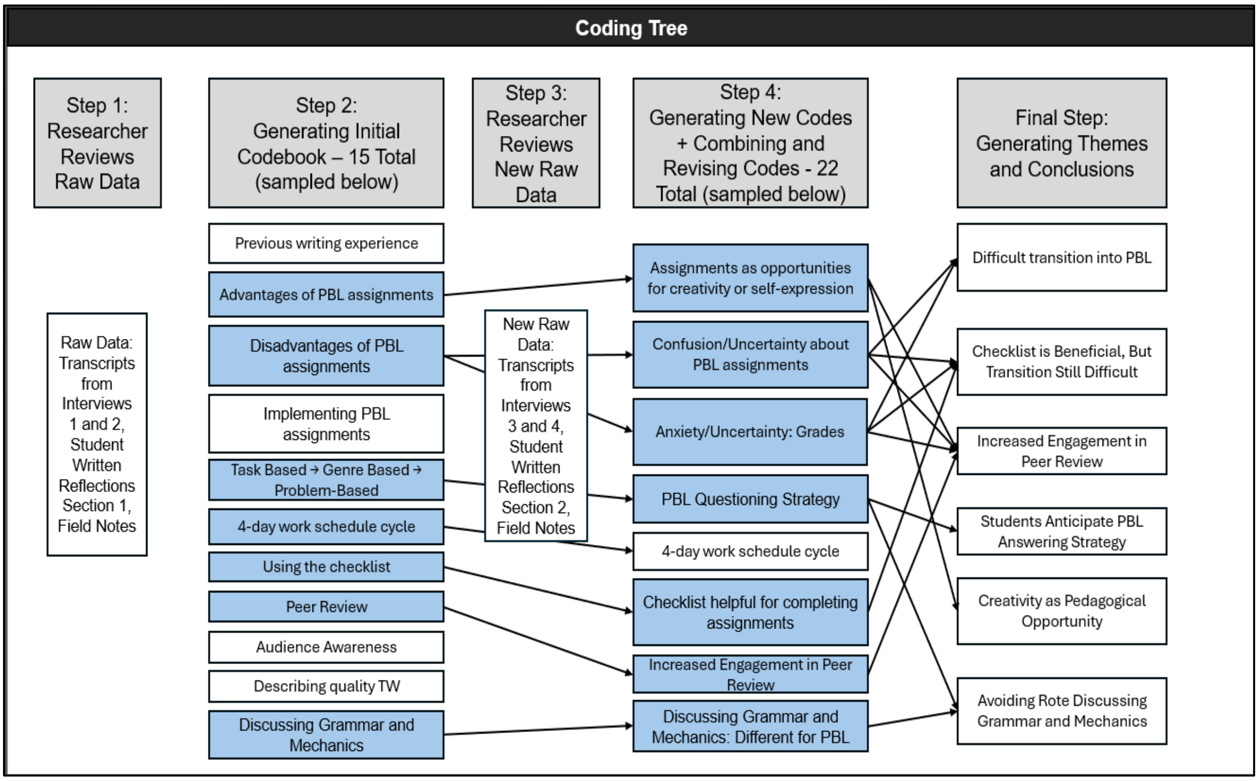

Figure 2. Coding Tree.

Findings and discussion

Student transition into PBL

As forecasted by previous research, students characterize their transition to PBL with frustration. As one student put it, “the [PBL] assignments were different from my other classes and that took getting used to.” When asking about the last two assignments, one student explained “we weren’t given the information we needed… in class like other classes.” They went on to say, “teachers are supposed to help me whenever I have a question.” Students’ frustration was particularly evident in class. For example, toward the end of one class in which our attention was focused largely on reading and understanding the problem, one student exasperatedly asked “But what are we supposed to do? You haven’t told us what we need to do.” Another, after a lengthy discussion of the assigned problem and development of the checklist, stated “Can I please get specific instructions for this assignment?”

There was also some consensus that students’ responses were motivated by uncertainty about meeting assessment standards. Multiple students connected their frustration with the assessment of their work. As one student put it in an interview, the PBL “assignments were harder because you didn't tell us exactly what to do” but went on to say that “I need to make good grades to keep my GPA and those assignments made me worried.” Another explained “I think students in general would be frustrated if they didn't receive the direct help. They are like, how do I know if I’m doing it right.”

The checklist

My hope was that our co-created checklist would quell assessment related anxiety because students would have access to, and some control over, specific assignment requirements they could focus on and work towards. While a thorough understanding of how students relied on either the checklist or our collaborative efforts to create it is beyond the scope of this research, a theme emerged indicating that students saw the checklist as helpful for completing assignments. During interviews, we discussed which assignments students thought were the hardest and why. One student indicated “for the last assignments, we did the checklist, which was good. I used that.” When discussing the final assignment, another student stated that “It's easier when you have a checklist for sure.” Students also remarked about the checklist in their reflections. One wrote, “from the beginning I used the list and the list conversation from class.” Another student wrote that they “used the checklist that was put together during the classes in hopes [of touching] on all the subject matter that was requested.” Given the consensus on the usefulness of the checklist when completing assignments, it is reasonable to conclude that the checklist did have some positive impact on students' transition into PBL. A positive impact, it should be remembered, that wasn't enough to curtail the negative experiences students related above. One student put it well when they explained, "Yes, I use the checklist. I use the checklist. But I still didn't know what to do. I still had to decide what to say and where it should go and what it should look like."

A final note before moving forward, I found the checklist to be very helpful when grading. While my own transition into PBL was also not an easy one, I was happy to have the checklist. I knew my students, at the very least, had access to a resource providing specific information about assignment requirements. Further, the communal production of the checklist led me to believe that students did not strenuously object to any of the criteria that we had arrived at. This combination helped me to be more confident with assigning grades.

These findings point out interesting implications for practice and directions for future research. Future instructors can rely on a contract-grading checklist to facilitate their students' transition into PBL. Future researchers might investigate if and how students relied upon the checklist as well as how doing so can mitigate specific aspects of anxiety and better facilitate students' transition into PBL. Further research could also investigate how the checklist, and the methods for its creation, could be altered in ways that elevate students' confidence in assessment outcomes. In addition, if the checklist was helpful for grading, future research could also look at how the checklist mitigates the instructor's experience as well as how that change in instructor experience impacts the students.

The four-day schedule cycle

No themes emerged to indicate students believed the four-day schedule cycle was helpful for transitioning into PBL. Nevertheless, answering classroom questions by delving into the problem description rather than providing simple straightforward answers did have an impact on students' preparation for problem-based learning, although its educational benefit is questionable. As mentioned above, I shifted to this more problem-based method of answering questions during the genre-based assignments. I did my best to make it clear that we would address questions together by looking into and better understanding the problem and its context such that students could arrive at their own answers. After a few weeks, it became evident to me that students had come to anticipate how questions would be answered in class. In fact, before the last two assignments, when students asked questions, I would turn to them and say, "where is the best place to get the information needed to answer this question?" Their responses made it clear to me they knew the answer, before we began the final two assignments. Further, across the data, a theme emerged indicating that, by the time students got to the PBL assignments, they had grown to anticipate how questions would be answered. One student reflected, “We didn’t always get the answers we were looking for but [the instructor] always worked with us to figure out something we could use.” Another reflected “I know [that when I have a question, I can] look into the purpose and audience and the situation [for the answer] like we always did in class” Students had already experienced not receiving straightforward answers and thus knew what awaited their questions.

Experiencing these non-traditional classroom interactions, however, does not mean students had an easier time transitioning into PBL. While students were aware of the method, as indicated above, not receiving straightforward answers was still a significant source of frustration and uncertainty. In fact, one student explained that it was “frustrating not getting answers [because we knew that the problem statement is] where you are going to get your response from.” Additionally, but importantly, though no student expressly stated they chose not to ask questions, a decreased willingness to ask questions when doing so renders no straightforward answer, and results in frustration, is a short conceptual leap.

While the above interactions point to mixed educational results, they also point to students anticipating parts of their PBL assignments before they were encountered. As such, instructors can call upon the classroom interactions discussed here as part of a greater preparation strategy for PBL. Future research could investigate how to maximize this anticipation in ways that facilitate the uptake of PBL methods. Future research might also investigate what supportive forms of engagement, such as classroom activities or additional reflective writing, might help students further engage in the questioning process and achieve more through it. Future instructors might also benefit from longitudinal research to understand whether and how students rely on the learning gained through the above process in their future classes or professional life. Perhaps the student frustration reported here served as preparation for future problem-solving efforts. Lastly, researchers could investigate if and in what ways students became less likely to ask questions or engage in class because of such unconventional classroom practices.

Fostering peer review engagement

Proponents of PBL have long identified effective collaboration to be one of their primary pedagogical concerns (Barber and King, 2016, 243; Hmelo-Silver, 2004; Hmelo-Silver and Eberbach, 2012, p. 3). Past research has found that PBL can create opportunities to significantly enhance the knowledge, attitudes, and skills important for collaborative learning (Murray-Harvey et al., 2013). This research has reached a similar finding. While we engaged in much collaborative work across both semesters (for example, in co-creating the checklist), the peer review required for each assignment and conducted in-class on the last day of the four-day cycle played a particularly important role. This research finds that there was enthusiastic engagement with in-class peer reviewing and that the PBL pedagogy played an impactful role in this engagement. Across the data, a theme emerged indicating that students saw the peer review as a way of dealing with frustration resulting from grade uncertainty. Students indicated that uncertainty associated with grades encouraged active engagement in the peer reviews. For example, one student stated "It was challenging, but, I feel like it was good to have the peer reviews because we could use the problem to think through each assignment to make sure we did it correctly. It was challenging but the peer reviews helped a lot." Another student put it well when they told me that the "peer reviews [for task-based assignments] were not all that helpful because I had a better sense of what to do but the peer reviews [for the PBL assignments] were really helpful because I wasn't sure if I was moving in the right direction."

These findings add insight into the practice of peer reviewing in TW classrooms. Writing education researchers have long recognized the productive capacity of peer review when teaching technical writing (see, for example, Eschenbach, 2001, pp. F3A-1; Gragson and Hagen, 2010; Guilford, 2001). If PBL functions to increase a student's reliance on and active engagement with peer reviewing, and peer reviewing is a beneficial pedagogical practice, then their combination may be particularly impactful for TW students and their instructors.

Creativity as pedagogical opportunity

Another finding that merits discussion here has to do with a particular positive interpretation students developed for their PBL assignments. Students made clear that, while PBL requires that students make their own determination for how to solve problems, the resulting agency could be recognized as an opportunity for creativity and personal expression that had a positive impact on students' experience in the class. For example, one student stated that "Even though it only has to do with this class, I would like to show [my work] off to the world, like, look at my assignments, look what I did." Another student told me that the "Confusion [he endured] was a little bad, but the opportunity to do what [he] thought was right makes it overall… a good thing." Another student explained that "We completed the assignment, but we kind of made it our own." Tangentially, another student remarked that she found the PBL assignments "interesting" because "they were more personal…you know, we could make the assignments our own."

Increased enjoyment with the assignments or class is an important pedagogical opportunity. On one hand, adding to the enjoyment students derive from their TW course and coursework may be especially generative given the lack of motivation that some have documented in their TW students (Linsdell and Anagnos, 2011, p. 21; Tatzl et al., 2012, p. 280; Peck et al., 1999, p. 4.2181.8). But, on the other hand, any added enjoyment may come as a welcome relief given the difficult transition into PBL.

On a final note, some TW instructors might worry that urging students to see their PBL assignments as opportunities for creativity could have negative consequences. Some might worry that students pursuing creativity might be led in directions that run contrary to effective technical communication, particularly when students have so much control over how their assignments are written and designed. For example, developing technical writers might overemphasize color, imagery or effects in ways that ultimately reduce usability. I would counter, however, that this research indicates that students can see their work as creative and still create effective TW. Importantly, thinking of their work as creative does not mean that students have unrestricted latitude in their writing. While this research suggests that encouraging students to see their assignments as opportunities for creativity can have a positive impact on their interpretation of the course and coursework, such encouragement should never be separate from the primacy of effective communication that is the main goal of TW. This research suggests that creativity *in the service of information transfer* is a pedagogical opportunity.

Avoiding rote discussion of grammar/mechanics

One last finding that deserves attention here concerns how PBL facilitated discussions of grammar and mechanics. In particular, because class discussions and all questions were answered in relation to the problem, all discussions of grammar and mechanics occurred in relation to the problem as well. We discussed grammar and mechanics numerous times across the semester, but, when we did, our discussions inevitably highlighted their operationalization as part of a strategic effort to assist readers with solving a problem. The result is that we never discussed grammar and mechanics apart from their function. Their learning went far beyond rote memorization of grammatical and punctuation rules. Students were instead asked to consider how different grammatical choices can lead to different readerly interpretations and thus different effectiveness for one's TW. Just as questions of tone were met with detailed descriptions of audience and genre expectations, so to where questions about grammatical person when writing to a supervisor. Such an analysis and the learning gained from it are not only much more likely to transfer beyond the classroom but, I would argue, also create more interesting discussions than those surrounding memorization. Given these affordances, future research might focus on how certain kinds of problems or solution approaches are more effective for learning particular grammatical structures or issues.

Conclusion

This study explored the multi-semester implementation of PBL in a TW course, focusing specifically on the student transition into this new pedagogy. Consistent with existing research, the findings reveal that integrating PBL principles within a more traditional learning environment presents significant didactic, institutional, and cultural challenges for students, evidenced by their initial experience of frustration and uncertainty when confronted with ill-structured problems and altered assessment practices. However, this research ultimately asserts that the transition can be managed to provide meaningful and effective learning experiences if conducted with care and specific pedagogical scaffolding. The research adds important nuance by detailing that a collaboratively created checklist mitigated assessment-related anxiety, uncertainty about grades drove students to rely heavily on required peer reviews, and the agency required by PBL led students to view their work as an opportunity for creativity and personal expression. Furthermore, the problem-centered approach facilitated functional and contextualized discussions of grammar and mechanics, connecting these skills directly to their strategic utility. These insights provide concrete strategies for future instructors to understand and mitigate transitional challenges, ultimately increasing student access to the significant pedagogical benefits PBL offers in fostering valuable technical writing skills.

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Collaborating Courses through Problem-Based Blended Learning

Analysis of Students' Perspectives

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Abstract

This study explores students' perspectives on the integration of Problem-Based Learning (PBL) and Blended Learning (BL) in a collaborative course environment. By examining a cohort of undergraduate students across two interdisciplinary courses, the research aims to understand how these pedagogical approaches influence student collaboration, engagement, and perceived learning outcomes. Data were collected through surveys and one-to-one semi-structured interviews, revealing that students generally appreciated the flexibility and interactive nature of BL and active learning of PBL. However, few students faced challenges with team coordination, time management, and guidance intensity during the PBBL implementation. The study concludes with recommendations for educators to enhance collaborative learning through strategic course design.

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Introduction

The Survey of Adult Skills (OECD, 2021) showed that the essential competencies required in the workplace or industry include literacy, numeracy, and problem-solving skills in a technology-based environment. The study results show that the problem-solving skills of students and graduates still need to be improved. The results of the 2016 PaySclae survey revealed that 60% of company owners who were respondents stated that university graduates have low problem-solving skills (Klegeris, 2021). Further, (Burkholder et al., 2021) stated that only some undergraduate programs have successfully trained students to solve authentic problems. The problems that students solve in the classroom are substantively different from those in the workplace (Grant & Dickson, 2006; Jonassen et al., 2006). As a result, many graduates find it challenging to solve authentic problems in the workplace (Jonassen et al., 2006; Klegeris, 2021). This fact is exacerbated by the rapid sophistication of technology that demands problem-solving in a technology-based environment. The Survey of Adult Skills results show that only 1 in 3 workers can solve problems using technology (OECD, 2021).

The low problem-solving skills of students can be attributed to the on-campus learning approach, which differs from the real-world work environment (Klegeris, 2021; Valiente & Lee, 2020). On-campus learning aims to enhance students' knowledge and skills in specific subject areas (Klegeris, 2021), emphasizing established theories and concepts (Dalsgaard & Godsk, 2007). The problems students encounter during their studies often require solutions from a single discipline, unlike the unstructured, complex, and multidisciplinary nature of real-world work problems (Burkholder et al., 2021; Jonassen et al., 2006).

One recommended approach for improving problem-solving skills is Problem-based Blended Learning (PBBL) (Dalsgaard & Godsk, 2007; Donnelly, 2010; Rahmawati et al., 2021; Siregar et al., 2019). PBBL combines problem-based learning (PBL) with blended learning (BL), which incorporates both offline and online modes of learning (S. Amin et al., 2020; Dalsgaard & Godsk, 2007; Woltering et al., 2009). By combining both approaches, students are expected to benefit from the strengths of each type of learning, developing problem-solving and collaborative skills as the core characteristics of PBL (A. Amin et al., 2021; Houghton, 2023).

The ideas of PBBL align with constructivist learning theory (Dalsgaard & Godsk, 2007; Donnelly, 2010; Houghton, 2023). The idea behind constructivism is that through reflection and experience, students actively create their world knowledge and understanding (Harlow et al., 2007; Schunk, 2012; Woolfolk & Hoy, 2018). In PBL, students are given real-life, unstructured, complex problems, encouraging them to collaborate to identify the issue, obtain pertinent data, and suggest solutions (Donnelly, 2010). In this learning, thus, students learn to think critically, solve problems, and create new knowledge (Klegeris, 2021; Yew & Goh, 2016). The use of a BL environment supports PBL by providing diverse learning modalities. Students can actively engage with course materials and collaborate with peers through more flexible and individualized learning experiences in BL (Han & Ellis, 2021; Susiyawati et al., 2022). Problem-solving processes in PBL can be enhanced using online resources, collaborative tools, and data analysis software, which are enabled in BL (S. Amin et al., 2020; Donnelly, 2010; Houghton, 2023). These tools facilitate deeper engagement and allow students to construct their understanding through a combination of independent exploration and guided instruction. Moreover, BL promotes self-directed learning (Cremers et al., 2014; Geng et al., 2019; Sriarunrasmee et al., 2015), a key element of constructivism. Students can control the pace and timing of their learning, choosing when to engage with online content and when to seek clarification through face-to-face interaction. Thus, it is evident that PBBL is in line with constructive principles.

PBBL also provides opportunities for students to participate in interdisciplinary learning (Crichton et al., 2022; Johnson & Griffin, 2023; MacLeod & van der Veen, 2020). Interdisciplinary learning focuses on the integration and interaction between different fields of study. Therefore, students merge knowledge from various disciplines to develop new perspectives on a specific problem (Borrego & Newswander, 2010; Stentoft, 2017). Previous research has identified five categories of learning outcomes associated explicitly with interdisciplinary learning, including integrating disciplines, teamwork for interdisciplinary learning, communication, and critical awareness (Borrego & Newswander, 2010; Cowden & Santiago, 2016; Routhe et al., 2021).

The interdisciplinary PBL among students is generally seen as beneficial, but some challenges exist. Challenges include student engagement, varying motivation, and group maturity (Agyeman et al., 2019; Crichton et al., 2022; Johnson & Griffin, 2023). Soares et al. (2013) highlighted the need for more student support than their lecturers had anticipated. Issues such as 'social loafing' (Aggarwal & O'Brien, 2008) and consequent lack of trust have been identified (Borrego & Newswander, 2010; Crichton et al., 2022), leading to some students not being enthusiastic about group PBL. Practical issues like scheduling across different disciplines are also potentially causing students to struggle to find meeting time (Crichton et al., 2022; Gombrich, 2018). Students' time management skills may also be insufficiently developed (Johnson & Griffin, 2023), exacerbating the difficulties of meeting together.

Therefore, assessing student perspectives is crucial in evaluating the efficacy of PBBL. Some studies suggest that students generally view PBBL positively (Crichton et al., 2022; Dalsgaard & Godsk, 2007; Donnelly, 2010; Ismail & Edi, 2022; Sattarova et al., 2021; Shimizu et al., 2019). However, opinions on its effectiveness vary based on how well it promotes engagement and interaction. The main strength of PBBL lies in its capacity to create adaptable learning environments, and students value the mix of independent learning and structured group work (Houghton, 2023), resulting in an increase in motivation and self-efficacy (Ismail & Edi, 2022; Shimizu et al., 2019). Many mentioned that online platforms effectively supported their learning, enabling seamless collaboration even in virtual settings (Houghton, 2023). Despite the benefits, some students highlighted difficulties with online collaboration, particularly regarding engagement (Crichton et al., 2022; Lomer & Palmer, 2023). Many still favored in-person sessions for the richer, more dynamic discussions that typically take place (Cronje, 2022; Lomer & Palmer, 2023; Susiyawati et al., 2022), as they considered as 'actual learning' (Lomer & Palmer, 2023). Students also feel that implementing PBBL did not provide educational services that matched the tuition fees they paid (Lomer & Palmer, 2023). More expenses are required for internet accessibility (Ismail & Edi, 2022).

Overall, PBBL is considered a viable and practical approach, with students expressing satisfaction with its ability to enhance learning outcomes and flexibility. However, there are concerns about optimizing engagement in digital formats. The inconsistent results indicate that the benefits of PBBL are not conclusive. Exploration of students' perception of PBBL implementation in more complex collaborative courses is essential since previous studies focused on PBBL in a single subject (Stentoft, 2017). Previous studies on students' attitudes toward PBBL in multidisciplinary contexts are limited to engineering problems (Crichton et al., 2022; Johnson & Griffin, 2023; MacLeod & van der Veen, 2020). This study explores students' perspectives on the effectiveness of collaborative courses in PBBL, focusing on a more general problem about the environment integrating two science courses. Specifically, it seeks to understand how this approach impacts student collaboration, engagement, perceived learning outcomes, and challenges during the implementation of PBBL.

Method

Research Context

This current study investigated the implementation of PBBL in a four-year undergraduate program of Science Education at the Universitas Negeri Surabaya, a state university in Surabaya, Indonesia. The PBBL was applied by collaborating with two interdisciplinary courses, "Ecology" and "Anatomy and Physiology of Living Things". Both were 15-week undergraduate lecturer-based courses run once a week in the Odd Semester in 2023. At the beginning of the semester, the lecturers discussed a potential authentic problem relevant to the collaborative courses' learning outcomes. Namely, students are able to (1) master the substantive concepts of plant anatomy and physiology of living things and their application to solve problems in daily life (Anatomy and Physiology of Living Things course) and (2) design scientific investigations to explain and solve problems related to Ecology (Ecology course). To achieve those outcomes, students in groups of five were required to identify environmental problems around them that affected the anatomy of plants and animals and propose solutions for the identified problem. The four-week PBBL blended face-to-face meetings and online learning using a SIDIA LMS to facilitate asynchronous and synchronous activities. All learning resources for both courses are also available in the SIDIA. Students' PBBL activities and results were recorded as a report and presented to the lecturers at the end of the PBBL. The assessment of the PBBL was conducted using a rubric focused on the quality of the report and presentation.

Research Design

This study employed a mixed-methods approach combining quantitative survey and qualitative interview data. Focusing on an explanatory sequential design (Creswell, 2015), this study collected quantitative data followed by qualitative information to elaborate on the quantitative results. This selected design allowed for a comprehensive analysis of student perspectives on implementing PBBL in collaborative courses.

Participants

The study involved undergraduate students from all (five) available classes who enrolled in the two courses: "Ecology" and "Anatomy and Physiology of Living Things", at a Science Education Study Program at a state university in Surabaya, Indonesia. A total of 120 of 136 students completed the survey, and 12 of them were invited to one-to-one semi-structured interview sessions. The interviewees were selected through purposive sampling based on their responses to the survey questions and class representation. This strategy gave more profound insights into their experiences during the implementation of PBBL in collaborative courses.

Data Collection Methods

This study used a 20-item survey of two identity elements, 12 five-point Likert-scale questions, and eight essay-format queries to collect quantitative data. The survey assessed students' perceptions of engagement, collaboration, and learning outcomes. The questionnaire was developed by the authors by referring to the four levels of training program evaluation, including reaction, learning, behavior, and results (Kirkpatrick & Kirkpatrick, 2006) in combination with the framework of collaborative PBBL: authentic problem, cooperation, self-regulated learning, and collaboration (Ibrahim et al., 2015). Examples of questionnaire questions are available in Figure 1. The questionnaire was administered to the participants at the end of the collaborative project using Google Forms. Additionally, 12 one-to-one semi-structured interview sessions were conducted for 30 minutes using an interview protocol to triangulate the collected survey data.

Please respond to the following questions based on your perceptions and experiences to determine the effectiveness of the Ecology, Anatomy, and Physiology of Living Organisms Collaboration Project.

Instruction: Please choose the appropriate response after each question!

1	How were the project objectives explained to you?	Very Unclear	1	2	3	4	5	Very Clear
2	How relevant was this project to the courses you took?	Not Relevant	1	2	3	4	5	Highly Relevant
3	How well was the collaboration between the integrated courses in this project?	Very Poor	1	2	3	4	5	Very Good
4	How effective was this project-based learning compared to traditional teaching methods?	Very Ineffective	1	2	3	4	5	Very Effective
5	How would you rate the level of difficulty of this project?	Very Easy	1	2	3	4	5	Very Difficult
6	What suggestions do you have to improve the collaboration between courses in future project-based learning?							

Figure 1. Examples of questionnaire questions on the Ecology and Anatomy and Physiology of Living Organisms collaboration project.

Data Analysis

The surveys provided quantitative data, which was analyzed using descriptive statistics, including frequencies and percentages. On the other hand, qualitative data from the interviews was analyzed using thematic analysis to identify key themes related to collaboration, engagement, effectiveness, and challenges. Both types of data were used to triangulate the research findings.

Results

A total of 136 students, distributed in five classes, participated in the PBBL-collaborating Ecology and Anatomy and Physiology of Living Things courses during the 2023-2024 Odd Semester. Students' satisfaction toward the PBBL implementation, collected from 120 participants, is shown in Figure 2.

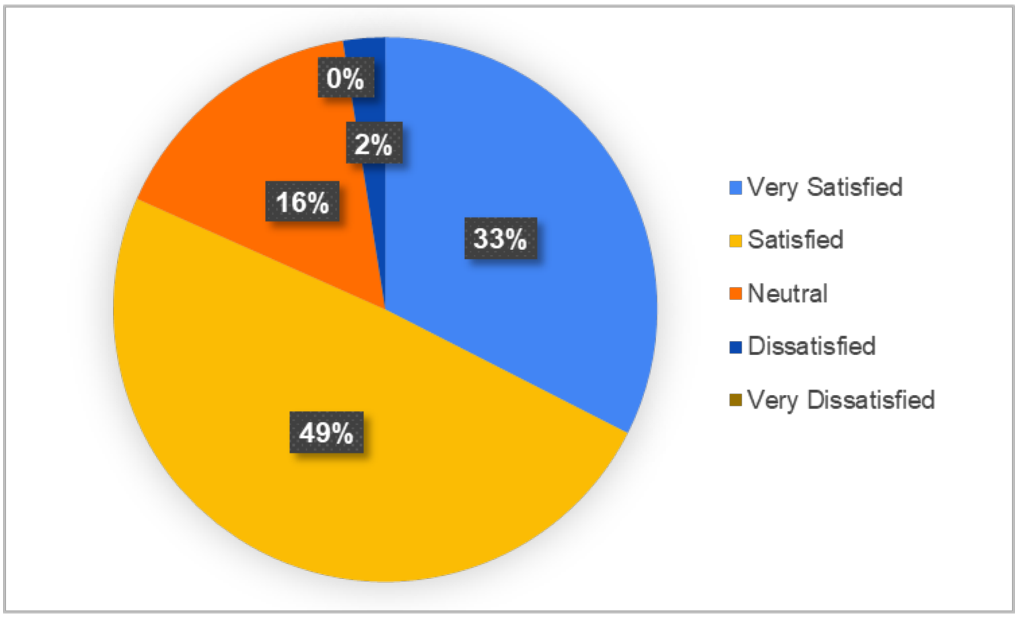

Figure 2. Percentages of students' satisfaction toward the PBBL implementation.

Figure 2 shows that most participants were satisfied (49%) and very satisfied (33%) with the PBBL implementation, which brought together two courses. Some students highlighted the benefits of this learning, including gaining a better understanding of scientific concepts and developing collaboration as well as problem-solving skills, as a student stated:

> (1) "Through observation and experiments, increase understanding of scientific concepts applied in authentic contexts, develop collaboration skills as well as problem-solving."

The students' satisfaction was influenced by various aspects of the PBL implementation in the collaborating courses, including collaboration, engagement, learning outcomes, and challenges. Each of these aspects will be further discussed in the following paragraphs.

Findings on Collaboration

The collaboration aspect during the PBBL implementation was assessed using the survey, which focused on questions about the quality of collaborative courses, group communication, and collaboration skills. The survey results for the three indicators are presented in Figure 3.

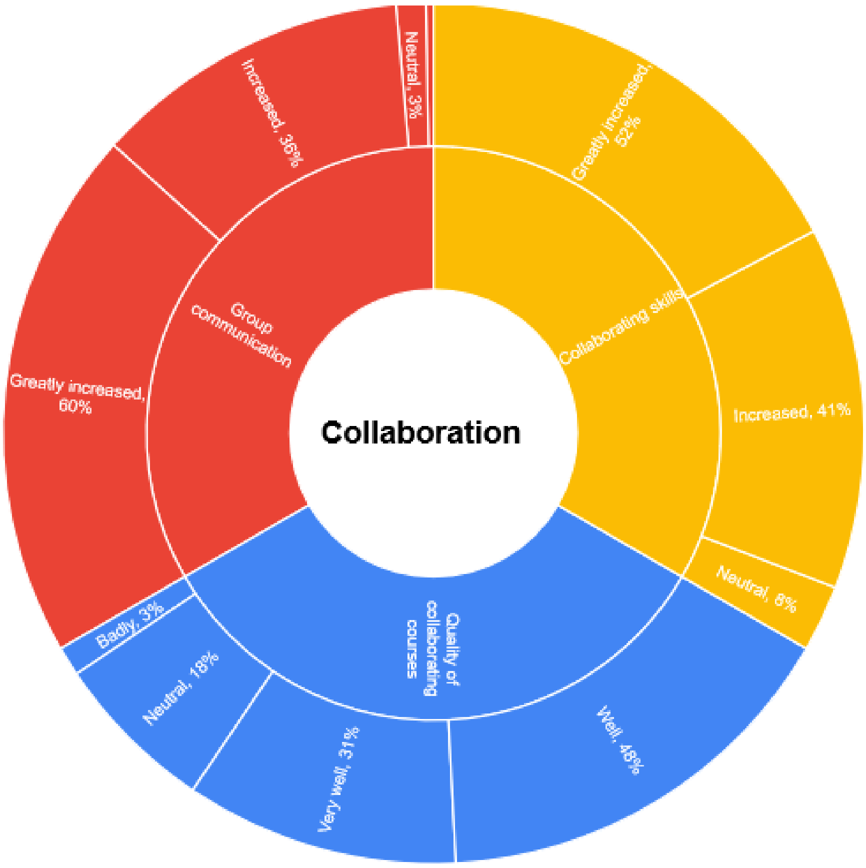

Figure 3. Percentages of students' survey responses on the quality of collaborating courses, group communication, and collaboration skills during the PBL implementation.

The data in Figure 3 reveal a significant trend: the majority of students participating in the PBBL activity viewed the collaboration between the Ecology and Anatomy and Physiology of Living Things courses in a positive light. They reported that the two courses collaborated well (48%) and even very well (31%) during the PBBL implementation. This positive feedback from students underscores the success of the collaborating courses. As one student put it,

> (2) "By studying living things in an ecosystem with certain conditions, it is possible to observe directly and indirectly how body structure and physiological functions are related to adaptation to their environment."

Another student added,

> (3) "Students can understand the concept of the environment and the anatomy of living things in it."

However, it is essential to note that 3% of the participants identified areas for improvement in the course collaboration. One student suggested,

> (4) "It is better to hold a learning session with the two subjects, where lecturers from both courses teach collaboratively, providing a broader perspective to students."

This feedback underscores the potential for a more integrated approach. Another student highlighted the issue of inconsistent lecturer explanations, stating,

> (5) "The explanations given by the lecturers on the anatomy and physiology of living things and ecology were slightly different, so we need to revise the activity several times."

This feedback underscores the need for consistent teacher guidance for a successful PBBL (MacLeod & van der Veen, 2020; Stentoft, 2017).

In terms of group communication, more than half of the participants indicated that the PBBL activity greatly increased (60%) and increased (36%) students' communication within a group (see Figure 3). This finding is due to the project's learning environment, the group selection method, and the nature of the PBBL, as explained in the following interview responses.

> (6) "The project provided group learning experiences with a more interesting and fun learning atmosphere, so each group member was actively communicated and involved in working on the project."

> *(7)* "Since the selection of group members is determined by the students, the collaboration becomes very interactive. Communication is carried out offline and online, even at night, because this project requires intensive discussions."

Thus, it is unsurprising that most students (52% and 41%) acknowledged enhancing their collaboration skills due to the PBBL activity.

Findings on Engagement

Students' engagement in PBBL activity was analyzed based on their responses to survey items focusing on goal clarity, course relevancy, guidance quality, and learning resource availability. Figure 4 exhibits the students' responses to the four indicators in the survey.

Figure 4. Percentages of students' survey responses on goal clarity, course relevancy, guidance quality, and learning resource availability during the PBL implementation.

When discussing goal clarity, most students indicated that the goals of the PBBL activity were conveyed to them very clearly (31%) or clearly (50%), encouraging their participation. An interviewee elaborated on this finding:

> (8) "I became more aware of the biotic and abiotic components in the project, the interaction between the two in improving or vice versa, even damaging the environment and ecosystem. In addition, it also improves my literacy, helps me understand how the ecosystem works, and helps me find solutions to the problems obtained from literacy."

In contrast, 4% of students struggled to understand the purpose of the PBBL that collaborating the two courses, as an interviewee explained:

> (9) "…clear instructions or directions are needed on what the purpose of this project is so that students are not confused in its implementation."

It implies the critical role of assistance during the PBBL.

The relevance of the PBBL activity to the courses being enrolled also encouraged students' engagement. As shown in Figure 2, most students suggested that the PBBL activity was highly relevant (53%) or relevant (41%) to the collaborating courses. The following interview responses elaborate on this finding:

> (10) "The project is relevant to the real world and connects the material in both courses with real situations and problems faced by the community so that we can determine the unsolved problems in certain areas."

> (11) "The best aspect of the collaborative project of the two courses is the cross-disciplinary integration that allows students to apply concepts in the anatomy and physiology of living things to solve real problems in ecology so that students feel more motivated because they see the direct relevance between what they are learning and its practical application."

Another factor in students' engagement with the PBBL activity was the quality of the lecturers' guidance. Figure 4 shows that most students agreed that lecturers provided very sufficient or sufficient assistance during the PBBL work. Related to this fact, a student mentioned

> (12) "The guidance provided was quite satisfactory. Panel discussions involving lecturers and students from both courses to discuss the project have been carried out online, followed by offline guidance and monitoring or forums in LMS so that the project can run smoothly. However, the intensity of guidance in both courses is not equal, so it needs to be improved."

The insufficiency of lecturers' assistance led to their difficulty in accomplishing the PBBL task, as shown in Responses (4) and (9).

In addition, the availability of learning resources affected students' engagement in the PBBL activity. According to most students, the learning resources provided during the PBBL were sufficient (44%) or very sufficient (23%) to support them to accomplish the task well. The provided learning resources included relevant textbooks, PowerPoint slides, a PBBL activity and assessment guideline, and a worksheet. Nevertheless, a few students mentioned that they needed more relevant resources to help them complete the PBBL activity, as a student stated:

> (13) "The self-study provided is still lacking; it is necessary to provide sample reports as a reference so that the project is more directed."

In contrast, another student argued:

(14) "The learning resources provided are quite helpful to complete the project. Because the problems identified by each group are different, it is the group's responsibility to find other relevant references."

Those contrary opinions suggest that students must develop self-directed learning for successful PBBL (Ghani et al., 2021; Yew & Goh, 2016).

Findings on Effectiveness

The effectiveness of the PBBL in this study was assessed using four indicators based on survey responses: comparison to the conventional approach, difficulty level, impact on understanding, and problem-solving skills. The survey results for those indicators are shown in Figure 5.

Figure 5. Percentages of students' survey responses in comparison of PBBL to the conventional approach, difficulty level, impact on understanding, and problem-solving skills during the PBL implementation.

Compared to the conventional approach, most students perceived the PBBL was more effective (53%) or highly effective (29%) in teaching collaborative courses. This effectiveness of PBBL is supported by students' responses on the survey item about the impact of PBBL on their conceptual understanding. As shown in Figure 5, most students perceived that their conceptual understanding of both courses was increased (61%) or greatly increased (28%) at the end of the PBBL activity, as a student mentioned:

> (15) "The best aspects of the project were comprehension of learning materials…"

Detailed information on how students gain benefits of PBBL on conceptual understanding is elaborated in Responses (2), (3), and (8).

Additionally, the effectiveness of the PBBL on problem-solving skills was also perceived by students. Due to the nature of the PBBL, students found that identifying problems and finding solutions during the PBBL improved (49%) or greatly improved (43%) their problem-solving skills. A student's response supported the finding:

> (16) "From this project, we can learn to be more independent by looking for ideas, innovations, and solutions to solve problems in the environment in real life, and become more confident in making all decisions together with the team."

This sense of independence and confidence is crucial to PBBL's empowerment.

However, most students perceived the PBBL task as difficult (43%) or very difficult (15%). A student argued:

> (17) "The most challenging aspect of this learning was identifying environments with problems that can affect the environmental ecosystem."

These findings indicated that the PBBL task in this current study met the nature of this approach, which involves an intricate problem that lacks clear structure, has conflicting objectives, has multiple solutions, and has criteria for evaluating solutions (Jonassen et al., 2006).

Findings on Challenges

Despite the positive perceptions, some challenges were experienced by students during the PBBL implementations. While most students perceived collaboration positively, few participants conveyed their obstacles when working together. A student stated:

> (18) "The most challenging aspect of this project was coordinating the team well and collaborating with members with various mindsets and opinions so that they could have the same mindset and teamwork could run in harmony without any obstacles detrimental to team members."

The nature of authentic problems leads to multiple perspectives and solutions (Jonassen et al., 2006). However, these differences caused frustration for some students when working in a team.

Contrary to the data in Figure 4, few students were less engaged during the PPBL. A student conveyed:

> (19) "Ensuring that all team members were actively involved and contributed to the project equally was a challenge, especially if there were those who tended to be passive or non-contributing."

This phenomenon is known as 'social loafing' when someone in a group does not contribute their fair share (Aggarwal & O'Brien, 2008). According to Crichton et al. (2022), the problem often stems from the clash between students' perceived priorities and ineffective time management. A student response supports this argument, as she mentioned

> (20) "The challenging aspect is conditioning the time of each group member to work on this project better and more efficiently because we all have different free time and other interests besides this project that are equally important."

Furthermore, while most students expressed the PBBL's effectiveness, a few complained about the lack of preparation and inadequate guidance. A student said:

> (21) "Lack of preparation from both lecturers and students so that students were overwhelmed at the beginning of working on the project."

Another student added:

> (22) "Lecturers need to provide constructive and regular feedback throughout the project to help students identify what has been done well and what needs to be improved."

These findings suggested that careful preparation and lecturer facilitation are critical for successful PBBL implementation (MacLeod & van der Veen, 2020).

Discussions

The findings of this study indicate that students generally had positive perceptions of PBBL in collaborative courses, as also reported in other studies (Crichton et al., 2022; Ismail & Edi, 2022; Johnson & Griffin, 2023; MacLeod & van der Veen, 2020; Shimizu et al., 2019; Woltering et al., 2009). Most participants of this study revealed an increase in collaboration, engagement, and learning outcomes when the PBBL was implemented.

The effectiveness of PBBL in fostering collaboration aligns with the findings in previous research (Crichton et al., 2022; Rahmawati et al., 2021; Woltering et al., 2009). The nature of problem-based learning, which exposes students to authentic problems, necessitates interdisciplinary discussions (Stentoft, 2017; Yew & Goh, 2016). Integrating relevant courses into a problem-based learning approach encourages students to collaborate, exchange ideas, and share responsibility in solving real, complex, and ill-structured problems (Crichton et al., 2022; MacLeod & van der Veen, 2020). Collaboration is a functional skill crucial for a successful PBBL (Ghani et al., 2021), and its development is facilitated in the PBBL through technology, which enables intensive and flexible interactions and communication (Donnelly, 2010). However, the challenge of ensuring consistency in lecturer explanations suggests that a more structured and integrated approach to instruction could further enhance the experience. Implementing co-teaching strategies where both lecturers collaboratively guide students may mitigate inconsistencies (Perera et al., 2020; Zach & Avugos, 2024).

Students' increased engagement in PBBL was also reported in relevant studies (Agyeman et al., 2019; Houghton, 2023; Wagino et al., 2024; Zhao et al., 2023). Several factors drive students' engagement in PBBL, including the clarity of goals, the relevance of the project, and the quality of guidance. Providing more explicit guidelines and structured orientations at the project's outset could improve engagement and reduce uncertainty (Crichton et al., 2022). The authenticity of problems in PBBL promotes students to actively engage in the activity because they see the applicability of the theories being learned (Houghton, 2023). The use of technology in this learning approach also increases the creativity of content delivery (Morton et al., 2016), accessibility of learning resources (Houghton, 2023), and maintains teacher-student and student-student interactions (Öncü & Bıchelmeyer, 2021; Susiyawati et al., 2024).

The effectiveness of PBBL compared to conventional approaches, as reported in this current research, has been recognized in similar studies (Dalsgaard & Godsk, 2007; Dawilai et al., 2021; Rahmawati et al., 2021). Previous investigations have also demonstrated that this learning approach has positive effects on learning outcomes (S. Amin et al., 2020; Nurkhin et al., 2020), conceptual understanding (Herliana et al., 2020; Johnson & Griffin, 2023; Nurkhin et al., 2020), and aids in the development of students' problem-solving skills (Crichton et al., 2022; Johnson & Griffin, 2023). Dawilai et al. (2021) contended that the effectiveness of PBBL is driven by the flexible learning environments that support students in solving authentic problems. The online platform in the PBBL also facilitates students' active learning to develop investigation, conduct inquiry processes, and analyze problem-solving strategies (Anderson et al., 2008; Klegeris, 2021; Stewart et al., 2007).

However, some challenges were noted, such as difficulties in team coordination, time management, and varying levels of lecturer guidance. These findings align with previous research on PBBL (Crichton et al., 2022; Johnson & Griffin, 2023; Rahmawati et al., 2021; Woltering et al., 2009). Strategies such as assigning specific roles to team members, incorporating peer assessments, and promoting accountability through progress-tracking tools could enhance group coordination and productivity (Crichton et al., 2022; Gombrich, 2018; Johnson & Griffin, 2023). The findings also suggest the need for consistent and intensive teacher guidance (MacLeod & van der Veen, 2020; Stentoft, 2017) and self-directed learning capability (Ghani et al., 2021; Yew & Goh, 2016) for successful PBBL.

A critical limitation of this study is the reliance on self-reported data from surveys and interviews, which may be subject to response bias. Future studies should incorporate objective student performance and engagement measures to validate these findings. Additionally, while the study was conducted in the context of two interdisciplinary science courses, its generalizability to other disciplines remains uncertain. Comparative studies involving different subject areas could provide a more comprehensive understanding of PBBL's effectiveness across educational contexts.

Implication for Educational Practice

The results suggest several implications for the implementation of PBBL in higher education, particularly in collaborative courses. First, educators should consider structured interventions to address team coordination and time management challenges. Strategies such as assigning defined roles within groups, incorporating peer evaluation mechanisms, and providing structured timelines could enhance group work efficiency. Second, lecturer involvement is crucial for student success in PBBL environments. The study findings indicate that inconsistent lecturer guidance led to confusion among students. To mitigate this, institutions should encourage collaborative teaching approaches where faculty members from different disciplines co-teach sessions, ensuring consistency in explanations and expectations. Additionally, providing regular formative feedback throughout the PBBL process can help students stay on track and refine their problem-solving approaches.

Conclusions and recommendations

The study emphasizes the potential of PBBL in improving collaboration, engagement, and learning outcomes in interdisciplinary courses. Overall, students positively perceived the integrated approach, although they did note challenges with group dynamics and technical aspects. Combining PBL and BL in collaborative courses shows promise for higher education, providing students with a more interactive and adaptable learning experience. However, it is essential to consider course design, careful preparations, and intensive guidance and support mechanisms to address the noted challenges. Educators and institutions should consider implementing and improving the PBBL approach in collaborative courses to better equip students for real-life challenges. Ongoing research and student feedback will be crucial in optimizing these educational practices.

While this study offers valuable insights, further research is needed to refine PBBL methodologies and expand their applicability. Future research should explore the long-term impact of PBBL on students' problem-solving and professional skills through longitudinal studies. Additionally, investigating the effectiveness of PBBL in different academic disciplines beyond science education could provide a more comprehensive understanding of its applicability. With the rapid advancement of educational technology, studies should also assess the integration of emerging tools, such as artificial intelligence-driven learning assistants, to support and enhance PBBL experiences. Furthermore, faculty training models should be developed and examined to improve lecturers' facilitation skills and ensure consistency in implementing PBBL. Addressing these research gaps will contribute to refining PBBL methodologies and strengthening its role as a practical pedagogical approach in higher education.

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Graduate Entry Students' Reflection on Alternating Problem-Based Learning and Clinical Placements

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Abstract

Problem-based learning (PBL) and early clinical placements (CP) are recognised as complementary strategies for developing clinical reasoning (CR) in medical education. However, how alternating between these formats influences the CR process from students' perspectives remains underexplored. This qualitative-led exploratory mixed-methods study examined how curriculum sequencing shapes Graduate Entry Medical students' perceptions of their CR process. Fourteen Year-2 students participated across two pre-existing streams: one began with PBL and the other with CP before switching. Across these alternating phases, students completed the Self-Assessment of Clinical Reflection and Reasoning (SACRR), applied reasoning through vignette-based single-best-answer (SBA) questions to prompt reflection on their reasoning processes. Students' reflections were further explored through in-depth semi-structured interviews. Thematic analysis formed the primary interpretive strand, supported by descriptive quantitative data. Interview findings revealed that alternating PBL and CP encouraged students to reflect on, apply, and

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progressively refine their reasoning skills. Students valued the complementary relationship between classroom discussion and authentic clinical exposure, citing case-based dialogue, GP teaching, and supportive environments as key enablers, while heavy workloads, examination pressures, and over-guided PBL sessions were perceived as barriers to CR process. Overall, CR development emerged as a gradual, experiential process enhanced by the dynamic interplay of PBL and clinical learning. These findings underscore the importance of integrating structured discussion with authentic patient encounters rather than privileging one learning format or sequence over the other.

Keywords: Clinical reasoning; Problem-based learning; Clinical placement; Graduate Entry Medicine; Medical education

Introduction

The School of Medicine at Ulster University employs problem-based learning (PBL) and early clinical placements (CP) to bridge the gap between theoretical and practical learning. These complementary formats encourage students to integrate biomedical knowledge with clinical experience and to develop the higher-order thinking processes that underpin clinical reasoning (CR). When designing placement models, logistical factors such as scheduling and cost often outweigh pedagogical considerations, even though sequencing between classroom-based and clinical experiences may affect the way reasoning skills evolve. Understanding this interaction is therefore essential for optimising curricula in graduate-entry medical education.

In medical education, PBL has long been recognised as a powerful approach for fostering the development of clinical reasoning and self-directed learning. By engaging students in authentic, context-rich problems, PBL promotes hypothesis generation, analytical thinking, and reflection, key components of clinical reasoning (Koh et al., 2008). Recent work further supports this link, showing that PBL not only enhances diagnostic reasoning but also improves knowledge integration, teamwork, and metacognitive awareness across different cultural and educational settings (Ishizuka et al., 2025).

Clinical reasoning is a multifaceted process encompassing data gathering, interpretation, hypothesis generation, and decision-making (Gruppen, 2017; Thampy et al., 2019). It has been described as *the cognitive and metacognitive processes clinicians use to evaluate and treat patients* (Crabtree, 2001). Other scholars have defined it as a cyclical process integrating knowledge with patient information to reach and test diagnostic hypotheses (Young et al., 2018). This study adopts the definition by Royeen et al. (2001), which conceptualises CR as a reflective thought process integrating information to guide action. Although originally developed in occupational-therapy education, this definition underpins the validated Self-Assessment of Clinical Reflection and Reasoning (SACRR) instrument used in this study and is consistent with reflective and constructivist learning theories widely applied in medical education.

The theoretical framework guiding this study draws on social constructivism and situativity theory, which view reasoning as emerging through interaction with authentic contexts and social dialogue (Vygotsky, 1978; Dornan et al., 2012; Billett, 2016). Within this lens, PBL provides a structured environment for collaborative hypothesis generation and reflection, while clinical placements situate reasoning in real-world uncertainty, allowing students to test, refine, and adapt their thinking through patient encounters and tutor feedback. In the Ulster model, PBL cases are designed to prompt diagnostic and therapeutic reasoning through scaffolded group discussion led by trained facilitators who guide questioning, hypothesis generation, and integration of new information. Clinical placements, in turn, enable students to apply and refine these reasoning processes with real patients under supervision from clinicians and general practitioners.

Meta-analytic evidence suggests that PBL enhances CR more effectively than traditional teaching (Wang et al., 2016; Trullàs et al., 2022). However, most studies examine PBL or placements in isolation; few explore their combined or sequential impact (Willis et al., 2018). Furthermore, quantitative evaluations of CR often overlook students' lived experiences of reasoning across settings. A qualitative-led mixed-methods approach allows both the measurable trends and the interpretive richness of these experiences to be captured.

Graduate Entry Medical (GEM) students represent a distinct population, typically older and with diverse academic backgrounds (Medical Schools Council, 2023). Their prior experiences may influence how they perceive and articulate reasoning processes, making them particularly suitable for an in-depth exploration of the CR process.

This study aimed to explore how curriculum design and the sequencing of learning experiences influence GEM students' perceptions of their CR process. Specifically, it sought to:

1. Understand students' experiences and perceptions of how alternation between settings affects their reasoning; and
2. Identify activities, sequences and approaches that students perceive affect their CR.

Materials and methods

Research design & sample

This study employed a qualitative-led exploratory mixed-methods design. This design was built on prior qualitative work in the field and provided a richer understanding of how PBL and CP interact to shape reasoning skills. Given the small cohort size typical of GEM programmes, quantitative data were analysed descriptively to contextualise qualitative insights, while qualitative findings provided the main interpretive depth. Integration aimed to achieve triangulation rather than statistical generalisation (Creswell & Plano Clark, 2018).

A convenience sample of fourteen Year-2 Graduate Entry Medical (GEM) students participated voluntarily. All Year-2 students (N = 72) enrolled in the 2022–2023 academic year were informed about the study via email. The cohort reflected the demographic profile of UK GEM programmes, comprising students aged 21 years and above with diverse academic and professional backgrounds (Medical Schools Council, 2023). While there are demographic differences between GEM and SE, graduate students make up approximately 20% of students studying medicine in the UK. Therefore, studies involving GEM student populations can be considered to represent a good proportion of students overall (Vasileiou et al., 2018). Students who expressed interest were provided with detailed study information and consent forms, and only those who returned signed consent forms were included in the study.

Curriculum design in Year 2:

Within Year 2 of the Ulster University School of Medicine programme, students complete a total of three PBL blocks and three placement blocks, alternating between them. Students are divided into two streams (Stream A & B): Stream A undertook PBL first, followed by placement, while Stream B started with placement before moving to PBL. This division was pre-determined by the existing timetable but allowed exploration of whether sequence influenced CR development. During the placement blocks, students alternated among three clinical settings: Medicine, Surgery, and General Practice (GP), in different sequences but same structure and teaching opportunities. Each rotation runs for a 5-week duration.

The sequencing of PBL and clinical placement blocks was primarily shaped by logistical considerations, with PBL following a module-based rather than system-based structure. Where feasible, PBL cases were thematically aligned with the content and clinical conditions students encountered during concurrent placements in general practice and hospital settings.

Stream A	**Stream B**
Induction	
PBL	Clinical placement
SACRR & SBAs for both streams	
PBL	Clinical placement
SACRR & SBAs for both streams	
PBL	Clinical placement
Semi-structured Interview	

Figure 1. The study design and curriculum sequence.

Study Steps & Data Collection

The main source of data in this study was semi-structured interviews designed to explore students' perceptions of their CR process. This qualitative approach was chosen because it allowed participants to articulate their experiences, reflections, and reasoning processes in depth, capturing the complexity and contextual nature of CR that could not be fully understood through quantitative measures alone. At the end of the first semester, after students had completed different clinical placements and PBL blocks, semi-structured interviews were conducted to capture their perceptions of the overall learning experience.

To complement and contextualise these insights, two quantitative data collection tools were employed to engage students in thinking about and reflecting on their CR processes before interviews. Students completed the self-reported Self-Assessment of Clinical Reflection and Reasoning (SACRR) questionnaire and answered a set of Vignette-based Single Best answers (SBAs) focused on reasoning after each rotation. These tools were selected to provide measurable indicators of students' self-perceived reasoning development (via SACRR) and to prompt analytical thinking through applied reasoning tasks (via SBAs), thereby reinforcing reflective engagement with the topic.

Quantitative data from the SACRR and SBA were analysed descriptively to identify indicative trends, while qualitative interview data formed the primary interpretive strand of the study and were analysed thematically to provide an in-depth understanding of students' perceptions and experiences.

Data Collection Methods

A: The Self-Assessment of Clinical Reflection and Reasoning (SACRR) Survey

The SACRR was used to capture students' self-perceived development of clinical reasoning (CR) across the study period. SACRR consists of 26 Likert-scale items (1 = strongly disagree to 5 = strongly agree) assessing reflection, metacognition, and reasoning processes within health-professional education contexts. Originally developed by Royeen et al. (2001), the instrument was selected for this study because it aligns conceptually with the reflective learning framework underpinning both PBL and clinical placements and provides a validated measure of self-perceived CR growth. Additionally, Reliability evidence from prior studies (α = 0.87–0.92) supports its use (Willis et al., 2018).

The tool was adapted for medical students by replacing the term *"client"* with *"patient"* to enhance contextual relevance. Question 24 was removed as it was not applicable to undergraduate learners, and Question 8 was modified to include *"if applicable"* because participants had limited experience in intervention planning (Appendix 1). The survey was administered via MS Forms, with clear instructions to create and maintain a unique, anonymous ID throughout the study.

B: *S*ingle-best answer (SBA)

A short set of vignette-based Single Best Answer (SBA) questions was developed to engage students in analytical reasoning and to assess their application of knowledge within authentic clinical contexts. This tool was designed to complement the SACRR by providing a task-based measure of students' reasoning processes, encouraging them to think through diagnostic and management decisions rather than recall isolated facts.

Questions were constructed using a PBL–CR table of specifications to ensure content validity and alignment with the learning objectives of the PBL and clinical placement blocks (Appendix 2). Each question mirrored the types of reasoning challenges students encountered in their actual cases, reinforcing transfer between tutorial discussion and clinical practice. The vignettes were developed by the school assessment lead and reviewed by two experienced medical educators to ensure clarity, relevance, and cognitive alignment with the intended reasoning level.

Students completed the same set of SBAs after each rotation to maintain internal consistency and to allow comparison of reasoning development across learning contexts. Responses were scored and analysed descriptively to identify indicative trends in students' reasoning performance. The findings were used to contextualise and triangulate the qualitative data from the interviews, providing an integrated understanding of students' reasoning development.

Since the SBA format aligns with summative assessments, these SBAs served as formative practice assessments, reducing participant burden. All students (regardless of consent) had answered SBAs, and cohort-level feedback was provided post-study. Consenting students' responses were anonymised using unique IDs.

C: Semi-Structured Interviews
Semi-structured interviews served as the primary qualitative data source in this study, allowing for an in-depth exploration of students' perceptions of how alternating PBL and clinical placements influenced their CR development. This approach was chosen to capture the nuanced, reflective, and experiential dimensions of CR that could not be fully accessed through quantitative instruments alone.

The interview guide was developed collaboratively by the research team and informed by the study's conceptual framework, relevant literature on PBL and CR, and the quantitative data collection tools. The CR definition was shared with the students at the start of the interview to ensure shared understanding. Questions prompted students to reflect on their reasoning experiences, perceived enablers and barriers, and the influence of sequencing between PBL and placements. The guide was reviewed for clarity and refined accordingly. The final version is included in Appendix 3.

Interviews were conducted at the end of the first semester, after students had completed both PBL and clinical placement rotations, to enable reflection on their full learning experience. Each interview was conducted in English via Microsoft Teams, lasted approximately 60–90 minutes, and was audio-recorded with consent before being transcribed verbatim. The insider-researcher status of the two interviewers (EA and RW) was acknowledged, and students were randomly assigned to interviewers to minimise potential bias.

Unique participant identifiers were used throughout the study, combining a participant number (1–14) with a cohort code to indicate the sequence of learning experiences. The code "AB" refers to students who experienced PBL first, followed by clinical placement, while "BA" refers to those who experienced clinical placement first, followed by PBL (e.g., Participant 1BA).

Data Analysis

Quantitative data were analysed descriptively (means, SDs, and patterns) using SPSS v29. Given the small sample, no inferential tests were applied, and the results were used primarily to provide context and support for the qualitative findings.

A small amount of missing quantitative data (n = 2 responses from stream B) occurred due to incomplete submissions of the second post-rotation assessment; these cases were excluded from analysis but retained in the qualitative sample to preserve participant representation.

Qualitative data from the semi-structured interviews constituted the primary analytic strand of the study. Qualitative themes were reviewed for any apparent differences between sequences (PBL-first vs CP-first); however, no consistent divergence was observed. The data were examined through thematic analysis following Braun and Clarke's (2006) six-step framework. Two researchers independently reviewed transcripts and engaged in deductive/reflective coding, reaching a consensus to ensure consistent interpretation of student experiences. The phases were:

Familiarization with the data: High-quality video recordings and verbatim transcriptions of each interview were stored using corresponding interview codes. Authors EA and RW immersed themselves in the data by repeated reading and listening, making preliminary analytic notes and reflective observations.

Code generation: Both researchers independently generated concise labels for significant data features relevant to the research questions. Each transcript was coded systematically, and codes were collated into an initial coding framework. Coding was conducted using a deductive/reflective approach guided by the study's conceptual framework of PBL and CR.

Theme identification: Codes were compared and clustered into broader themes that reflected patterns across participants. This stage involved identifying relationships and contrasts between PBL and clinical learning experiences.

Theme review: The developing themes were iteratively reviewed against the coded extracts and the complete dataset to ensure coherence and credibility. The Authors, EA and RW assessed whether the themes provided a convincing narrative of the data, while also refining the definition of each theme and exploring their interrelationships.

Determining theme significance: JB and PH contributed to the in-depth review of each theme, helping to define their conceptual boundaries and ensure analytic depth. Each theme was given a concise, descriptive name representing its core meaning.

Reporting findings: EA and RW collaboratively crafted a coherent narrative that integrated the thematic findings with supporting data extracts. The narrative was contextualised within existing literature on clinical reasoning and experiential learning, highlighting convergence and contrast with prior studies. The final thematic structure and interpretations were reviewed and approved by all authors to ensure analytical rigour and consensus.

Results

A: The Self-Assessment of Clinical Reflection and Reasoning (SACRR)

Descriptive analysis of the Self-Assessment of Clinical Reflection and Reasoning (SACRR) data revealed small variations in self-perceived development of clinical reasoning (CR) between streams across the study period. As shown in Table 1, students who began with PBL (stream A) reported slightly higher mean SACRR scores after the first learning block (Post-test 1: *M* = 4.04, SD = 0.30) compared with those who began with clinical placements (stream B: *M* = 3.87, SD = 0.12). However, this difference was not sustained by the end of the second learning block (Post-test 2: stream A *M* = 3.92, SD = 0.34; stream B *M* = 3.86, SD = 0.31).

	Streams	N	Mean
Post-test 1	B	5	3.87 (SD .121)
	A	9	4.04 (SD .302)
Post-test 2	B	5	3.86 (SD .314)
	A	9	3.92 (SD .340)

Table 1. Descriptive analysis of the SACRR mean score among study groups, N=14.

At the item level, four SACRR statements showed noticeable early differences between stream A (PBL first) and stream B (placement first). These items are: *'I ask myself and others questions as a way of learning'*, *'I think in terms of comparing and contrasting information about a patient's problems and the proposed solutions to them'*, *'I try to understand clinical problems by using a variety of frames of reference'*, and *'I ask for colleagues' ideas and viewpoints'*. All four reflect higher-order reflective and analytical thinking. By the second assessment, these differences had diminished, and both cohorts demonstrated similar patterns of reflective reasoning. Across the full sample, stream A showed improvement on 7 of 25 items, while stream B improved on 10 of 25 items.

B: Vignette-Based Single Best Answer (SBA) Questions

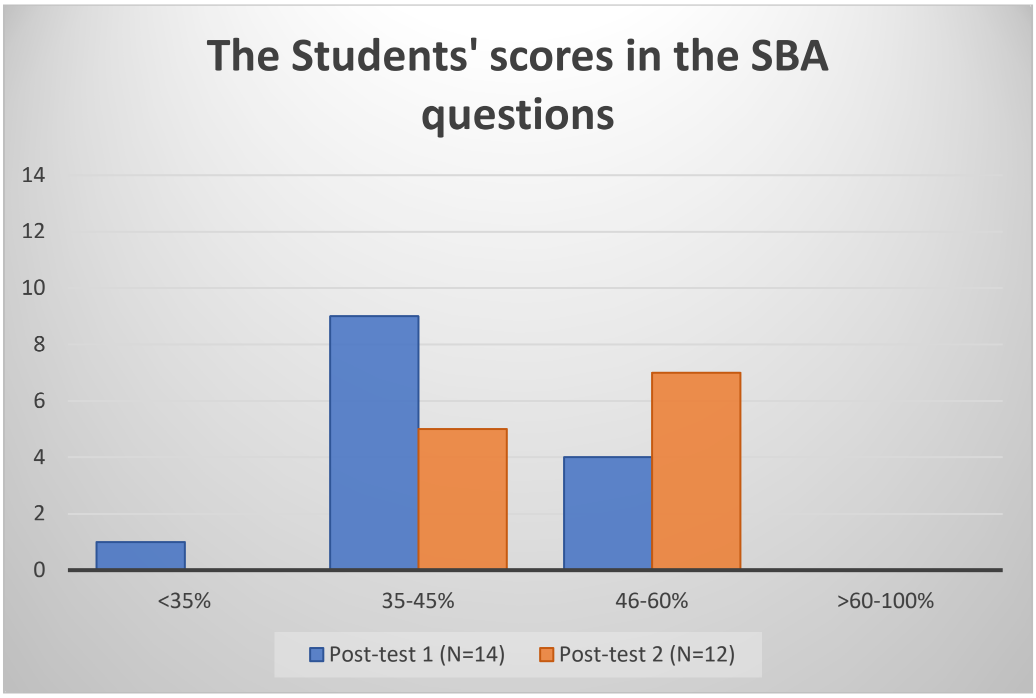

Figure 2. The students' scores in the SBA questions, N=14.

Descriptive findings from the vignette-based SBA assessments provided complementary insights into students' applied reasoning. When all students were considered collectively, the mean SBA score was 45.4% (SD = 7.46, n = 14) after the first block and 44.2% (SD = 7.33, n = 12) after the second block. Although overall scores remained stable, the distribution of results shifted slightly upward, with a higher proportion of students achieving scores in the 46–60% range after the second assessment. This suggests greater consistency in reasoning performance over time rather than dramatic gains. Figure 2 illustrates the spread of SBA results across the two time points.

C: Semi-structured interviews

These descriptive trends indicate that students' self-perceived reflection (from SACRR) and applied reasoning (from SBAs) developed gradually and in parallel across the semester. Quantitative findings, therefore, provided contextual support for the qualitative analysis, which explored how students experienced and described these shifts in reasoning during alternating PBL and clinical placement learning.

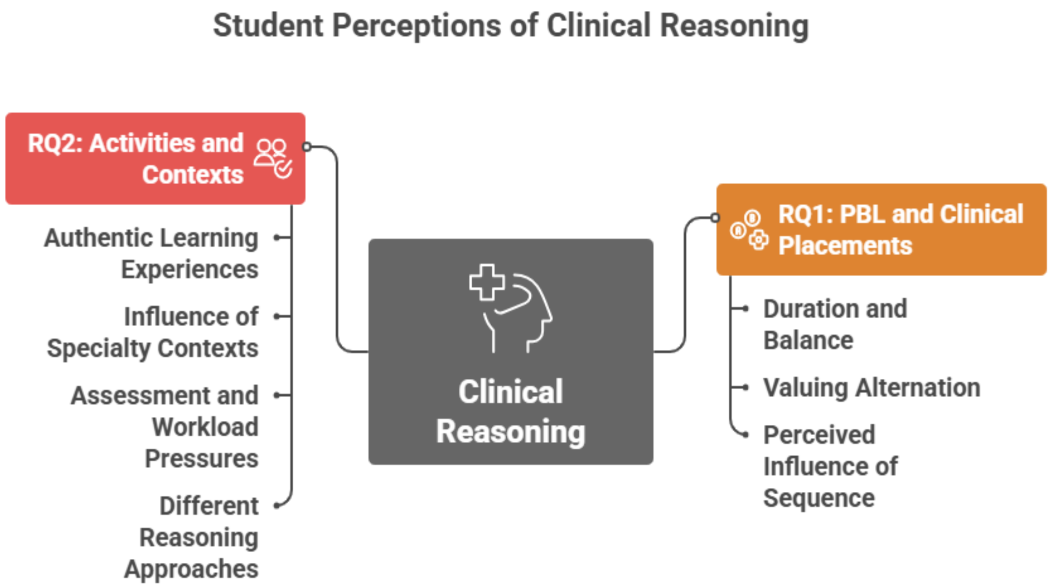

Figure 3. Thematic analysis of the interview data.

RQ1: How do students perceive the alternation of PBL and clinical placements as shaping their clinical reasoning (CR)?

Students described alternating between PBL and clinical placements as a cyclical, integrative process that enabled them to build, apply, and refine their reasoning skills. Rather than viewing each format as separate, they recognised that PBL supported analytical understanding, while clinical placements deepened practical application. Together, these experiences created a "layered learning" cycle that progressively enhanced their clinical reasoning. These qualitative insights correspond with the SACRR trends, which showed modest early gains that later stabilised, suggesting reflective maturity rather than simple linear improvement.

Duration and Balance

Before considering their perception of alternation, students reflected on the balance of time between the two settings. Some viewed the five-week rotation as well-paced, offering sufficient immersion in both environments, while others found the frequency of transitions demanding:

> "It probably takes you about three or four weeks to feel settled on a placement. And then you basically have one more week to go… you're also constantly making new starts which is physically and emotionally draining." (3AB)

This recurring shift required adaptability but also encouraged flexibility and resilience, traits students later linked to clinical reasoning.

Valuing Alternation and Complementarity

Students consistently highlighted the complementary relationship between PBL and placements. PBL enabled analytical thinking and pattern recognition, while placements contextualised and reinforced learning:

Students recognised the value of PBL in facilitating a thorough understanding of medical cases. PBL allows them the time and opportunity to delve into cases, analyse details, and extract important information. This understanding, acquired through PBL, then serves as a foundation for better performance during clinical placements. *"PBL gives you time to go back and have a thorough read to make sure that you can pull out important bits"* (3BA); while placement allows application to reinforce learning.

Meanwhile, placements allowed the application to reinforce learning. Clinical placements were seen as an opportunity to witness real patients and understand how CR is applied in practice.

Students express that this practical experience during placements makes the theoretical knowledge gained from PBL *"make more sense"*. A second student agreed and argued that *"PBL mirrors placement"* (7AB) due to the way the cases are structured which forces them to stop and think.

Students explained that alternating between PBL and placement helped them to understand relevant PBL content and the reason for each word mentioned in the case, hence improving performance:

> "Seeing how the doctor's CR was based on what went before and what is happening now, made a lot more sense." (7AB)

One student noted that real patient encounters improved memory, while PBL allowed deeper exploration of differentials:

> "I think ward rounds are very useful because you're seeing that CR process over and over and over again in the morning. this helps you to remember… and PBL is just full as well because you are helped that time to work out what's happening and why it's happening, and you have a bit of a safety net, to pose there to ask maybe questions that you wouldn't ask on a ward round." (1BA)

A student emphasised the reciprocal benefit of PBL and placement on each other and explained that placement helped them to pick more important bits easier whenever they get back to PBL and equally PBL lets them think and make connections with patients that you can see on placement,

> "I think you do become a bit more biased to what you've seen on your placement, but I do think that also let us narrow down a differential that we've got more. Whereas in the first PBL block, we were just putting up everything that we could think of and write it down on the board. On the other hand, placement engrave it in your brain in a wee bit better." (8AB)

This cyclical approach contributes to ongoing learning and skill development. The alternation of PBL and clinical placement was seen as a way to build layers of understanding.

Students described how PBL lays the foundation of knowledge, and clinical placement adds practical depth to their learning. This layering approach was seen as valuable in gradually expanding their clinical competence

> "...both bring different things to your ability to understand the CR and I think it's nice that you alternate them because you know one layer a bit and the other one layers on top of it and I feel like it's building block really and it's learned different things as you go." (1BA)

Students noted that their ability to **narrow down differential diagnoses** became more refined over time, attributing this growth to alternation between PBL and placements:

> "I think it improves it and I think every time you go back to PBL, especially in the first week, that's when you notice it because you start thinking, I've seen different conditions. So you start to think…you start to realise that your differentials are getting better." (3AB)

> "Every time we come back from a round of placement, we were just a lot more good and like you haven't missed any differential diagnosis. Like we were just all working through the systems in a systematic way." (6AB)

Perceived Influence of Sequence

Students expressed different preferences regarding the sequence of PBL and placements. Some perceived no difference, noting that:

As stated earlier, one thought that *"PBL mirrors placement due to the way the cases are structured that enforce them to stop and think"*.

Others valued starting with PBL as it provided preparation and confidence before applying learning in clinical settings. Having PBL first was thought to consolidate information, allow talking about learnt topics and clarify misunderstanding or unanswered questions therefore it enriches the discussion during placement which promotes learning:

> "PBL gives you time to go back and have a thorough read to make sure that you can pull out important bits."

> "I like learning first and then doing the placement…I do find the placement more challenging and I'm glad that I was learning first and then trying to put it into practice." (1AB)

> "I don't think if you've done the placement without having done PBL first, I think I would have struggled with it… I think doing PBL first is valuable in that lets you get the most out of your placement." (8AB)

> "I think maybe prefer to do PBL first, because then you've got a quite good amount of questions that you've learned for the five weeks and then you can come into GP practice and ask those questions." (3BA)

> "I do think having PBL sessions, those three sessions beforehand [during induction] really helped by getting us back into the way of thinking." (5BA)

Some argued for starting with GP placements as a foundational experience due to their exposure to undifferentiated presentations, while others suggested beginning with GP before progressing to more specialised secondary care.

These discissions demonstrated that students were not considering year 2 clinical placement as building on Year 1 PBL (as intended in the curriculum), and students were seeking an explicate correlation between the year 2 PBL cases and their placement rotation:

> "If they match the colorectal stuff that we went through…with the surgery rotation, I think that would really just match up so well because you're really going through the in depth study of PBL and then you're maybe matching that with what you've just learned or what you're about to go out and learn on placement." (5BA)

RQ2: What are the activities, sequences and approaches that students perceive affect their CR?

Authentic, discussion-rich, and feedback-oriented contexts were perceived as key enablers of CR development, while excessive workload, assessment pressures, and overly structured materials acted as barriers. This theme aligns with the gradual reflective growth shown in SACRR data, suggesting that CR flourishes in flexible, supportive environments that encourage independent reasoning.

Authentic learning experiences

The use of clinical cases in teaching enables clinical reasoning (CR), allowing students to apply knowledge.

> "Looking into patients' files and making sense of all things that the consultants have written on." (1AB)

Exposure to undifferentiated presentations, especially in PBL and GP placements, is beneficial, as engaging GP tutors challenges students and encourage participation.

> "The real enabler is getting access to undifferentiated presentation... sitting in with the GP and then letting me do three things, taking a history, examining a patient and presenting my findings... triggered me to think." (3AB)

Discussion of cases, whether in PBL or placement, enhances CR, with tutor competency playing a role. *"Big influence on the dynamic of the group"* (3AB), "*Getting feedback from someone who knows the game as well*" (7AB).

Various teaching methods, such as ward rounds, simulations, mock OSCEs, and bedside teaching, bridge theory and practice.

> "I love PBL... but on placement, I really utilised the resources... simulation sessions… bedside teaching was brilliant." (5BA)

A supportive learning environment is crucial, as a dyslexic student shared, "*It just takes me a wee bit longer... I've had a lot of support... once I find that I see improvement*" (5BA).

Specialties

There was a distinction in students' perceptions towards placement rotation allocation.

PBL and GP placements were seen as highly beneficial for CR skills and therefore it were better to have early in the year, Surgery and Medicine placements are mentioned as less helpful in this regard.

> "PBL and GP placement are great to develop clinical reasoning skills due to undifferentiated presentation; while Surgery and Medicine placements didn't help a lot in this regards." (4BA)

One student mentioned that hospital placements are *"somehow different"* being *"more methodical and practical"*.

This difference in the effect of learning methods on different specialisations is noteworthy.

> "I think that GP and PBL are building the bases for when you go to the hospital…to have GP first out of the three was really good because it was like a good introduction, built on the knowledge that we learned from first year which was like a lot of the communication with the patient and a lot of very common general Conditions that come in." (3BA)

Another student agreed that starting with GP placement gives a "*really good overview*" and allows for the development of different skills. Similarly, a student who started with Medicine placement before PBL suggested that PBL and GP before other placements would have been better:

> "I think I would like to do probably PBL first, then GP, and then keep your medicine in the middle and then surgery last, I think that would probably be a good way of doing it." (5BA)

In contrast, another student valued starting with Medicine:

> "Starting with Medicine. I think that it was like basically what you do in PBL." (6AB)

Assessment and Workload Pressures

Students highlighted a potential tension between exam requirements and CR skill development.

One explained that exam schedules shaped their views on sequencing more than CR itself:

> "Well, actually probably, it helped me cope more with the exam times, in general. Take the exams out of the equation and not sure it would. I would mind the order." (8AB)

> "I felt GP placement was less heavy in terms of running into the exams….I felt we were so well supported in the hospital, that it wouldn't really matter what order would it be done." (1BA)

Others suggested that alternation itself, rather than order, was the key benefit:

> "I don't think the order had any effect on CR. I just think the way it was broke up into five weeks on five weeks off [placement]. That was really good." (7AB)

Students also described **lecture overload** and **over-structured PBL-cases** as barriers to CR:

> "I find the options in the PBL... leading because you find yourself jumping a few crucial steps... The GP would turn out and ask what test do you want to run? And I'm in my head going ohh because I haven't had the opportunity to select." (3BA)

> "The number of lectures in the last five weeks and the specialty programme is very heavy." (3BA)

> "It can feel overwhelming at the start because not everything makes sense." (1BA)

Despite these challenges, students still valued structured learning in supporting CR skill development.

Different reasoning approaches

Through the interviews, students described how they approached the SBA reasoning questions, providing insight into the ways their cognitive strategies evolved through the alternation of PBL and clinical placements. These reflections highlight how students experienced assessment as both an opportunity and a challenge in developing CR.

Educated guessing and Familiarity

Students often rely on familiarity with certain options or educated guesses when faced with unfamiliar situations or questions.

> "There were a lot of times when I knew what all the information was, but I couldn't work out how to answer the questions. So definitely it wasn't a problem of recognising the words and the questions. It was definitely a question of application of the knowledge to work out the answer." (1AB)

> "... one of the options was something I've seen before, so, I was more inclined to pick that option I think it was mainly just like familiarity with that option. So, I think it's like a pattern-based." (4BA)

> "there were some things that you recognise. But you're just trying to put things together. The majority of them I might have an educated guess. ... I made the guess probably from the knowledge that I already had." (1BA)

Building blocks from Experience

Students also attempted to build their reasoning based on what they had learned in PBL sessions and during clinical placements. They draw on their limited understanding to answer questions, particularly when encountering unfamiliar scenarios.

> 'If you haven't really seen it, you're basically just either taking an educated guess or just trying to build from what you know, your limited understanding from what you've learned from PBL and all that sort of stuff... (3BA)'

> "Compared to last year, we have a much more broader amount of clinical conditions like a like a library of clinical conditions that we can build on and because you get a patent of the signs and symptoms, you can pick those up and then decide sort of narrow down which signs and symptoms are much more significant for you to sort of have it like a top two to three differential diagnosis. For those conditions. So I think it's really good. And then placement has really like being able to consolidate that information. And then again ask questions and stuff about you know, like do blood tests or imaging that that normally gets done..." (8AB)

Better-informed decisions with practice

Some students noted that question uncertainty stimulated deeper reasoning. Consequently, they had to thoroughly analyse and compare the information in order to make an informed decision, leading to uncertainty in their choices.

> "The main problem I found there was so much uncertainty about choosing an answer. All the other options were like… Very close to being correct as well. ... I found those questions really good." (3AB)

They expressed that retaking assessments allowed reflection and improved decision-making:

> "I was just looking for a jump-out Thing I remember not properly paying attention to Every bit of detail on the first one. I think the second time I noticed details. So on the second one, after placement I Approached that more with sort of everything here is important." (7AB)

> "where I felt a big shortcoming the first time I did it. I felt slightly better about it the second time I did it. I felt I was better able to apply the knowledge, but I was still aware that there were things where I was guessing." (1AB)

> "The second one I think I was much more like ah well they're having this symptom so you could rule that one out and then use the information that you had gathered from the last few questions to answer the next one. I probably got the questions wrong, but just my mindset was different going into the second one because I had a bit more, PBL and placement, maybe a bit more experience." (6AB)

A student suggested tracking progress over time to enhance reflection:

> "I think in an ideal world, it would be if you got a bit of feedback saying no, you... have Progressed, we can see it or so you're just in that you are progressing from the previous exam. OK. So, I like a progress test throughout the year. You don't always need a tangible percentage. You just need to reflect on yourself and say well what was your thought process during that?" (6AB)

Emotional Response and Guilt

On the other hand, some students did not notice improvement between assessments, leading to frustration and guilt:

> "Yes, I found those very difficult, and some of them to be fair, I should have known them. But most of them, I think, were very difficult. I found no difference between both tests, only more guilt at feeling that I should have known them." (3AB)

Others felt the second test was less focused on CR but on recall:

> "The second one was very much; it didn't test my clinical reason as much. It was more to remember what question I had answered before." (8AB)

Discussion

At Ulster University, CR is emphasized both implicitly through curriculum design and explicitly in teaching. This study explored how curriculum design and the sequencing of learning experiences influence GEM students' perceptions of their CR process.

Students perceived alternating PBL and CP as a cyclical and complementary process that allowed them to build, apply, and refine their reasoning progressively. This dynamic reflects the theoretical view that reasoning is both socially constructed and situated within authentic practice (Vygotsky, 1978; Dornan et al., 2012; Billett, 2016).

The alternation between settings encouraged students to integrate conceptual and experiential learning. This interplay supports the notion that clinical reasoning develops not linearly but through recursive exposure to varied contexts, enabling iterative reflection and synthesis (Gruppen, 2017). The absence of significant quantitative differences between streams suggests that sequence alone was less influential than the overall integration of both learning environments. This interpretation is based on the modest variations observed in SACRR and SBA scores, which suggest gradual reflective growth, and is further reinforced by students' interview accounts describing how alternation between PBL and clinical placements progressively shaped their reasoning processes. Students' reflections thus highlight that CR is enhanced when theoretical and practical reasoning are closely interwoven, regardless of order.

Students attributed their CR development to opportunities for discussion and application across different learning contexts. While PBL group discussions were valued for fostering analytical thinking and long-term knowledge retention (Posner et al., 2023; Trullàs et al., 2022), most students reported that engaging with undifferentiated patient cases during general practice (GP) placements had a stronger impact on their reasoning skills. They perceived that GP tutors' questioning and feedback encouraged deeper analysis and hypothesis generation, supporting previous evidence that primary care settings are uniquely effective for developing broad diagnostic reasoning due to the prevalence of uncertainty and diverse presentations (Fazio et al., 2016; Bansal et al., 2020). These experiences mirror findings on the effectiveness of structured case discussions in promoting reasoning (Weidenbusch et al., 2019) and reflect the critical role of history-taking and symptom interpretation, which underpin most diagnoses in general practice (Baerheim, 2001; Stolper, 2010). Unlike speciality care, where presentations are more defined, GP settings expose students to early, ambiguous stages of illness that demand flexibility and the formulation of distinct diagnostic hypotheses (McWhinney, 1980; Roger et al., 2010).

Students did not perceive that the sequence of PBL and clinical rotations influenced CR process, suggesting that the juxtaposition of these learning opportunities at short intervals (e.g., 5 weeks) reinforces CR skills. Clinical teaching aligns with the "acquisition metaphor," where competence is transferred from teachers to learners, while PBL embodies the "participation metaphor," framing learning as a social process (Dornan et al., 2012). Alternating these approaches provides students with a comprehensive, integrative experience, enabling them to apply knowledge in authentic settings. Studies show that courses combining case vignettes and PBL-style teaching yield higher student performance, underscoring the value of this model (Dubin, 2016).

Beyond their perceptions of curriculum design, students' reflections revealed distinct reasoning approaches that evolved across the alternating learning contexts. Initially, many described relying on recognition-based strategies, choosing answers through *familiarity* or *pattern recognition* without fully analysing the underlying logic. This early dependence on surface cues and "educated guessing" aligns with novice reasoning models, in which learners apply intuitive heuristics before developing integrated illness scripts (Norman, 2005; Monteiro & Norman, 2013).

As students engaged in both PBL and clinical placements, their reasoning became progressively analytical and experience-informed. They began to connect symptoms, patterns, and contextual information, demonstrating movement from *non-analytical recognition* toward hypothetico-deductive reasoning. This developmental trajectory reflects the dual-process theory of clinical reasoning, which suggests that Type 1 intuitive reasoning (rapid, recognition-based) gradually integrates with Type 2 analytical reasoning (deliberate, reflective) as expertise grows (Croskerry, 2009; Eva, 2005).

Students who described "building from experience" exemplified this shift. Exposure to real patients allowed them to test and refine hypotheses, fostering the construction of illness scripts, structured cognitive representations that link clinical features to underlying mechanisms (Lubarsky et al., 2015). PBL discussions supported this process by encouraging collaborative analysis and articulation of reasoning steps, reinforcing metacognitive awareness (Schmidt & Mamede, 2015).

By the second SBA's experience, some students described approaching reasoning tasks with greater attention to detail and *self-monitoring*, consistent with metacognitive calibration, the ability to evaluate and adjust one's reasoning process (Croskerry et al., 2013). Others expressed frustration or guilt at not perceiving improvement, suggesting varying degrees of self-efficacy and tolerance of diagnostic uncertainty, both critical affective components of CR (Ilgen et al., 2011).

Students identified several enablers and barriers to CR development that align with existing research. Enablers included authentic patient encounters, case-based discussions, opportunities for feedback, and supportive tutor relationships. These features mirror conditions described as conducive to clinical learning, namely, authenticity, reflection, and feedback within safe environments (Dornan et al., 2012; Thampy et al., 2019). GP placements were particularly valued for involving undifferentiated presentations, echoing prior work showing that general practice fosters broad diagnostic reasoning through exposure to clinical uncertainty (Fazio et al., 2016; Bansal et al., 2020). Barriers included heavy workload, examination pressure, and over-guided PBL sessions, which students felt restricted independent reasoning. These findings align with literature on cognitive load and performance, showing that excessive structure or stress can limit analytical depth and reflection (Jordan et al., 2019; Dendle et al., 2018). Medical students face unique stressors, including workload and curriculum demands, which can hinder skill acquisition and academic achievement (Aziz et al., 2020). Importantly, students noted that alignment between PBL cases and clinical experiences enhanced learning transfer and reinforced reasoning processes, supporting evidence that curricular coherence strengthens the integration of theoretical and practical knowledge (Brauer & Ferguson, 2015).

For curriculum design, the findings emphasise the importance of integrating authentic case discussions with early clinical exposure, allowing students to connect theoretical understanding with real patient contexts. Facilitators play a crucial role in this process by using questioning techniques that stimulate reasoning rather than simple recall, prompting learners to articulate hypotheses, justify decisions, and explore alternative explanations. Additionally, structured opportunities for reflection and feedback are essential to nurture metacognitive awareness, helping students evaluate their own thinking processes, recognise reasoning gaps, and progressively refine their clinical judgement.

Despite the study's methodological rigour, the results should be interpreted with caution due to some limitations. This qualitative-led exploratory mixed-methods study is based on a small, single-institution sample (n=14) of volunteers, which limits generalisability and precludes inferential testing; self-report measures (SACRR) are susceptible to response bias; incomplete SBA data in one cohort reduced comparability; insider-researcher involvement risks relational/confirmatory bias despite reflexive safeguards; and the short, single-semester window captures perceptions rather than longer-term reasoning performance. To strengthen causal inference and validate these conclusions, future work should use a longitudinal, mixed-methods cohort following students across multiple rotations (and into clinical years) could combine validated CR assessments (e.g., Script Concordance Test, Key-Features/SBA items mapped to CR, CR-focused OSCE stations, workplace-based assessments with reasoning anchors) with repeated SACRR and interview/reflection data.

Conclusion

In conclusion, students perceive the alternation between PBL and clinical placements as a dynamic, cyclical process that progressively shapes their clinical reasoning. Rather than privileging one learning format or sequence, participants viewed the interplay between analytical discussion and authentic patient contact as fundamental to their reasoning process. Authentic, discussion-rich, and feedback-oriented activities, particularly exposure to undifferentiated cases, structured reflection, and Feedback, emerged as key enablers of reasoning development. Conversely, assessment pressures, lecture overload, and overly structured PBL materials were perceived as barriers that limited independent thought. Students suggested that aligning PBL cases with placement encounters, embedding formative reasoning assessments, and fostering a safe environment for reflection may collectively enhance the experiential development of clinical reasoning.

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Authors contributions

All authors contributed to the study's conception and design.

Declarations

Ethical Consideration
This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ulster University School of Biomedical Sciences Ethics Filter Committee (FCBMS) FCBMS-22-122-D. The two streams were exposed to the same educational strategies and measurement tools. Students who did not take part in the research experienced no disadvantage. Only those who agreed to be involved in the study and who provided written informed consent were included under the reassurance that any information the participants provided in the survey or interview would be dealt with anonymously.

Disclosure statement
The authors report there are no competing interests to declare.

Data availability
Minimal data for this study are publicly available. Appendices 1–3 available as online supplementary materials upon publication

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Appendix 1

The SACRR scores among the study groups in post-test 1, N=14

Questions	Groups	N	Mean	Std. Deviation
1. I question how, what, and why I do things in practice	B	5	4.20	.447
	A	9	4.44	.527
2. I ask myself and others questions as a way of learning.	B	5	4.60	.548
	A	9	4.89	.333
3. I do not make judgments until I have sufficient data	B	5	3.80	1.095
	A	9	3.89	.782
4. Before acting, I seek various solutions	B	5	3.80	.447
	A	9	4.00	.707
5. Regarding the outcome of proposed interventions, I try to keep an open mind	B	5	4.20	.447
	A	9	4.11	.333
6. I think in terms of comparing and contrasting information about a patient's problems and the proposed solutions to them.	B	5	3.40	1.140
	A	9	4.00	.500
7. I look to theory for understanding a patient's problems and the proposed solutions to them.	B	5	4.40	.548
	A	9	4.00	.707
8. If applicable, I check multiple resources/references for planning my intervention strategy	B	5	4.00	1.000
	A	9	4.22	.833
9. I use theory to understand treatment techniques.	B	5	4.40	.548
	A	9	4.44	.527
10. I try to understand clinical problems by using a variety of frames of reference.	B	5	4.00	.000
	A	9	3.78	.667
11. When there is conflicting information about a clinical problem, I identify assumptions underlying the differing views.	B	5	3.00	.707
	A	9	3.44	1.014
12. When planning intervention strategies, I ask "What if" for a variety of options.	B	5	3.20	.837
	A	9	3.89	.601
13. I ask for colleagues' ideas and viewpoints	B	5	5.00	.000
	A	9	4.56	.527
14. I would ask for the viewpoints of the patient's family members.	B	5	4.20	.447
	A	9	3.44	.527
15. I cope well with change.	B	5	3.40	.894
	A	9	3.44	1.014
16. I can function with uncertainty.	B	5	3.20	1.095
	A	9	3.67	.866

17. I regularly hypothesize about the reasons for my patients' problems.	B	5	4.20	.447
	A	9	4.44	.527
18. I must validate clinical hypotheses through my own experience.	B	5	3.00	1.414
	A	9	3.78	1.093
19. I clearly identify the clinical problems prior to planning interventions.	B	5	4.20	.447
	A	9	4.33	.500
20. I anticipate the sequence of events likely to result from planned interventions.	B	5	3.60	.894
	A	9	3.89	.782
21. Regarding a proposed intervention strategy, I think, "What makes it work?"	B	5	4.00	.707
	A	9	4.11	.601
22. Regarding a particular intervention, I ask, "In what context would it work?"	B	5	3.00	.707
	A	9	3.89	.782
23. Regarding a particular intervention with a particular patient, I determine whether it worked.	B	5	4.40	.548
	A	9	4.11	.601
24. Regarding a particular intervention with a particular patient, I determine whether it worked.	B	5	3.40	1.140
	A	9	3.67	1.118
25. I use theory to understand intervention strategies.	B	5	4.20	.447
	A	9	4.44	.527

The SACRR scores among the study groups in post-test 2, N=14

Questions	Groups	N	Mean	Std. Deviation
1. I question how, what, and why I do things in practice	B	5	4.40	.548
	A	9	4.33	.500
2. I ask myself and others questions as a way of learning.	B	5	4.60	.548
	A	9	4.67	.500
3. I do not make judgments until I have sufficient data	B	5	3.80	1.304
	A	9	3.78	.833
4. Before acting, I seek various solutions	B	5	3.20	1.304
	A	9	3.67	.866
5. Regarding the outcome of proposed interventions, I try to keep an open mind	B	5	4.20	.447
	A	9	4.22	.833
6. I think in terms of comparing and contrasting information about a patient's problems and the proposed solutions to them.	B	5	3.60	1.140
	A	9	3.78	.667
7. I look to theory for understanding a patient's problems and the proposed solutions to them.	B	5	4.40	.548
	A	9	4.00	.866
8. If applicable, I check multiple resources/references for planning my intervention strategy	B	5	4.20	.837
	A	9	3.56	1.130

9. I use theory to understand treatment techniques.	B	5	4.20	.447
	A	9	4.44	.527
10. I try to understand clinical problems by using a variety of frames of reference.	B	5	3.80	1.095
	A	9	4.33	.707
11. When there is conflicting information about a clinical problem, I identify assumptions underlying the differing views.	B	5	3.20	1.095
	A	9	3.67	.707
12. When planning intervention strategies, I ask "What if" for a variety of options.	B	5	4.00	.707
	A	9	4.00	.866
13. I ask for colleagues' ideas and viewpoints	B	5	4.80	.447
	A	9	4.44	.726
14. I would ask for the viewpoints of the patient's family members.	B	5	4.20	.447
	A	9	3.89	.928
15. I cope well with change.	B	5	3.60	1.140
	A	9	2.89	1.167
16. I can function with uncertainty.	B	5	3.20	1.095
	A	9	3.22	1.093
17. I regularly hypothesize about the reasons for my patients' problems.	B	5	3.20	1.304
	A	9	4.22	.667
18. I must validate clinical hypotheses through my own experience.	B	5	2.80	1.095
	A	9	3.33	1.323
19. I clearly identify the clinical problems prior to planning interventions.	B	5	4.00	.707
	A	9	3.56	.882
20. I anticipate the sequence of events likely to result from planned interventions.	B	5	3.40	.894
	A	9	3.67	.707
21. Regarding a proposed intervention strategy, I think, "What makes it work?"	B	5	4.20	.447
	A	9	4.22	.441
22. Regarding a particular intervention, I ask, "In what context would it work?"	B	5	3.20	.837
	A	9	3.78	.667
23. Regarding a particular intervention with a particular patient, I determine whether it worked.	B	5	4.00	.707
	A	9	3.89	.782
24. Regarding a particular intervention with a particular patient, I determine whether it worked.	B	5	3.60	1.140
	A	9	4.00	1.000
25. I use theory to understand intervention strategies.	B	5	4.60	.548
	A	9	4.33	.707

Appendix 2

Clinical reasoning questions

Ulster University
SCHOOL OF MEDICINE

Clinical Reasoning MCQs

PBL Case 1:
Unit: Life Protection
Learning objectives:
- **Describe the clinical features of meningitis at each age. (PBL 2)**
- **Discuss the acute and long-term management of meningitis. (PBL 2)**

PBL Case 2:
Unit: Life Control
Learning objectives:
- **Define hydrocephalus and describe its causes and consequences. (PBL 2)**
- **Describe the different modalities for imaging the brain and identify key radiological characteristics of common clinical conditions, with reference to clinical examples. (session)**

A 49 year old man presents to the emergency department complaining of gradual onset headache, malaise and feeling dizzy. He has alcohol dependence and drinks approximately 1 litre of vodka daily. He has not had any alcohol for 12 hours. On examination, he looks unwell, is photo- and phonophobic. His heart rate is 120bpm, blood pressure is 82/42mmHg, respiratory rate is 28/min, his temperature is 38.2°C and his GCS is 11/15 [E3, V3, M5]. He has no known drug allergies. Serum blood glucose is 7.5mmol/L.

Q1. What is the most likely diagnosis?

A. Acute alcohol withdrawal
B. Encephalitis
C. Meningitis
D. Subarachnoid haemorrhage
E. Wernicke's encephalopathy

Q2. What is the most important investigation to perform?

A. Blood culture
B. CT Brain
C. Full blood count
D. Lumbar puncture
E. Throat swab

Q3. If an infective aetiology was considered, what is the most likely potential organism in this patient?

A. Haemophilus influenzae type b (Hib) bacteria
B. Herpes Simplex virus
C. Listeria monocytogenes
D. Neisseria meningitidis
E. **Streptococcus pneumonia**

Q4. What is the most important therapeutic intervention in this case?

A. Acyclovir 800mg IV
B. Ceftriaxone 2g IV
C. Ceftriaxone 2g IV and amoxicillin 2g
D. Dexamethasone 10mg IV
E. Vancomycin IV

A lumbar puncture and cerebral spinal (CSF) analysis is performed following administration of your therapy in Q4.

Results: White cell count 89 – predominantly lymphocytes (Normal range <10)
Gram stain – negative
Protein 1.7g/l (Normal rage 0.1-0.4g/l)
Glucose 3.2mmol/l

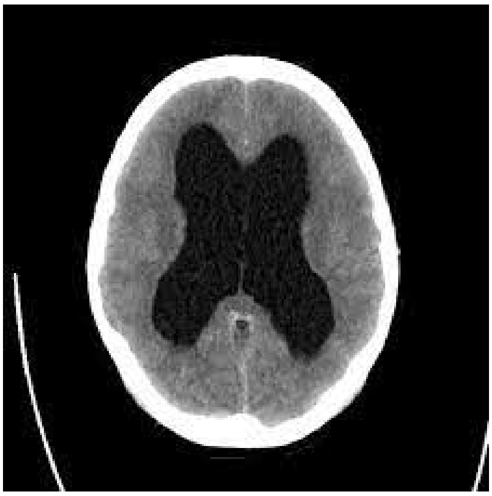
Q5. From the results above, what is the most likely diagnosis now?

A. Ascetic meningitis
B. Bacterial meningitis
C. TB meningitis
D. Viral encephalitis
E. Viral meningitis

Q6. What other investigations would now be a priority?

A. Blood film
B. CSF polymerase chain reaction (PCR)
C. CT thorax and abdomen
D. HIV p24 Antigen
E. Interferon gamma release assay (IGRA)

Within 24 hours of admission, the patient deteriorates further, and his GCS falls rapidly. An emergency CT is undertaken and shown below:



Q7. What is the CT brain scan in keeping with?

A. Acute hydrocephalus
B. Ischaemic stroke
C. Normal brain
D. Periventricular haemorrhage
E. Subarachnoid haemorrhage

The patient is subjected to a trapezius squeeze and is observed to move their arm up to their shoulder. Their eyes open and they make incomprehensible sounds.

Q8. What is their Glasgow Coma Score (GCS)?

A. GCS 7
B. GCS 8
C. GCS 9
D. GCS 10
E. GCS 11

Q9. Given the history and image above, what is the most appropriate immediate management?

A. Administer nimodipine
B. Administer phenytoin
C. Call neurosurgery
D. Ensure patient is lying flat
E. Neurological observations hourly

PBL Case 3:

Unit: Life Maintenance

Learning Objectives:

- **Describe and explain the principal laboratory findings that indicate acute kidney injury. (PBL 1 + session)**
- **Explain how the classification of pre-renal, renal, and post-renal failure determines initial investigation and management of acute kidney injury. (PBL 1)**

A 74-year-old lady is admitted medically with gastroenteritis. She has been vomiting and having severe diarrhoea for two days. On examination, she looks dehydrated. Past medical history includes atrial fibrillation (on bisoprolol and warfarin), hypertension (on lisinopril and amlodipine) and osteoarthritis. Urea and electrolytes reveal:

	Result	**Normal ranges**
Sodium (mmol/l)	149	**135 – 145**
Potassium (mmol/l)	7.2	**3.5 – 5.4**
Bicarbonate (mmol/l)	18	**22 – 28**
Urea (mmol/l)	19.4	**2.5 – 6.7**
Creatinine (μmol/l)	198	**50 – 110**

Q10. What is the diagnosis?

A. Haemolytic uraemic syndrome

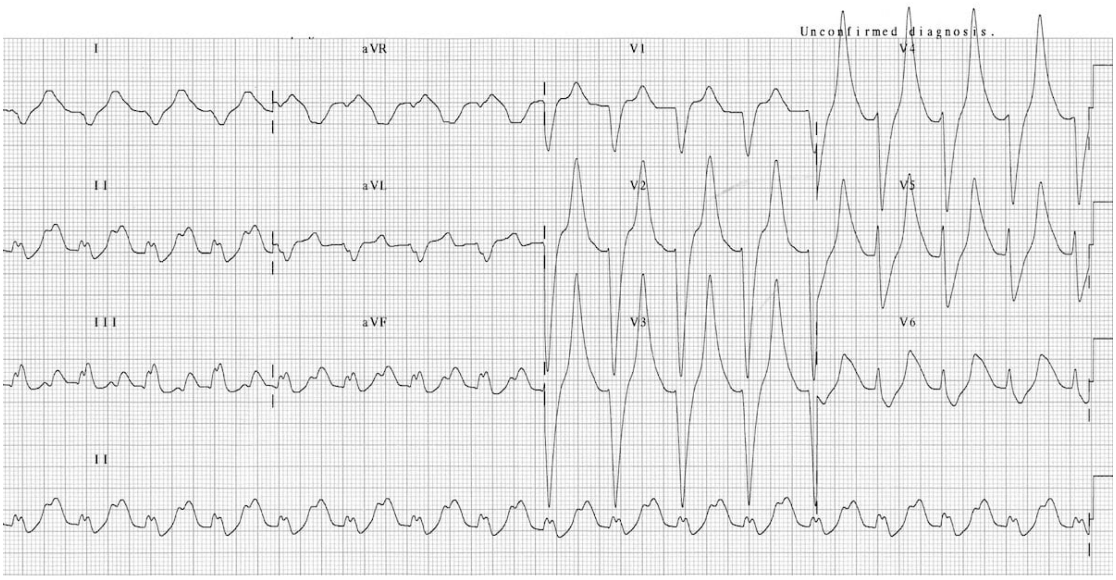
B. Intravascular depletion

C. Post-renal acute kidney injury

D. Pre-renal acute kidney injury

E. Renal acute kidney injury

A 12 lead ECG from this patient shows the following:



Q11. The first line treatment to prevent this patient from having a cardiac arrest should be to?

A. Give 500ml of 0.9% sodium chloride IV

B. Give 50ml of 8.4% sodium bicarbonate IV

C. Give 50ml of 50% glucose and 10 units of actrapid insulin IV over 5 minutes

D. Give 10ml of 10% calcium gluconate over 2 minutes

E. Give 10ml of 10% calcium chloride over 20 minutes

Following administering your treatment in Q11, you review this 74-year-old woman's drug Kardex:

Drug	Dose	Route	Frequency	Sign
LISINOPRIL	10mg	PO	OD	GM
BISOPROLOL	5mg	PO	OD	GM
SPIRONOLACTONE	50mg	PO	BD	GM
TRIMETHOPRIM	200mg	PO	BD	GM
AMLODIPINE	10mg	PO	OD	GM

Q12. Which one of these drugs would unlikely exacerbate the underlying problem causing the ECG changes in Q11?

A. Amlodipine

B. Bisoprolol

C. Digoxin

D. Spironolactone

E. Trimethoprim

The 74 year old woman is admitted to hospital and becomes confused with impaired attention and poor concentration. She is restless and frightened. She is verbally abusive and has perceptual abnormalities. There is no significant previous psychiatric history.

Q13. What is the single most likely diagnosis?

A. Delirium

B. Drug induced psychosis

C. Lewy body dementia

D. Multi-infarct dementia

E. Psychotic depression

PBL Case 4:

Unit: Life Support

Learning Objectives:

- **Define asthma and outline its prevalence in the UK. (PBL 1 + Management session)**
- **Be able to perform and interpret peak flow, spirometry and understand measurement of transfer factor. (PBL 1 + Resp workshop)**
- **Describe the control of respiration and explain common abnormalities of arterial blood gases seen in clinical practice. (ABG session)**

A 27-year-old woman presents to the emergency department with a 4-hour history of shortness of breath and wheezing. Following your assessment of her, you find features of acute asthma. She has a history of multiple admissions for acute exacerbations of asthma.

Q14. What finding would indicate that this exacerbation of his asthma should be regarded as life threatening?

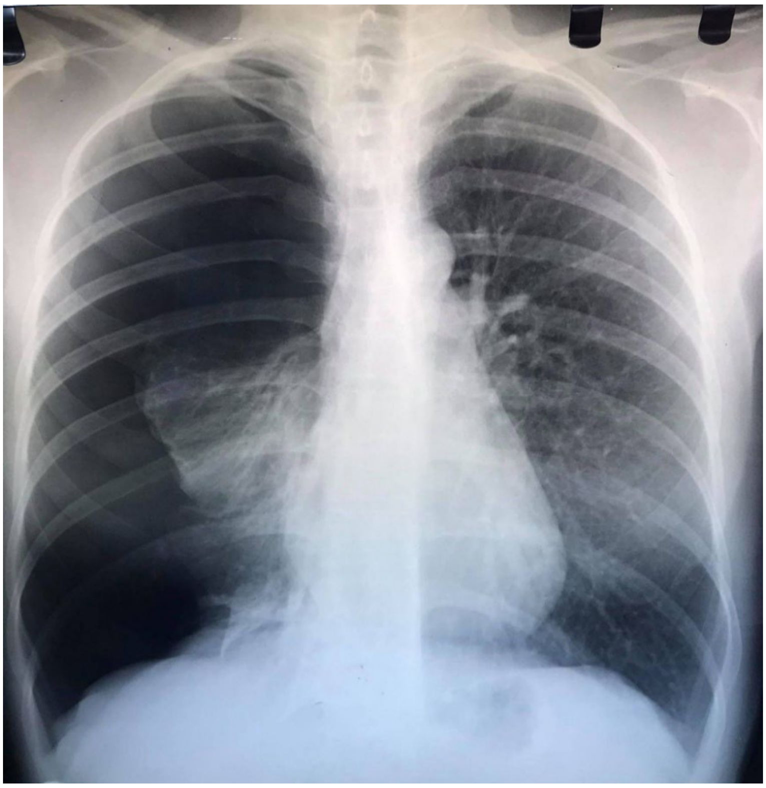
A. $PaCO_2$ 5.3 Kpa
B. PaO_2 of 8.4 KPa on room air
C. Peak flow 35% predicted
D. Pulse 116 beats per minute
E. Respiratory rate 30 breaths per minute

The patient with life threatening asthma is being treated with bronchodilators. She weighs 50Kg and has a current theophylline plasma concentration of 5 mg/L. As she has not improved, the plan is to increase her plasma theophylline concentration from 5 mg/L to 15 mg/L. Theophylline has a volume of distribution (Vd) of 0.5L/Kg.

Q15. What would be the precise loading dose needed to increase the theophylline plasma concentration?

A. 100mg
B. 125mg
C. 375mg
D. 500mg
E. 750mg

The patient deteriorates further with increasing respiratory distress. A chest x-ray is taken and shown below.



Q16. What is the most likely cause of this patient's deterioration?

A. Concurrent lower respiratory tract infection

B. Exhaustion and decompensation

C. Failure of bronchodilator therapy

D. Progression to near fatal asthma

E. Tension pneumothorax

You are a foundation doctor on a respiratory ward managing the asthmatic patient above. You are asked by the respiratory to obtain the patients consent for a chest drain procedure but are unsure of the complications when asked by the patient.

Q17.What is the most appropriate next action?

A. Ask her to sign the form but leave the complications as blank

B. Ask the registrar performing the procedure to obtain consent

C. Due to the urgency, continue without further explanation

D. Give a standard list of complications such as pain and bleeding

E. Tell her that verbal consent is all that is needed

PBL Case 5:
Unit: Life Cycle
Learning Objectives:

- **Outline the basic orthopaedic management of a Colles' fracture.**
- **Describe the pathology and the management of osteoporosis. (PBL 1)**
- **Describe how bone mineral density is used to derive T- and Z- scores in order to diagnose osteoporosis and osteopenia. (PBL 1)**

A 66-year-old woman presents to the emergency department after falling onto her flexed wrist. She is fit and well, a non-smoker and consumes 12 units of alcohol per week. She has never had a fracture before and there is no family history of fractures.

X-rays (AP and lateral) are taken and shown below.

Q18. What is the eponymous name of the fracture shown in the image above?

A. Barton fracture
B. Colle's fracture
C. Reverse Barton fracture
D. Scaphoid fracture
E. Smith fracture

The patient is in severe pain, and you are asked to prescribe analgesia.

Q19. When prescribing for the elderly, which pharmacokinetic factor needs to be considered?

A. Increased albumin binding
B. Increased first pass hepatic metabolism
C. Increased renal clearance
D. Reduced distribution volume for fat soluble drugs
E. Reduced distribution volume for water soluble drugs

This patient is subsequently sent for a dual energy x-ray absorptiometry (DEXA) scan. The results show a T-score of -4.1 in her hip and -2.9 in her spine.

Q20. What is the next most appropriate step in her management?

A. Assess diet and consider calcium and vitamin D supplementation
B. Commence a bisphosphonate, and calcium and vitamin D supplementation
C. Commence denusomab
D. Commence on hormone replacement therapy
E. No treatment, repeat DEXA in 1 year

Appendix 3

The interview guide

Thank you for being available to talk about your experience in developing CR.

I just want to be sure that we are on the same page in terms of discussing CR. It is a term that has many different interpretations and synonyms. What we want to explore is thinking and decision-making processes associated with a clinical practice including the diagnosis of the patient's problem, making a therapeutic decision and estimating the prognosis for the patient.

1. Can I confirm whether did you the clinical placement before or after your PBL sessions?

2. Firstly, I'd like to ask you how you approached the CR test questions. Did the questions provoke any thoughts about your CR skills?

Secondly, I'd like to move on to your own experience of learning CR.

3. Could you describe what differences you noticed in the approach to CR between clinical placement and problem-based learning sessions? Learning approach

4. From your experience what was the effect of alternating clinical placement and problem-based learning sessions on your progressive development of CR skills and how did you cope with change? Which arrangement do you think would allow better development of CR and why?

5. What are the most effective activities that you participated in that promoted your development of CR skills and why?

6. Is there anything else that you'd like to tell me about how your CR has developed during the last year? What were enablers and what were barriers?

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Striking a new Balance?

Courses, Project Work, and Problem-based Learning

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Abstract

This article examines how two content courses in the first and second semesters of a master's program were redesigned to promote problem-based learning (PBL). In both cases, the syllabi were revised to emphasize problem-orientation, group work, and exemplarity. The impetus for these changes was a study reform initiated by the department management, which reduced the weight of project work in each semester from 15 to 10 ECTS credits. The article provides an account of the study board's deliberations and analyzes student evaluations of the redesigned courses. Finally, in light of the current pressures on student-driven project work, the article discusses the potential for reinforcing the PBL model through course-level innovations.

Keywords: University pedagogy; Curriculum reform; Content courses; Problem-based learning; Political science education.

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Introduction

How can study boards and university teachers strengthen the foundations of problem-based learning (PBL) in the face of financial constraints and increasing pressure to scale down student-driven project work? This article explores that question through the lens of pedagogical changes implemented in two content courses within Aalborg University's master's program in political science.

The university's political science programs – both bachelor's and master's – have undergone several reforms. This was also the case in 2022 when the department management sought to pave way for the approval of a formal title change – from *Politics and Administration* (*Politik og Administration*) to *Political Science* (*Statskundskab*). The latter was considered a stronger and more widely recognized brand. As such, the title change was expected to result in more and better-qualified applicants, thereby benefiting both the programs and the department's financial situation[1].

However, to obtain the new title, the Aalborg programs had to align more closely with the political science programs offered at the universities of Copenhagen, Aarhus, and Southern Denmark. In a joint consultation response to the Ministry of Higher Education and Science, the three universities stated that:

> The three existing Political Science programs use a classical, university-based pedagogical and didactic approach (…) whereas Politics and Administration at AAU is based on a more focused, project-oriented structure (...) A change in title and name should therefore also entail a shift in the educational approach (SDU et al., 2022, own translation).

Accordingly, the management required that the study board substantially revise the curriculum and reduce the extent of project work. For the master's program, the head of department specifically demanded that the first and second semesters follow a 10-10-10 ECTS structure instead of the previous 5-10-15 distribution.

The study board welcomed the ambition to obtain a new program title, but its members were critical of the proposed ECTS redistribution. They feared that significant reductions to the project module would seriously undermine the conditions for PBL. In the new program, students would be able to spend only five weeks per semester on project work, compared to eight weeks in the old.

[1] From 2019 to 2022, enrollment in the bachelor's program steadily declined from 104 to 56 students. During the same period, the master's program maintained a more stable intake of approximately 50 students per year.

	Old program	New program
1st semester	Methods course (5)	Methods course (10)
	Content course (10)	Content course (10)
	Project work (15)	Project work (10)
2nd semester	Employability course (5)	Topical seminar (10)
	Content course (10)	Content course (10)
	Project work (15)	Project work (10)
3rd semester	Electives or internship (30)	Electives or internship (30)
4th semester	Master thesis (30)	Master thesis (30)

Table 1. Modules and ECTS distribution, old and new master's program.

Yet sometimes necessity is the mother of innovation. Unable to prevent the implementation of the new ECTS distribution, the study board members engaged in a deliberative process on how to 'take back PBL' by transforming the program's content courses. This led to substantial changes in both the syllabus and the pedagogical approach. The new program, including the revised courses, was implemented and came into effect in the autumn of 2022, although the title change wasn't approved until 2025.

The article proceeds as follows. The next section reviews how the two content courses and their exams were changed to accommodate PBL. This author served on the study board during the revision process, taught in one of the courses, and was the coordinator of the master's program from 2020 to 2024. Personal notes and meeting materials were used to reconstruct the process. The third section outlines key points from the students' qualitative evaluations of the two courses, based on the minutes from the eight assessment committee meetings held between the autumn of 2022 and the spring of 2024. The article then discusses whether course redesign can adequately compensate for the decline in student-driven project work and thus sustain the core principles of PBL. The final section provides a conclusion.

Transforming content courses in accordance with PBL

While project work is at the heart of Aalborg University's PBL model, content and methods courses are important too. The PBL statute of the university states that "courses support the project work [by introducing] a wide range of theories and methods which [the students] can use in their project work" (Aalborg University, 2015). Regarding didactics, courses typically follow a more classical approach. They are organized by the teachers, include a series of two-hour lectures, and are finalized with an individual written or oral exam (Aalborg University, 2024).

In broad terms, this was also the arrangement of the two 10 ECTS content courses in the Politics and Administration master's program (*public policymaking* and *multi-level governance*). The question was whether they could be made more PBL-like. The deliberation centered around three of the PBL principles, including 1) problem orientation, 2) group work, and 3) exemplarity.

Problem-orientation

The first idea was to make the courses more problem-oriented, including a new focus on problem-solving. Problem-solving has always been an integral part of Aalborg University's PBL approach in its engineering programs (Kjærsdam & Enemark, 1994; Kolmos 1996), but less so in the social sciences and humanities (SSH) programs.

In the SSH programs, problem-orientation has largely followed a hermeneutic methodology (Højbjerg, 2014), meaning that students first learn to identify a scientific problem and then to design an investigation aimed at understanding the nature and root causes of that problem (Adolphsen, 1997). From this backward-looking perspective, many SSH student projects are guided by a "why" question in their problem formulation, often addressing an anomaly or paradoxical situation (Holgaard et al., 2021, p. 39). The courses underpin this approach by introducing theories and methods that help students understand problems in retrospect.

However, a forward-looking problem-solving approach *is* feasible, also in SSH. Problem-solving essentially means developing a concrete solution to a known complex problem for which no method or solution is immediately obvious (Knöpfel et al., 2024). If a practical test of the solution is not possible, students could instead formulate a set of recommendations (Holgaard et al., 2021, p. 40). In the public policymaking course, problem-solving was embedded by teaching the students how to formulate and assess policies – a craft also known as *policy analysis* (Hjelholt & Tranekær, 2019). The course still included an overview of various theories, but this was integrated with a forward-looking perspective through a series of seminars, each focusing on a specific policy area. All the seminars concluded with an exercise in which students were tasked with developing a solution to a perceived political problem. For example: *How can the government accelerate the deployment of onshore wind turbines without facing increasing not-in-my-backyard (NIMBY) protests?*

A similar structure was planned for the multi-level governance course. Here, the forward-looking perspective focused specifically on teaching students the skill of writing ministerial memos addressing urgent matters in European Union politics.

Group work

The second idea was to introduce group work and transform the individual exams into group-based ones. In this way, group exams would account for two-thirds of each semester's 30 ECTS points (including the semester project and the content course). Moreover, the period during which students would be engaged in collective, group-based activity would be considerably extended, covering most of the semester. A group size of 4 or 5 people was considered ideal.

Collaboration in student-driven project groups has been a central component of Aalborg University's PBL approach since the mid-1970s (Hultengren, 1979). At that time, it was believed to add a dimension of emancipatory learning to the technical (theoretical) and practical (empirical) aspects of a university education. However, student groups are not necessarily confined to project work; they can serve as a didactic element in courses too. At universities such as Maastricht in the Netherlands and McMaster in Canada, study groups are used to facilitate learning across all blocks of the curriculum (De Graaff & Kolmos, 2003).

As discussed by Feilberg (2022; 2024), the group process holds many potentials, but also possible pitfalls. By engaging in group work, students learn how to cooperate, share knowledge, and provide feedback. They become aware of the psychological and relational conditions that influence collaborative failure and success. In this regard, organizing the lion's share of the semester – and not just the final five weeks – around group work was seen as a major advantage by the study board members, and not merely as a pushback against the department management's decisions.

Consequently, the group formation day had to be scheduled relatively early. Groups had to be formed in time to be operational for the content courses' exercises – that is, well ahead of the project work. One possible downside of this was that students might form groups without yet having a clear idea of what they wanted to write about in their projects. On the other hand, early group formation could compel them to think ahead, thereby cognitively establishing clearer links between the themes of the content course and potential project ideas. Generally, the study board members expected that the group work in the courses would have positive spillover effects on the semester projects.

Exemplarity

The last PBL element the study board members sought to bring into play in the content courses was exemplarity. According to Aalborg university's PBL statute:

> Exemplarity implies that learning outcomes achieved during concrete project work are transferable to similar situations encountered by students in their professional careers (…) The exemplarity of the project ensures that (…) the students will acquire knowledge and competences which are applicable in a wider context than that of the project itself (Aalborg University, 2015).

In contrast to problem-orientation and group work, exemplarity is a newer element. It entered the university's formal discourse in 2015 and can be interpreted as a response to the employability agenda raised by the government vis-à-vis the higher education sector in the early 2010s (Klindt et al., 2021; Telléus, 2024).

The study board members reached the conclusion that exemplarity could just as well characterize the content courses. It would require that the theoretical content coming from textbook material and academic articles was contextualized by relevant empirical cases conveyed by an "external partner" (as suggested by Andersson & Clausen, 2022). Based on this, it was decided to make more use of guest lecturers.

Finally, the board members discussed the use of role-play exercises. Role-play exercises give students the opportunity to take on the role of an agent in a concrete organization or a given situation that mimics a complex real-world scenario. They can be performed individually, in groups, or involve the entire class. Higher education research suggests that role-plays encourage active student participation, stimulate collaborative learning (Bonwell & Eison, 1991), and significantly improve the outcomes of low-performing students (Barrera et al., 2021).

When designed appropriately, role-plays align well with the principles of problem-orientation, group work, and exemplarity too. Consequently, it was agreed that the written group-based exams would partly be organized as role-plays.

	Old program	**New program**
Syllabus	18-20 traditional lectures	5 seminars including lectures, guest lectures, excursions, and group exercises
Readings	Textbook chapters and journal articles	Textbook chapters, journal articles, and case material
Exam form	Individual written 48-hour exam	Group-based written 48-hour exam
Learning approach	Classical	Problem-based

Table 2. Content course pedagogy.

Student evaluations of the redesigned courses

Aalborg University's political science programs are evaluated primarily through qualitative feedback. Assessment meetings are held twice every semester. The first meeting evaluates the semester introduction, group formation day, and course instructions. The second meeting provides feedback on group work, supervision, and exams.

Public policymaking course

For the students who started the master's program in the autumn of 2022, as well as for the teachers, it was a new experience to complete a content course designed to emulate PBL. Nevertheless, most comments regarding the syllabus and the learning approach were positive.

In particular, the involvement of guest lecturers several times during the course was highly valued. For the students, this helped clarify how their academic competences could be applied in a professional context. The students also confirmed that working in groups during the course exercises was a positive experience (Minutes of the 1st meeting in the assessment committee, Politics & Administration, master's program, autumn of 2022).

The 2023 class was somewhat more critical. While they also appreciated the problem-oriented seminars and guest lectures, they noted that the group formation process had taken place very early, offering little foundation for discussing problem formulations to be used in their projects (Minutes of the 1st meeting in the assessment committee, Politics & Administration, master's program, autumn of 2023). That is, the decision to use identical groups for course assignments and project work was not unproblematic.

The 2023 class was also more critical of the exam format. Although the exam remained a group-based assignment, as in the previous year, it now had to be conducted in a way that allowed examiners to make individual assessments – a requirement emphasized by the university's legal department. As a result, students were required to specify which parts of the submission each group member had contributed to.

Several groups reported that this was complicated. One student on the assessment committee described the experience as "unpleasant." Another noted that the deeper purpose of a group-based exam is undermined when group members are forced to compartmentalize the assignment into individual areas of responsibility (Minutes of the 2nd meeting in the assessment committee, Politics & Administration, master's program, autumn of 2023). An idea that emerged from the assessment meeting was to revise the group assignment format to include a predefined collective part followed by individual parts for each group member.

Multi-level governance course

The spring semester generally followed the same structure as used in the autumn. However, in the multi-level governance course, role-play exercises were used more systematically than in the public policymaking course. The groups acted as units within the Ministry of Foreign Affairs. In weekly assignments, they were tasked with briefing the minister on a specific issue or case and writing a short memo.

The students were very pleased with these exercises and responded positively to the process of gradually learning the skill of memo writing: "It's been a very instructive course where one gets closer to a professional competence one can actually use in a job situation" (Minutes of the 2nd meeting in the assessment committee, Politics & Administration, master's program, spring of 2024).

Another difference was that in the spring semester, the groups for the role-play exercises, including the course exam, were formed administratively. The teachers emphasized that not being able to choose one's group partners was a central feature of the role-play. They also wanted to ensure a fair distribution of workload, which meant that group sizes needed to be relatively consistent. The students appeared to accept these arguments as fair (Minutes of the 1st meeting in the assessment committee, Politics & Administration, master's program, spring of 2023).

Once the multi-level governance course was completed, the students were given the opportunity to form new groups for the project work. Some chose to remain in their existing groups, while others broke up and formed new ones. In the spring of 2023, this process went smoothly. In 2024, the process was only partly successful, and a few students ended up in one-person groups.

Discussion: can course innovations preserve the PBL model?

Aalborg University has been a pioneer in PBL since the mid-1970s. Its learning model, which combines teacher-driven courses with student-driven project work, is internationally renowned and spans across scientific realms (Kolmos et al., 2004). The university hosts a UNESCO Center for PBL[2] and has recently

[2] See https://www.ucpbl.net/

established an Institute for Advanced Studies in PBL[3] that disseminates knowledge to a global audience.

However, there are troubles in paradise. In SSH, PBL is increasingly under pressure. Financial constraints are one issue. For more than a decade, national higher education policy has prioritized STEM fields at the expense of SSH. To make ends meet, deans and department heads have reduced the number of teaching hours allocated to supervision (Gregersen, 2024).

Another challenge is ideological. Some individuals within academia continue to view student-driven project work as inferior to more classical university pedagogy. When advocates of conventional models gain influence – often idealizing the programs and teaching methods of traditional elite institutions – faculty and study boards committed to comprehensive project work may find themselves facing growing resistance (Jensen, 2024).

Can revising courses be a way to sustain or reinforce PBL? As outlined in this article, the study board for the Politics and Administration program sought to do just that after 2021, when management imposed a streamlining of the curriculum. Two content courses were redesigned to incorporate problem-orientation, group work, and exemplarity. Most of these changes were feasible and well-received by students, although the written group exam format proved problematic.

The experiences offer some important insights for teachers in SSH programs at Aalborg and other PBL universities. While student-driven projects often take a backward-looking perspective, analyzing problems in retrospect, content courses can be used to introduce a forward-looking, problem-solving approach (Holgaard et al., 2021). Guest lecturers and role-play exercises proved to be effective facilitators of these learning elements, as also suggested by Andersson & Clausen (2022) and Bonwell & Eison (1991). Moreover, when group work is a central feature across two modules during a semester – not just in the project module – the group process extends over time, allowing for more sustained development of collaborative competencies (Feilberg, 2022).

Still, from a PBL perspective, the 10-10-10 ECTS distribution remains problematic. Five weeks is simply not enough time to complete a meaningful student-driven semester project. Ideally, project work involves identifying a scientific problem, constructing a theoretical framework, considering methodological approaches, collecting data, conducting analysis, and writing the final report. However, with the compressed timeline, several of these steps

[3] See https://www.iaspbl.aau.dk/

are either shortened or skipped altogether. As a result, many student groups end up writing theory-oriented projects without collecting their own data.

Projects that do generate new empirical material often rely on familiar single-case designs and a few qualitative interviews. In the new program, it has become rare to see projects employing the more advanced designs taught in the methods course. Consequently, the connection between the methods course and project work has weakened. Students no longer clearly see how the methods they are taught can realistically be applied in their projects (a point also raised in one of the assessment meetings; Minutes of the 1st meeting in the assessment committee, Politics & Administration, master's program, spring of 2023).

Another issue with the shortened project period is that students become overly focused on staying within safe boundaries and avoiding mistakes. With only five weeks for project work, many feel that their problem formulation and methodological decisions must be perfect from the outset. As a result, the new program misses out on a valuable form of experiential learning – learning that comes from trial and error.

Conclusion

This article has explored how courses in Aalborg University's master's program in Politics and Administration were redesigned to uphold the principles of PBL. Faced with the challenge of a shortened project module, the study board sought to infuse PBL elements – problem orientation, group work, and exemplarity – into the program's content courses, thereby redistributing some of the learning objectives typically achieved through longer project work. Student evaluations suggest that the transformed courses succeeded in enhancing employability, practical relevance, and collaborative learning, although exam formats posed certain difficulties.

However, the new 10-10-10 ECTS distribution remains problematic. The shortened timeline for project work limits students' ability to engage deeply with methodological tools and reduces opportunities for experiential learning. While the content course innovations represent a valuable response, the findings ultimately underscore that robust project work is indispensable for maintaining the full educational value of PBL.

As such, these adjustments should not be seen as equivalent replacements for comprehensive project work. Rather, they are pragmatic responses to shifting managerial priorities. For Aalborg University – and other institutions committed to PBL – the broader challenge remains: how to safeguard a pedagogical model that depends on time, resources, and institutional support in an increasingly efficiency-driven higher education landscape.

If PBL is to remain a defining feature of SSH education at Aalborg University and beyond, it will require continued advocacy from study boards, faculty, learning experts, and students alike – as well as a willingness to adapt without losing sight of the model's core components.

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A Systems Thinking Approach to Student-supervisor Interactions and their Effect on Psychological Safety

A Case for Student Learning Labs

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Abstract

The increasing trend of anxiety among students is closely linked to psychological safety, which refers to an environment where individuals feel comfortable expressing their thoughts without fear of negative consequences. Conversely, environments lacking psychological safety can heighten anxiety. This report examines the impact of transitioning from group work to solo projects on master-level students at Aalborg University. The shift to solo projects, with only a supervisor for support, may affect students' psychological safety.

This study investigates the psychological safety of students during this transition, identifying factors that influence their sense of security and confidence when working independently. By understanding these factors, the study aims to provide insight for educators to better support students in solo

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projects and mitigate the entrenchment of group-work learning styles while retaining the benefits. Strategies to enhance psychological safety, such as forming learning labs, are explored to break the feedback loop leading to poor solo work experiences and reinforce positive learning outcomes.

Keywords: Psychological safety; student learning labs; solo projects; causal loop diagrams; feedback loop theory

Introduction

Anxiety has become one of the major concerns in tertiary education, not only because of student welfare, but as it has implications for lower academic achievement (Tan et al., 2023). The current trend of anxiety in students is increasing and globally, around one in three students (34.8%) suffer from anxiety according to a meta-analysis by Chi et al. (2023).

Psychological safety and anxiety are closely related. Psychological safety refers to an environment where individuals feel comfortable expressing their thoughts, ideas, and concerns without fear of negative consequences. It is characterised by mutual respect and trust, allowing group members to take risks, ask questions, and admit mistakes without the fear of being judged or punished (Han et al., 2022). This fosters open communication, creativity, and collaboration, leading to higher levels of engagement and innovation (Clausen et al., 2025).

Psychological safety is typically divided into four levels: included, learning, contributing, and challenging (Clark, 2020). Reaching the latter levels of psychological safety is essential for students engaging with supervisors as it enables individuals to contribute fully and authentically, asking questions, sense-checking, and admitting mistakes without fear of negative consequences (ibid.). These characteristics are particularly important in project-based pedagogical environments, as students need to feel secure enough to explore new ideas and approaches (Gonda et al., 2024).

Conversely, in environments lacking psychological safety, individuals may experience heightened anxiety. They might fear making mistakes, asking questions, or sharing ideas, leading to increased stress and a reluctance to engage fully (Harris et al., 2024). This can create a cycle where anxiety inhibits open communication, further eroding psychological safety (ibid.).

Psychological safety may be affected when students shift from familiar group work to unfamiliar solo projects (Edmondson, 1999). This can pose a problem for educators and organisations primarily working with group project-based assessment, such as Aalborg University, when students are expected to pivot to solo projects with only a supervisor to provide project feedback. This paper investigates the psychological safety of students during this transition, exploring the factors that influence their sense of security and confidence when working independently. By identifying these factors, the study aims to provide insights for educators to better support students both in solo projects, and to mitigate potential entrenching of learning styles associated with group-work. Through this process, we hope to develop strategies to enhance psychological safety to the third and fourth levels (contributing and challenging), thereby facilitating stronger student confidence and learning efficacy.

Methods

Educational intervention method

The data were collected from supervision meetings with Master students working on solo projects. During and after supervision meetings with the students, comments on supervision style were recorded using a reflective feedback approach. Reflective feedback is a method by which individuals reflect on and critically assess their performance from the feedback they receive (O'Connor & McCurtin, 2021; Yaman, 2020). By engaging in reflective feedback, supervisors can identify strengths and areas for development, ultimately enhancing their effectiveness and achieving their goals more efficiently (Cornu & Peters, 2005).

Feedback is one of the most important characteristics in the Aalborg PBL model (Clausen, 2024; Jiang et al., 2023). The method is aimed at understanding how these students working on solo projects are adapting to the pressure of working alone and engaging differently with their supervisor. Moreover, the feedback allows adaption of the supervision to their needs, hopefully improving the support of them.

Data collection and analysis

The students were asked to give feedback at the start and end of each supervision meeting about the supervision methods and how the supervisor could improve support for them and future students. Data were recorded from 17 meetings from October to December.

At the beginning of each meeting, students were asked to share conversational style feedback on the past week/days of their work. These reflections were recorded and, key words were noted, with tick marks or crosses to indicate the degree of emphasis being conveyed.

At the end of the meeting, the supervisor asked the student to give constructive feedback on the meeting, how helpful it was for them, if all their questions were well-understood and well-answered, and what improvements could be made. Space was also given for their answers to wander into other feedback topics.

A thematic analysis inspired by Madison (2011) was conducted based on the written notes applying the following approach. 1) The data were collected in a table for each student. Notes from each meeting were typed into these slots, including language indicative of positive and negative tones. 2) The results from the meetings were then organised by month and aggregated for student anonymity. 3) Within each month, salient themes were identified in order to analyse the progression in the student-supervisor relationship throughout the supervision period. 4) Themes were continuously discussed with my two pedagogical supervisors to counteract bias.

Results

October meetings

Feedback began in October. Two themes were immediately visible. On one hand, students gave positive feedback on supervisor engagement, consistency and speed of responses. It was noted that the students had previously experienced that some supervisors are not interested in students' work and sometimes give contradictory feedback. On the other hand, students gave the constructive feedback that more direct encouragement, especially early in project ideation would help, and the absence of this created feelings of disheartenment and confusion.

A distinct topic emerged across students with regard to working solo rather than in groups. Students noted they were used to working in groups with friends and using them for bouncing ideas off. Without this option during the internship, students noted they used their supervisors in a similar way and that this change of roles created a feeling of insecurity due to the sheer number of questions that were being presented during supervision meetings.

November meetings

Feedback during November meetings was also lumped into two themes. In some cases, this period marked the crossing of a threshold in the relationship between the supervisor and the students. For example, some discussions included explicit statements of appreciation. Again, the theme of supervisor engagement was highlighted in the feedback, this time associated with the positivity of comments on the project work. This helped create belief about being on the right track, which was a topic for students who felt isolation during their solo project work.

Another theme included doubtfulness about some of the supervision suggestions. For example, it was noted that some supervisor comments on project work were unique among supervisors, and that this took students by surprise, again leading to confusion.

December meetings

The final meetings were held in December. At this point, student projects were in good shape, and the feedback was reflected the positivity of the students as well as the trust built over the duration of the semester. Feedback themes included gratitude for pushing students outside their comfort zones. This was also linked to concessions about the difficulty in accepting challenging comments on students' work.

Students suggested that in the future, supervisory comments on student projects could be structured into the following three points: one thing that is going well with the work; one thing that is not going well and should be improved; and one thing to think about changing. The first point is useful to help students understand which part of the work could be developed into other parts of the report. The second point obviously helps students know what to avoid doing. The third point helps students see how a good idea could be more impactful.

Discussion

Reflections on student engagement

Over the observations, student-supervisor interactions were generally positive or constructive, and continued to develop well during the projects. This is demonstrated in the depth of feedback which increased over time. The feedback grew increasingly more honest but also critical at times, indicating the student-supervisor trust progressed from a learning level to a challenging level of psychological safety.

This finding is a good demonstration of what does work. On the other hand, it is difficult to know from this what would not have worked. Few difficult conversations were had, so it is difficult to know how things would have turned out under different circumstances. In general, student-supervisor engagement may also be a function of personalities and likely fostered higher levels of mutual trust and psychological safety.

Considering the literature on feedback, constructive feedback sessions can be crucial to rehabilitating student-supervisor relationships and recovering higher levels of psychological safety (A. C. Edmondson & Lei, 2014; Maximo et al., 2019).

Group work versus individual work

During the supervision meetings, a common point was mentioned multiple times in students' supervision meetings. That is, that the internship semester was more challenging because the students have become used to working in groups for project reports in the PBL environment. While initially group-based projects can be difficult for some students, when it becomes habitual, it creates a safety net for students who motivate each other and use their peers as sounding boards for sense-checking ideas. Ultimately, the mutual benefits of group work cultivate a dependency between students.

The students observed for this study struggled with self-confidence when making autonomous decisions for their projects. This was due to the shift from normally having the safety of a group in which to seek direct feedback. They alluded to using supervision meetings (rather than peer-to-peer student group meetings) as their bouncing board for ideas, and that this was different because it exposed them to feeling vulnerable and potentially revealing their weaknesses. On the other hand, students found this necessary because they were otherwise isolated. This shows the value of group work for consensus building, and refinement of ideas in a safe space of peers. It also seems to foster the spirit of constructivism in general, as a group of students must make concessions to reach a compromise, acknowledging that no single member of the group is necessarily objectively more correct than another. In the internship semester, this reflexivity is more difficult because the student and supervisor dynamic is academically hierarchical. Understandably, the student may feel (as the feedback discussions showed) that there is a more objective truth, and that the supervisor has access to that truth. In reality, the supervisor is also a construct and may in fact be much more institutionally constrained to think within a certain academic paradigm, than say a student who still retains some idealist normativity and a sensitivity for the factors that influence them.

The studied effect on self-confidence and vulnerability sheds light on the psychological safety of students in different supervisory and group-work contexts. It then becomes relevant to consider, what are the different types of support, different students need along the stages of their educational development to feel psychologically safe? From the experiences and observations during this study, psychological safety is high at the beginning of the semester and can deteriorate as stress and deadlines mount as the semester bares down on the students. Not only that, but as there are aspects, as discussed above, of differing expectations on learning development before the internship semester that build a reliance on group work. This expectation changes when the students are taken out of that comfort zone and expected to work on a report alone.

Unlike the beneficial reinforcing feedback loops between group work and psychological safety, solo work risks a loss of psychological safety as students experience isolation with their untested ideas, which they now have to present to their supervisor for sense-checking in lieu of group peers. Through the prioritisation of group work, experience of solo work is undeveloped leading to less feeling of safety in solo work, resulting in a reinforcing lock-in. This is illustrated in Figure 1.

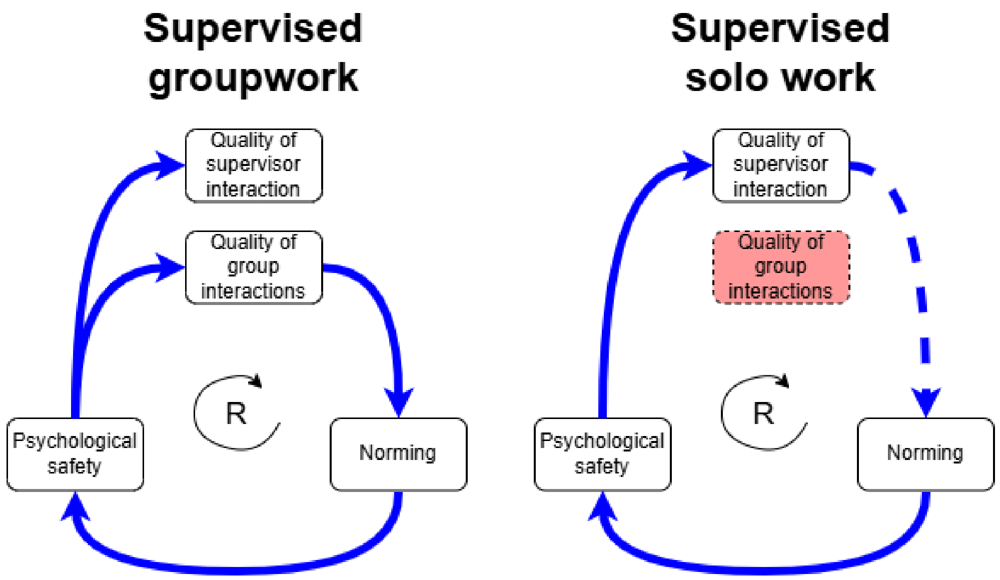

Figure 1. Casual Loop Diagrams showing two archetypes: working in a supervised group (left) and working on a supervised solo project. Red shading indicates the loss of group interactions that drive group norming, which is instead driven by interactions with the supervisor. R stands for Reinforcing loop leading to lock-in.

In the left loop, Figure 1 shows a supervised groupwork archetype. The student who experiences high quality group interactions, and subsequently experiences higher group formation (indicated by norming in the figure), further elevates their psychological safety. The right loop shows a supervised solo work archetype. The student who experienced high quality group interactions is now working without a group and must substitute their group interactions with supervisor interactions (dashed causal influence). These two archetypes may also work to reinforce negative experiences. For example, low quality group interactions can lead to low group cohesion and erode psychological safety. This is especially relevant if in the case of solo work, the quality of interactions from the supervisor is insufficient, this can lead to decreasing psychological safety, and a negative lock-in may arise.

Figure 1 illustrates the theory put forward by this study, that a preference for either format can become entrenched through a reinforcing feedback loop, resulting in a lock-in to one or the other. This finding is described in systems thinking literature as a lock-in, or an eroding goal (Meadows & Wright, 2008).

Learning can be seen as a complex dynamic system due to the multiple elements and reinforcing feedbacks between them that relate to learning, such as institutional conditions and cultural values (Du et al., 2025). From this systems thinking perspective, it follows that improving the institutional conditions, i.e. the learning environment, and tailoring them to suit the variety of cultural values, can improve psychological safety and consequently also learning outcomes (Guerra et al., 2023). While PBL focuses on achieving highly beneficial group dynamics (e.g. Jiang et al., 2023), there is an underinvestment in solo work. This leads to some students (even high-achieving students) struggling to sense-check their ideas due to their learned reliance on group members for that role. One possible solution is to offer solo-working students the possibility to form proxy groups within which they can avoid isolation and foster aspects of group work such as sharing ideas while filtering the outcomes into their solo projects.

A case for student learning labs

Student learning labs offer a collaborative educational environment where students work together on their individual projects. Examples of student learning labs include monthly or bi-weekly sessions where several solo-students meet with each other and their supervisors. All students present progressions and challenges in their respective projects followed by rounds of discussions with all involved. Meetings can be focused on specific common topics such as data collection, literature review etc. Student learning labs can have different compositions which may follow the definition by Sanchez et al. (2022), providing solo students with a community (of students) who work on shared activities (their projects) in a shared space.

In the case of solo students, this environment can foster the type of psychological safety they otherwise experience in group work environments, because the lab participants substitute the role of the group as a sounding board for ideas while allowing them to progress their individual work. Among other benefits such as improved learning outcomes (Admiraal et al., 2024), improved PBL competences for inexperienced students (Nordahl & Kofoed, 2007) and increased innovation (Sanchez et al., 2022), it minimises the feeling of isolation (Asgari et al., 2024). As illustrated in Figure 2, student learning labs thus have potential to break the feedback loop that leads to a negative lock-in of poor experiences by reversing the polarity of the causal link between experience of solo work (when experiences are few) and psychological safety in solo work (due to the work being supported by peers in a lab).

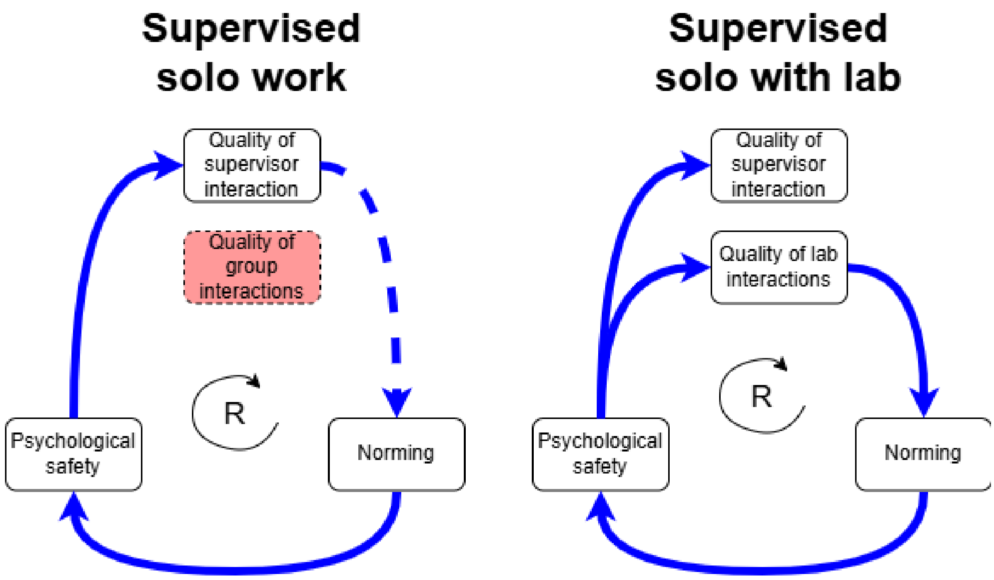

Figure 2. Casual Loop Diagrams showing supervised solo work (left, as in Figure 1) and solo work supported by a supervised student learning lab (right, as a solution to Figure 1). Red shading indicates the absence of group interactions that drive group norming, which on the right is instead driven by interactions within the student learning lab acting as a proxy group. R stands for reinforcing feedback loop leading to lock-in.

Limitations and future work opportunities

This study was limited due to the data and potential biases. During the supervision meetings when the data were being gathered, the subjective interpretations and lack of impartial coding of verbal information was difficult to manage while retaining a supervisory role. At one time, trying to elicit genuine feedback from the students that avoids pandering while interpreting and note taking proved difficult. Biases were handled by continuous discussions with colleagues (pedagogical supervisors). Limitations were exacerbated by the limited sample size, which was constrained due to the semester schedule. Ideally, a larger number of students could be included in the sample, and from different year cohorts to shed light on how the psychological safety of students may change over time with their experiences in group work settings, allowing for more general conclusions to be drawn. More work could be done to explore this, for example at Aalborg University in the University Pedagogy programme, which exposes educators to PBL methods and encourages them to experiment with such approaches.

Conclusions

The increasing importance of anxiety among students is closely linked to psychological safety, which refers to an environment where individuals feel comfortable expressing their thoughts without fear of negative consequences. This study investigates the psychological safety of students during the transition from group projects to solo projects, identifying student-supervisor interactions that influence their sense of security and confidence when working independently. By understanding these factors, the study aims to provide insights for educators to better support students in solo projects and mitigate the entrenchment of group-work learning styles while retaining the benefits. Learning labs are discussed as a possible solution to break the feedback loop leading to poor solo work experiences and reinforce positive learning outcomes.

We found that students enjoy feedback sessions. It empowers them to help create a learning environment tailored to them. Students showed keen interest in the feedback sessions and were willing to share positive and constructive feedback about supervision styles. This contributed to comforting some of their anxieties about working solo and creating a psychologically safer environment.

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Building Critical Thinking and Self-Confidence in Speaking Class for Non-Native English Speakers

Obstacles and Perspectives

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Abstract

Developing critical thinking and self-confidence in speaking classes is essential for non-native English speakers learning English as a foreign language. This study explores the challenges and effectiveness of Problem-Based Learning (PBL) in speaking classes at Gajah Tunggal Polytechnic through qualitative analysis of student and lecturer perspectives. Findings reveal that language barriers, passive learning habits, and fear of mistakes hinder active participation. However, PBL enhances speaking proficiency, independent learning, and collaborative problem-solving skills. Despite its benefits, challenges such as limited resources and insufficient educator training impede implementation. This study emphasizes the need for institutional support, pedagogical adjustments, and targeted interventions to optimize PBL for non-Native English Speakers. The insights gained provide guidance for educators

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and policymakers seeking to improve English language instruction in similar contexts.

Keywords: Critical thinking; self-confidence; Problem-Based Learning (PBL); Non-Native English Speakers; speaking skills; English as a foreign language (EFL)

Introduction

Critical thinking and self-confidence are essential components for effective communication, particularly among non-Native English Speakers (NNES) striving to develop their speaking skills. In higher education, nurturing these abilities is crucial to help students articulate ideas clearly, participate in meaningful discussions, and adapt to diverse linguistic and cultural contexts (Ennis, 2011; Moghadam, Narafshan, & Tajadini, 2023). However, NNES students often face persistent challenges in speaking classes, such as language anxiety, limited opportunities for real-world practice, and a lack of confidence in expressing themselves (Horwitz et al., 1986; Liu & Jackson, 2008).

One promising pedagogical approach to addressing these challenges is Problem-Based Learning (PBL). PBL emphasizes student-centered instruction, requiring learners to actively engage in solving real-life problems, collaborating with peers, and reflecting critically on their learning process (Hmelo-Silver, 2004; Darmawati & Mustadi, 2023). By offering authentic speaking opportunities, PBL not only enhances linguistic proficiency but also fosters critical thinking and boosts students' confidence in using English (Guo et al., 2024; Torp & Sage, 2002).

The importance of critical thinking in language learning is well-established in several theoretical frameworks. Bloom’s Taxonomy categorizes cognitive skills from basic knowledge recall to higher-order thinking such as analysis, evaluation, and creation, thus highlighting the integral role of critical thinking in effective communication (Anderson & Krathwohl, 2001; Marzano, 2001). In parallel, Vygotsky’s Sociocultural Theory emphasizes the importance of social interaction and scaffolding in language development, suggesting that confidence and cognitive skills emerge through guided collaboration and meaningful communication (Vygotsky, 1978; Moghadam, Narafshan, & Tajadini, 2023). These frameworks are central to this study as they align with the goals of developing both cognitive and communicative competencies through PBL.

Despite the recognized advantages of integrating PBL into speaking classes, practical implementation remains challenging. NNES students often struggle with a lack of motivation, limited English exposure outside of the classroom, and the fear of negative evaluation by peers and instructors (Liu & Jackson, 2008; Krashen, 1982). Additionally, educators face difficulties designing PBL activities that not only engage students but also ensure substantial language development and critical thinking (Torp & Sage, 2002; Brown, 2007).

Research gap and significance

Although previous studies have demonstrated the potential of PBL to enhance language skills and cognitive development, there remains a significant research gap concerning its specific impact on NNES students' speaking classes in technical education settings, such as polytechnics. Furthermore, limited studies have critically examined the dual role of PBL in fostering both critical thinking and self-confidence simultaneously. By addressing this gap, this study provides insights into how PBL can be effectively adapted to meet the needs of engineering students who require strong communication skills for their future careers.

The significance of this research lies in its potential contributions to both theory and practice. Theoretically, it strengthens the understanding of how socio-cognitive frameworks like Bloom's Taxonomy and Vygotsky's Sociocultural Theory operate in PBL-based language classrooms. Practically, the findings can guide educators in designing more effective PBL speaking activities and inform policy makers in higher education about innovative teaching approaches that better prepare students for global communication demands. Ultimately, enhancing critical thinking and self-confidence among NNES students can lead to more competent and self-assured graduates who are ready to contribute meaningfully to society.

Research Questions

This study seeks to answer the following research questions:

1. What are the main obstacles faced by non-Native English Speakers in developing critical thinking and self-confidence in speaking classes?
2. How does the implementation of Problem-Based Learning (PBL) influence students' speaking performance and confidence?
3. What perspectives do students and educators have regarding the effectiveness of PBL in fostering critical thinking and self-confidence?

Methodology

This study adopts a mixed-methods research design to examine the impact of Problem-Based Learning (PBL) on students' critical thinking skills and self-confidence in speaking classes. Specifically, a convergent parallel design is employed, combining quantitative and qualitative approaches to offer a more comprehensive understanding of how PBL influences students' learning experiences (Cottrell, 2017; Jonassen, 2011). By using this design, the study strengthens its credibility through triangulation, enabling the cross-validation of findings from multiple data sources.

The mixed-methods framework was chosen because it captures both measurable improvements in student competencies and rich, nuanced insights into their learning processes—elements that are essential when evaluating complex educational interventions like PBL. Moreover, it responds to a research gap where most studies in technical education tend to emphasize either linguistic performance or content knowledge, often neglecting critical thinking and self-confidence development.

To assess critical thinking and self-confidence, the study used adapted versions of the Critical Thinking Disposition Scale and the Self-Confidence in Speaking Scale. These instruments were selected due to their proven validity in educational research and their specific relevance to the competencies targeted by the intervention (Ellis, 2003; Swain & Lapkin, 1995). Adaptations were made to better align the scales with the technical and communicative contexts of engineering education, ensuring greater relevance and applicability for participants.

Research Context and Participants

The research was conducted at Gajah Tunggal Polytechnic, a technical and vocational institution specializing in engineering education. Here, students are required to wear uniforms, reflecting the institution's strong emphasis on discipline and professional preparation. English Communication is a compulsory course designed to equip future engineers with essential language skills for the workplace.

Participants were non-native English-speaking students enrolled in speaking classes across three departments: Mechanical Engineering, Industrial Engineering, and Electrical Engineering. The target population consisted of students with varying levels of English proficiency, ensuring representation of diverse skill levels and learning experiences.

A total of 80 students were selected through purposive sampling, considering criteria such as language proficiency, prior educational experiences, and exposure to PBL methodologies (De Graaff & Housen, 2009; Chappell, 2014). Each class consisted of approximately 26–27 students. This sampling method was employed to enhance the applicability of the results to similar educational contexts, ensuring that the findings reflect realistic classroom diversity.

Intervention Design

The PBL intervention was implemented over a 10-week period, integrated into regular speaking class sessions. Each instructional cycle followed standard PBL procedures. Students were presented with real-world communication problems related to engineering fields, which they had to solve collaboratively using English. Students worked in small groups (4–5 students per group) to complete tasks such as:

1. Designing and delivering engineering presentations,
2. Proposing solutions to technical problems,
3. Simulating professional conversations and meetings.

Instructional materials included authentic resources such as technical manuals and engineering case studies. Activities were supported by guided worksheets and structured peer discussions. Throughout the intervention, instructors served as facilitators rather than traditional lecturers, promoting student-centered learning environments.

Data Collection

To examine the impact of Problem-Based Learning (PBL) on students' critical thinking and self-confidence in speaking, this study adopts a mixed-methods approach, collecting both quantitative and qualitative data through a range of instruments.

For the quantitative component, data were collected through a structured questionnaire administered before and after the PBL intervention. Two validated scales were utilized: the Critical Thinking Disposition Scale (CTDS) (Sosu, 2013), which assesses students' ability to critically analyze, evaluate, and synthesize information, and the Self-Confidence in Speaking Scale (SCSS) (adapted from Ozturk & Gurbuz, 2014), which measures perceived confidence in oral communication tasks. These instruments provided reliable and objective measurements of students’ cognitive and affective development, allowing for meaningful statistical comparison and analysis.

For the qualitative component, semi-structured interviews and focus group discussions (FGDs) were conducted with both students and instructors. These sessions aimed to capture in-depth insights regarding the effectiveness of PBL, the challenges faced during implementation, and observed improvements in students' speaking proficiency and self-assurance. The interviews explored students' personal experiences engaging with PBL tasks, their critical reflection processes, and their emotional and intellectual growth. Instructors contributed perspectives on classroom dynamics, instructional strategies, and students' observable progress throughout the intervention. Together, these qualitative methods enriched the statistical findings by providing nuanced, narrative-driven evidence.

This study addresses a key research gap by offering empirical data on PBL's impact on non-native English-speaking engineering students, an area often overlooked in current literature (Hmelo-Silver, 2004; Hung, 2011). It thus contributes practical insights into the integration of PBL within technical higher education settings, where communication skills are increasingly vital for career readiness.

Data Analysis

To ensure a comprehensive interpretation of the collected data, both quantitative and qualitative analyses were carried out.

For the quantitative analysis, descriptive statistics were first computed to profile students' initial and final scores. Subsequently, a paired t-test was used to determine whether there were statistically significant improvements in students' critical thinking and speaking self-confidence following the PBL intervention. Furthermore, regression analysis was conducted to explore the relationship between PBL participation and improvements in learning outcomes, helping to identify specific factors that contributed to students' development. These statistical procedures provided robust evidence regarding the effectiveness of PBL in enhancing both cognitive and affective competencies.

For the qualitative analysis, data from interviews and FGDs were analyzed thematically following Braun and Clarke's (2021) six-phase framework. This approach involved familiarizing with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing a final interpretative report. Emerging themes included enhanced problem-solving skills, increased willingness to speak in public, initial resistance to active learning methods, and strategies that helped build student confidence over time. These qualitative findings were then cross-referenced with quantitative results, ensuring triangulation and enriching the validity of the study's conclusions.

By integrating both sets of data, the study offers a multidimensional understanding of how PBL influences language acquisition and critical thinking development. These findings have significant implications for curriculum designers, instructors, and policymakers who aim to create more dynamic and student-centered learning environments in higher education.

Importantly, the study highlights the potential for PBL to bridge the gap between technical knowledge and soft skills development — a need increasingly emphasized in global industry and academic standards (World Economic Forum, 2020). By contributing evidence from a non-Western, polytechnic context, this research also enhances theoretical models of PBL application across diverse educational settings.

Results

Obstacles in Developing Critical Thinking and Self-Confidence

The study revealed three primary obstacles that hinder students' development of critical thinking and self-confidence in PBL-based speaking classes. These challenges are interpreted through established theories, including communicative competence (Richards & Rodgers, 2014), motivational frameworks (Dörnyei, 2005), and active learning models (Deslauriers et al., 2020).

a. Language Barriers
Language proficiency emerged as a significant impediment to students' active participation, particularly regarding the use of technical vocabulary and complex sentence structures. This finding aligns with Richards and Rodgers' (2014) theory of communicative competence, which emphasizes the role of linguistic ability in effective communication.

Supporting Evidence:

1. Survey Results:
   a) 68% (n = 54/80) agreed or strongly agreed that limited vocabulary and unfamiliar expressions hindered participation.
   b) Among Mechanical Engineering students, this rate was slightly higher at 72%.

2. Student Testimonies:

a) MAS (Mechanical Engineering Student, Year 3) remarked, "Sometimes, I understand the concept in my native language, but I struggle to explain it in English, especially using the correct technical words."
b) TRP (Electrical Engineering Student, Year 3) added, "When the topic is about circuits or machinery, I get stuck finding the English words."

3. Lecturer Observations:
   a) Students at CEFR A2–B1 levels used basic expressions or remained silent more often during group discussions.
   b) In contrast, classes with B2 proficiency or higher saw a 35% increase in student interactions, based on engagement logs.

These findings mirror Li & Pei's (2024) results, emphasizing that linguistic competence directly influences self-confidence and engagement in English-medium instruction (EMI) contexts.

b. Passive Learning Culture

Transitioning from a passive learning background posed another major obstacle. Consistent with Kember's (2000) concept of passive learning cultures, students initially struggled to adapt to the active, discussion-driven PBL environment.

Supporting Evidence:

1. Survey Results:
   a) 55% (n = 44) found it significantly difficult to adjust to PBL during the first half of the semester.
   b) Industrial Engineering students, traditionally exposed to lecture-based instruction, reported a 10% higher adjustment difficulty than their Electrical Engineering peers.

2. Student Testimonies:
   a) ADF (Industrial Engineering Student, Year 3) reflected, "In my previous classes, we just listened and took notes. It feels strange now that I have to talk and ask questions."
   b) MA (Mechanical Engineering Student, Year 3) noted, "I was used to being silent and writing everything down. Speaking in front of others was very new to me."

3. Lecturer Feedback:
   a) Students with prior exposure to interactive methods adapted in 3–4 weeks, whereas others took 6–8 weeks.

b) Faster adapters engaged in 20% more group discussions based on classroom observations.

This supports Deslauriers et al.'s (2020) assertion that the shift to PBL initially provokes discomfort before fostering deeper engagement and critical thinking.

c. Lack of Confidence

Fear of negative evaluation, a central concept in foreign language anxiety theory (Horwitz et al., 1986), emerged as the third major obstacle. Many students hesitated to speak, particularly when complex ideas needed to be expressed, fearing judgment or errors.

Supporting Evidence:

1. Survey Results:
   a) 72% (n = 58) felt anxious about speaking due to fear of mistakes.
   b) Female students reported slightly higher anxiety (75%) compared to male students (69%).

2. Student Testimonies:
   a) GAP (Electrical Engineering Student, Year 3) stated, "I hesitate because I'm afraid of saying it incorrectly. I don't want others to laugh or think I don't know the topic."
   b) YI (Mechanical Engineering Student, Year 3) explained, "I understand the material, but when speaking, I worry my English sounds wrong."

3. Lecturer Observations:
   a) Speaking confidence increased by about 30% by the 8th week, based on participation logs.
   b) Low-stakes speaking practices helped reduce anxiety symptoms for 45% of students.

These findings highlight the crucial role of affective factors in language development, as emphasized by Dörnyei (2005), reinforcing the need for continuous, supportive speaking opportunities.

Implementation of PBL at Gajah Tunggal Polytechnic

At Gajah Tunggal Polytechnic, PBL was strategically implemented to simulate real-world professional scenarios, supporting both language acquisition and technical skill development. This approach reflects Situated Learning Theory (Lave & Wenger, 1991) and Vygotsky's (1978) Zone of Proximal Development (ZPD), emphasizing authentic, scaffolded learning experiences.

Institutional Context

Founded through a Corporate Social Responsibility (CSR) initiative by PT. Gajah Tunggal, the Polytechnic aims to produce globally competitive engineering graduates. English communication courses are mandatory for first- and second-year students, focusing on:

1. Participating in team meetings
2. Writing technical reports and professional emails
3. Delivering project presentations

PBL Activity	Description	Target Skills	Example Topic
Group Discussions	Collaborative exploration of problems	Critical thinking, articulation	"Improving production efficiency"
Case Studies	Analysis of real-world technical issues	Problem-solving, technical vocabulary	"Failure analysis in manufacturing"
Simulations	Role-playing technical meetings	Confidence, professional communication	"Presenting new machinery to a client"
Project Presentations	Public presentation of solutions	Public speaking, report writing	"Designing energy-efficient systems"

Table 1. PBL Activities and Framework.

Implementation Data:

1. All English courses (4 sections, n = 80 students) adopted PBL starting Week 3.
2. Each student completed two case studies, four group discussions, one simulation, and one final presentation over 16 weeks.
3. Activities focused 40% on speaking, 30% on writing, 20% on reading, and 10% on listening.

Observed Outcomes:

PBL led to measurable improvements:

1. Critical Thinking:
    a) 68% improved in problem identification, solution evaluation, and recommendation skills.

b) Mean critical thinking scores rose by 15% (from 62 to 71.3).

2. Problem-Solving Skills:
   a) 70% successfully integrated technical knowledge and English communication in case studies.
   b) 75% felt more confident proposing solutions after two major projects.

3. Self-Confidence:
   a) 30% average increase in perceived speaking confidence.
   b) 82% reported greater comfort participating in technical discussions.
   c) Simulation activities were rated as the most confidence-boosting.

Alignment with Broader Goals
The PBL approach directly supports Gajah Tunggal Polytechnic's mission to enhance employability. By bridging technical expertise and English proficiency, students are better prepared for competitive, internationalized work environments. This finding underlines the real-world impact of the study and its contribution to corporate education strategies.

Perspectives of Students and Lecturers on PBL

Despite facing notable challenges, both students and lecturers recognized the transformative potential of PBL, reinforcing the principles of constructivist learning theories (Savery, 2006; Guo et al., 2024).

a. Increased Engagement
PBL fostered deeper engagement compared to traditional instruction.

Supporting Evidence:

1. 78% of students agreed that PBL made learning more interactive and stimulating.
2. AFS (Industrial Engineering Student Year 3) : "In traditional classes, I just listen passively, but in PBL, I have to express my thoughts and solve problems. It makes me think harder."
3. Lecturers observed a clear increase in student proactivity over the semester.

This transition from surface to deep learning reflects Savery's (2006) findings on active learning benefits.

b. Development of Collaborative Skills
Collaboration was a key benefit, aligned with Guo et al.'s (2024) social interdependence theory.

Supporting Evidence:

1. 84% of students felt that working in groups improved their speaking confidence.
2. RP (Mechanical Engineering Student, Year 3): "Working in a team made me more comfortable because my friends would support me."
3. Lecturer observations confirmed that group settings scaffolded participation, especially for lower-proficiency students.

These outcomes suggest that peer collaboration can effectively mitigate language anxiety and enhance academic performance.

c. Challenges in Implementation
Despite positive outcomes, systemic challenges were reported.

Supporting Evidence:

1. **Lecturer Training**: Many lecturers lacked formal PBL training, relying instead on self-learning or informal support networks.
2. **Resource Limitations**: Limited access to English-language case studies and outdated technology hindered dynamic implementation.
3. **Administrative Constraints**: Large class sizes and rigid curricula constrained deeper inquiry-based learning.

Significance, Research Gap, and Practical Implications
This study addresses a notable research gap by examining the integration of PBL in English communication instruction within a technical, non-native English speakers context — a setting that remains underexplored in current literature (Savery, 2006; Li & Pei, 2024). The findings are significant for academia, policymakers, and educators, offering evidence of PBL's effectiveness while also highlighting the infrastructural and pedagogical challenges that must be addressed.

Practically, the results suggest that institutions seeking to internationalize their curricula must pair PBL implementation with systemic support measures. These include professional development programs for lecturers, investment in updated educational resources, and the design of flexible, student-centered curricula.

Discussion, conclusion and recommendations

The implementation of Problem-Based Learning (PBL) at Gajah Tunggal Polytechnic has demonstrated significant potential in enhancing critical thinking and self-confidence among non-native English speakers. PBL's student-centered approach, which focuses on real-world problem-solving activities, fosters independent learning and active participation—skills essential for both academic and professional success. This pedagogical strategy encourages students to take a more active role in shaping their educational journey, which contrasts with traditional rote learning methods.

Despite these promising outcomes, challenges persist in ensuring that all students benefit equally from PBL. A major barrier is the insufficient support structures, particularly for non-native English speakers who may find the language demands of PBL overwhelming. While PBL is an effective educational strategy, its success depends largely on the institution's capacity to provide necessary resources and adjustments. Felder and Brent (2016) stress that faculty training, resource availability, and curriculum modifications are essential to address the needs of diverse learners. Without these supports, the benefits of PBL may not be fully realized, particularly for students who face challenges in language proficiency or cultural adaptation.

At Gajah Tunggal Polytechnic, the application of PBL in English communication courses underscores the necessity of addressing these concerns. The lack of extensive faculty training in PBL methodology and language support, coupled with limited educational resources, can limit the potential of this approach. To overcome these challenges, higher education institutions should focus on understanding and addressing the linguistic and cultural diversity within their student populations. Freire (1970) advocates for an education system that acknowledges students' lived experiences, calling for teaching strategies that are both culturally relevant and linguistically accessible. Therefore, providing additional language support, professional development for educators, and curriculum adjustments tailored to the needs of English learners is critical.

To maximize the effectiveness of PBL, institutions should invest in comprehensive professional development programs for educators. These programs should equip instructors not only with PBL-specific teaching strategies but also with the tools to support students' language development. Moreover, providing resources such as textbooks, digital tools, and interactive materials will enrich the learning experience. Adapting the curriculum to students' linguistic abilities and academic needs is essential to ensure that PBL activities are engaging and accessible for all learners. Without these modifications, students may struggle to fully engage with the content, potentially undermining the intended educational outcomes.

In addition to curriculum adjustments, fostering an inclusive learning environment is crucial. Institutions should implement strategies that actively engage diverse learners, such as mentorship programs, peer-assisted learning, and ongoing formative assessments. These initiatives create a supportive learning environment, allowing students to receive timely feedback and interventions when needed. Schmidt et al. (2011) emphasize the importance of continuous feedback and adaptive teaching methods, which can bridge the gap between students' current competencies and the learning objectives of PBL. By implementing these strategies, institutions can create a more inclusive and effective learning environment for English language learners. A combination of professional development, resource allocation, and curriculum adaptation will not only enhance the outcomes of PBL but also empower students to develop critical thinking, problem-solving skills, and self-confidence.

Conclusion and Recommendations

In conclusion, the implementation of Problem-Based Learning (PBL) at Gajah Tunggal Polytechnic has proven beneficial in enhancing critical thinking and self-confidence among non-native English speakers. However, to fully realize the potential of PBL, challenges such as limited language support and insufficient educator training must be addressed.

The following actions are recommended to optimize the effectiveness of PBL:

1. **Invest in Professional Development for Educators**: Educators should be equipped with strategies specific to PBL and language support techniques.
2. **Provide Additional Language Resources**: Institutions should supply textbooks, digital tools, and interactive materials to support diverse learners in their language development.
3. **Adapt the Curriculum**: Tailoring the curriculum to meet the linguistic and academic needs of students ensures that PBL activities remain accessible and engaging.
4. **Foster an Inclusive Learning Environment**: Implement mentorship programs, peer-assisted learning, and formative assessments to offer ongoing support and feedback.

These recommendations aim to create a more inclusive and supportive learning environment that will enhance the effectiveness of PBL and empower students to thrive in both their academic and professional pursuits. Furthermore, institutions must continually assess the real-world impact and theoretical contributions of such studies to better inform policy and practice in education.

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Appendix

Appendix A: Survey Instruments

A.1 Critical Thinking Disposition Scale (CTDS)

Participants were asked to rate their agreement with the following statements on a **5-point Likert scale** (1 = Strongly Disagree, 5 = Strongly Agree):

1. I enjoy solving complex problems.
2. I actively seek different perspectives on an issue.
3. I question assumptions rather than accept them at face value.
4. I feel comfortable analyzing different viewpoints before making a decision.
5. I apply logical reasoning when evaluating arguments.

A.2 Self-Confidence in Speaking Scale (SCSS)

Participants were asked to rate their confidence levels using a **5-point Likert scale** (1 = Not Confident at All, 5 = Very Confident):

1. I feel confident speaking English in group discussions.
2. I can express my opinions clearly in English.
3. I am comfortable asking questions in English during class.
4. I am not afraid of making mistakes when speaking English.
5. I can handle spontaneous conversations in English.

Appendix B: Interview Questions

B.1 Student Interview Questions

1. How has PBL influenced your ability to think critically?
2. What challenges have you encountered while participating in PBL discussions?
3. In what ways has PBL helped (or hindered) your confidence in speaking?
4. How do you feel about working in groups during PBL activities?
5. What improvements would you suggest for better implementation of PBL?

B.2 Lecturer Interview Questions

1. What are your perceptions of students' engagement in PBL sessions?
2. What challenges do you face when implementing PBL in speaking courses?

3. Have you noticed any improvements in students' critical thinking or confidence levels?
4. What resources or support do you believe are necessary for effective PBL implementation?
5. How do you assess the impact of PBL on students' learning outcomes?

Appendix C: Focus Group Discussion (FGD) Guidelines

1. **Introduction:** Explain the purpose of the discussion and set ground rules.
2. **Icebreaker:** Ask participants about their general experience with PBL.
3. **Key Discussion Topics:**
    a. How PBL has influenced critical thinking development.
    b. Challenges in adapting to PBL methods.
    c. The role of teamwork in building speaking confidence.
    d. Recommendations for improving PBL implementation.
4. **Conclusion:** Summarize key points and allow participants to share final thoughts.

Appendix D: Statistical Analysis Results

D.1 Paired t-test Results (Pre- and Post-PBL Implementation)

Variable	**Mean (Pre)**	**Mean (Post)**	**t-value**	**p-value (Sig.)**
Critical Thinking Score	3.2	4.1	6.21	<0.001
Self-Confidence Score	2.9	4.0	5.87	<0.001
Interpretation: The significant p-values (<0.05) indicate that **PBL had a positive impact** on both critical thinking and self-confidence.				

D.2 Regression Analysis: PBL's Influence on Student Outcomes

Predictor	Beta Coefficient	t-value	p-value
PBL Implementation	0.74	7.89	<0.001
Interpretation: A strong positive relationship was found between PBL implementation and students' **critical thinking and self-confidence** in speaking.			

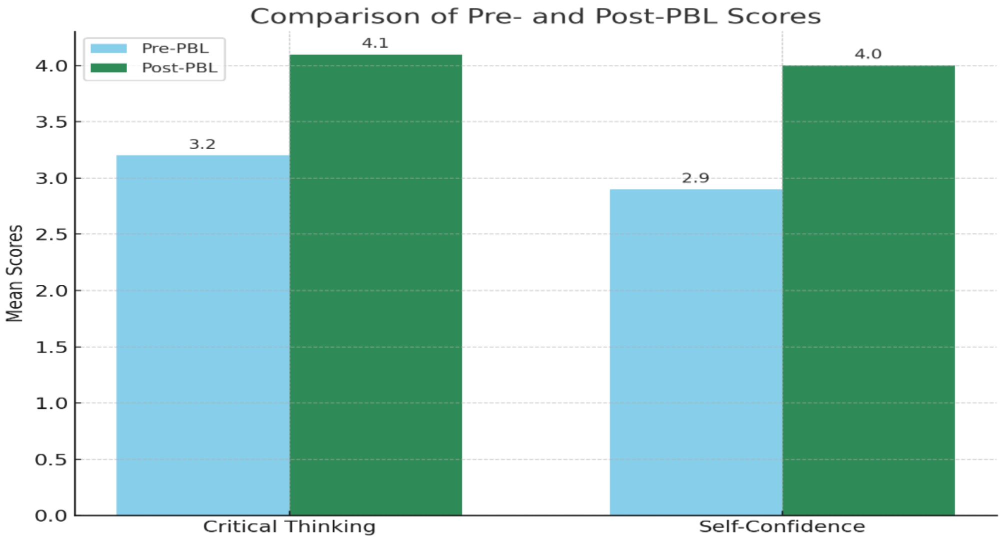

Figure 1.1. Comparison Result in Critical Thinking and Self-Confidence.

Appendix E: Student Responses from Interviews

1. *"At first, I was scared to speak, but after doing PBL activities, I feel more comfortable sharing my thoughts."* AS, Industrial Engineering Student with Mr. M. Iqbal Firdaus
2. *"I struggled with the English terminology, but discussing in groups helped me understand and remember better."* D, Mechanical Engineering Student with Mr. Yudhie Indra G
3. *"PBL made me think more critically about problems rather than just memorizing information." AA, Electrical Engineering Student with Mr. Bruce Riseley*
4. *"I like working in teams because it gives me the confidence to speak, knowing my friends are supporting me."RDP,* Mechanical Engineering Student with Mr. Yudhie Indra G

Appendix F: Student Testimonies

1. *"Sometimes, I understand the concept in my native language, but I struggle to explain it in English."* FS, *Electrical Engineering Student.*
2. *"In my previous classes, we just listened and took notes. I had to learn how to express my ideas here."* ES, Mechanical Engineering Student.
3. *"I hesitate because I'm afraid of making mistakes in front of my classmates."* MRRA, Industrial Engineering Student.
4. *"Working in a team made me more comfortable to speak and share my opinions."* AR, Mechanical Engineering Student.

Appendix G: Lecturer Comments

1. *"Students with stronger English backgrounds adjusted quickly to PBL discussions, while others needed more scaffolding."* (M. Iqbal Firdaus, M. Hum)
2. *"Limited resources and large class sizes made it difficult to apply PBL optimally."* (Bruce Riseley, M.Ed)
3. *"Gradually, students became more confident after several group projects and presentations."* (Yudhie Indra Gunawan, M.Pd)

Picture 1.1. Gajah Tunggal Polytechnic Students in Mechanical Engineering.

Picture 1.2. Gajah Tunggal Polytechnic Students in Industrial Engineering.