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RESEARCH ARTICLE

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Student conceptions of problem and project based learning in engineering education: A phenomenographic investigation

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Abstract

Background: Problem-oriented project work, also known as problem and project-based learning (PBL), is a popular educational approach in engineering education. However, the focus of the literature on the implementation of PBL has been at the course and institutional levels. Scant attention has been paid to the student experience, especially regarding student conceptions of PBL.

Purpose: This is a phenomenographic study of student conceptions of PBL in a Danish engineering program that uses a systemic PBL model.

Design/method: This study follows a phenomenographic qualitative design. Sixteen participants from four different engineering disciplines were asked to share their views and experiences with PBL. The interview transcripts were analyzed to identify emerging variations in the student conceptions of PBL.

Results: The outcome space suggests three levels of students' conceptions of PBL: individual, group and society levels. Within the categories of description, sublevel variations appear: PBL as an unsupportive process and environment, PBL as a supportive process and environment, and PBL as a structured education method. These conceptions were organized hierarchically from a narrow individual to a broader society level.

Conclusions: Student conceptions of PBL as a structured education method echo the literature on the intended learning outcomes of PBL. However, our study shows that conceptions of PBL as personal and social processes fall outside of the scope of current scholarly discussions on PBL. Issues of societal relevance, while prominent in the literature on PBL, do not feature in students' thinking about PBL at this stage. Introducing broader reflection practices informed by exemplarity could address some of these discrepancies.

KEYWORDS

phenomenography, problem and project-based learning, reflection

1 | INTRODUCTION

Problem-oriented project work, also known as problem and project-based learning (PBL), in the engineering education literature (Kolmos et al., 2004), is an active learning approach organized around interdisciplinary participant-directed projects. Its roots can be traced to the Frankfurt School critical pedagogy movement of the 1960s. It gained traction in the Humanities and Social Sciences faculties of the so-called "New Universities" in Denmark and Germany in the early 1970s (Whitehead, 1981, p. 91). PBL was adopted in engineering education in 1974 when pre-existing engineering education institutions of Northern Jutland merged into the new Aalborg University Centre. Although initially skeptical, engineering educators seized on the potential of problem-oriented project work for educating work-ready engineers, particularly regarding collaboration and problem-solving experiences (Servant-Miklos & Spliid, 2017). Over time, data has demonstrated the effectiveness of this approach, consistently rating PBL engineering schools highly for the work-readiness of their graduates (Kolmos et al., 2020; Mann et al., 2020; Mitchell et al., 2019). This success helped turn PBL into one of the most popular pedagogical approaches in the engineering education literature (Du et al., 2009).

The growing popularity of PBL does not mean that adopting a partial or systemic PBL pedagogy comes easily, particularly in institutions that already function with a different approach. The challenges of managing change to PBL are well documented. They include organizational and curricular issues at all levels of an institution. Recent reviews of PBL in engineering education have outlined concerns with the implementation and effectiveness of PBL at the course and institutional levels (Chen et al., 2020; Condliffe et al., 2016). At the institutional level, generating widespread motivation for change among academic staff remains a challenge (Kolmos et al., 2016; Voogt & Roblin, 2012).

Studies at the student level have focused on learning outcomes of a PBL education, such as knowledge, skills, and competences acquired during the learning process (Johnson et al., 2015; Kolmos et al., 2020; Yadav et al., 2011). Specific aspects, such as motivation, engagement, and persistence, have also been examined (Bédard et al., 2010; Jeon et al., 2014). However, engineering students' perspectives and experiences of PBL as an educational object have not been studied, meaning that we do not know how engineering students conceive of PBL. This is not the same as questioning whether students enjoy learning with PBL or think it is an effective educational approach. It is also not the same as asking how students conceive of learning or knowledge in a systemic PBL environment. Rather, it is asking how students conceive of PBL as an educational object from the vantage point of their diverse experiences of PBL within a systemic PBL environment. The question is both experiential and relational—we are interested in the lived experience of PBL from the students' perspectives rather than PBL as an "objective fact" that is "out there" (Åkerlind, 2005, p. 72), but we are interested in the students' experience only insofar as it relates to the phenomenon under study, namely PBL. The purpose of this study is to identify different conceptions of PBL among engineering students and organize these into meaningful phenomenographic patterns.

Research question:

> What are the qualitatively different conceptions of problem-oriented project work (PBL) that engineering students hold in the context of a systemic PBL environment?

This question is interesting and relevant because it allows engineering educators to identify conceptions of PBL that could explain why PBL works for some engineering students and not others. It could also help engineering educators to build better student training programs that address the various conceptions of PBL, focused on overcoming conceptions with less positive educational outcomes while promoting conceptions with more positive outcomes through appropriate scaffolding. Being aware of student conceptions of PBL could be a powerful help for implementing PBL in new programs or expanding existing implementations systemically. There is precedent to support this claim: a recent historical account of educators' appraisal of PBL in medical education highlighted the impact of differing conceptions of PBL on curriculum structure and learning outcomes, with better learning outcomes for programs designed by educators with a constructivist conception of PBL—in which PBL is seen as a method of knowledge acquisition—and worse outcomes for programs designed by educators with an information-processing conception of PBL—in which PBL is seen as a method to learn clinical reasoning skills (Neville et al., 2019; Servant-Miklos, 2019). Such an appraisal has not yet been conducted in engineering education. Students' conceptions should be prioritized for study because PBL in engineering education is significantly more student-driven than in medical education (De Graaff & Kolmos, 2003; Servant-Miklos, 2020). In particular, whereas educators formulate the problems in PBL in medical education, students formulate the problems in PBL in engineering education. Understanding how students apprehend PBL could help engineering educators currently using or intending to implement PBL to anticipate potential project trajectories and project learning outcomes.

Our research question requires a methodology appropriate for analyzing variation in data rather than the common qualitative approach of searching for common themes. The best approach to study variations in experiential conceptions of a phenomenon is phenomenography, a research approach developed by Marton (1981, 1986). This paper will therefore offer a phenomenographic study of conceptions of PBL among undergraduate engineering students in a systemic PBL university.

2 | RESEARCH FRAMEWORK

Phenomenography is a research method in which conceptualizations emerge from the data rather than from a predetermined theoretical framework. The design of this research was nonetheless informed by the body of research on PBL.

2.1 | Problem-oriented project work

One must be careful to outline what is meant by problem-oriented project work since other student-centered pedagogies with different practices also use the acronym PBL, including problem-based learning and project-based learning. Perhaps the choice of an acronym is unfortunate in its propensity to sow confusion, but as it has been used in engineering education literature for 30 years, we will do so in this article. In this paper, PBL designates a method of learning whereby students work in groups on lengthy projects (between 1 month and 1 semester) under the guidance of one or two project supervisors (Kolmos, 1996). In PBL, the projects are problem-based rather than task-based, as in project-based learning (De Graaff & Kolmos, 2003). This means that students examine real-life situations and formulate problems to work on by themselves instead of following instructions from a teacher. In theory, projects in PBL should be interdisciplinary, although, in practice, this is not always the case (Guerra, 2014). PBL has been implemented in all forms of hybrid ways, where project work accounts for less than 20% of student learning credits, fits into a single course, or combines with other pedagogies (Kolmos, 2017; Servant-Miklos, 2019). In recent years, to clarify the practices behind the acronym, some scholars refer to systemic PBL to designate a curriculum that is structured around project work (Kolmos, 2017).

2.2 | Systemic PBL

In systemic PBL, the curriculum is characterized by three components: first, the use of a range of problems, from narrow and well-defined to ill-defined; second, an interlinkage that binds all the components of the curriculum; and third, a focus on learning PBL competences explicitly formulated in the curriculum (Kolmos et al., 2020). In systemic PBL, students receive half of their learning credits for the completion of problem-oriented, group-based projects, as shown in Figure 1 (Kolmos et al., 2004). In Figure 1, ECTS stands for European Credit Transfer System, where 60 ECTS is equivalent to one year of full-time study. As shown in Figure 1, the other half of the credits come from disciplinary courses using a range of pedagogies, from traditional lectures to applied lab-based work and individual course-based exams and coursework. Courses may or may not be tied to the project work. But project work is pervasive across all engineering disciplines and all years of study in the entire engineering faculty.

PBL competences are explicitly formulated in the curriculum as intended learning outcomes (ILOs) for the first year of the program. In practice, few engineering institutions manage to implement PBL at such a level, but quite a number are taking steps in that direction (Kolmos, 2017). There is only one university with a long history of using systemic PBL, which is why this Danish university was chosen for our study (Kolmos et al., 2004). While there are differences in the application of PBL between programs, especially in Humanities and Social Sciences (Servant-Miklos & Spliid, 2017), PBL is applied consistently throughout engineering programs, as described below in Figure 2. One feature of systemic PBL is the group-examination format. As noted in Figure 1, courses are evaluated using individual examinations. However, project work is evaluated using a group-based examination, where all project participants present their work and answer questions from examiners. Initially, the group received a group mark for the whole project; however, national discussions around group examinations led to a government-mandated abolition of group marks nationally in 2007, and students are now given individual marks for the collective project and project examination (Krogh & Rasmussen, 2007).

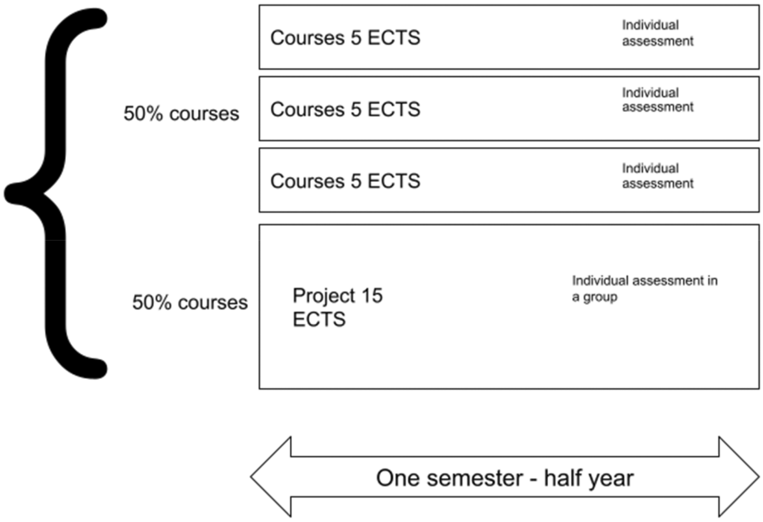

FIGURE 1 Structure of the problem and project-based (PBL) curriculum at a systemic PBL university in Denmark, where one European Credit Transfer System (ECTS) represents 25 study hours, and courses are disciplinary, teacher-led, and content-driven activities.

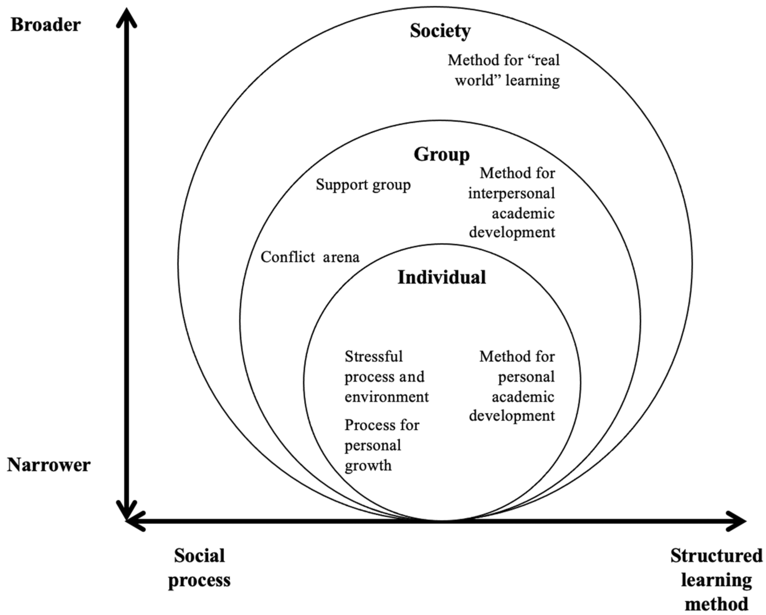

FIGURE 2 Hierarchy of categories within the outcome space of students' conceptions of PBL, mapped from narrow to broad aspects and from social to structured learning processes. PBL, problem and project-based learning

2.3 | Progression of PBL competences

A key feature of systemic PBL is the development of PBL competences during the learning process. Holgaard and Kolmos (2019) identified the following categories of competences as key to the successful practice of PBL: metacognitive competences (including motivation and learning strategies), problem-oriented competences (including problem identification, analysis, and link to societal issues), interpersonal competences (managing teamwork), and structural competences (structuring project activities).

To develop these competences, the faculty of engineering uses a system of progression across all engineering undergraduate programs, shown below in Table 1, where each "P" represents one project.

The first two semesters focus on ILOs for learning to practice and reflect on PBL. The first semester comprises two projects, P0 and P1. P0 is an introductory project to let students experience project teams and facilitate the transition

TABLE 1 Progression of project work in the first 18 months of undergraduate engineering programs

P0	P1	P2	P3+
• One month long • Focus on structural and problem-oriented competences • Learning to write a report • Learning group-based assessment	• Two months long • Focus on metacognitive and interpersonal competences • Disciplinary scientific contents begin to be integrated	• One semester long • Project is oriented toward disciplinary scientific contents • Written evaluation of PBL competences	• One project per semester • Focus is exclusively on disciplinary scientific contents

Note: P stands for project. The number represents the order of the projects.
Abbreviation: PBL, problem and project-based learning.

from high school. During P0, students work on identifying problems, writing project reports, and participating in group-based assessments. P1 introduces scientific content and the application of PBL in domain-specific areas. But there are also ILOs on PBL, particularly on individual and collaborative learning experiences. Together with the project report, the students submit an analysis of their team process. In P2, which runs throughout the second semester, the project focuses on technical and scientific content, and students are expected to work independently in their project teams. Students still submit a reflection report on the collaborative process and prepare an individual profile on PBL competences that is assessed on a pass/fail basis before they undergo their group-based project exam. This profile covers the four areas of competences mentioned above. From the third semester onward, PBL practices are assumed to be assimilated, and ILOs for the following projects are entirely technical and scientific.

2.4 | Student experiences in PBL

Investigations of student experiences in problem-oriented project work have focused on student motivation in projects, group processes, and learning outcomes.

Regarding motivation, Buus and Pedersen (2021) identified differences in motivation as a key factor in determining one of four experiential outcomes for engineering students: job-focused practitioners, subject-enthusiasts, social collaborators, and directionless explorers. Jones et al. (2013) looked at the experience of engineering students with problem-based capstone projects and found three elements of student experiences that increased motivation: the ability to design their own problems, the control over group processes, and the facilitative role of the supervisor.

Regarding group processes, Mabley et al. (2020) found that students in project groups tend to impose rigid, disciplinary structures on the group problem-solving process, thereby decreasing the depth of individual student engagement with the problem. Pihl (2015) showed that forming a group consensus around the project's design and direction can harm individual student creativity. Du et al. (2022) refined the study of group processes by investigating how student perceptions of agency shape group process outcomes. Looking at the agency through three dimensions—intrapersonal, behavioral, and environmental—this study showed that PBL novices manifest increased dependency on the project supervisor and decreased group independence. The authors recommended developing individual learners' understanding of the significance of agency in PBL early on to improve project outcomes.

The investigation of learning outcomes in a problem-oriented project work environment has focused on PBL competences and metacognitive skills. Marra et al. (2022) looked at the impact of PBL on students' self-directed learning (SDL) abilities and found an increase in the complexity of SDL thinking resulting from project experience. Boelt et al. (2021) found that students' focus on generic PBL competences decreased after the first semester, and expressed concern that this might hamper the development of professional identities based on these competences.

The studies cited investigated different facets of students' experiences with PBL but did not look at student conceptions of PBL emerging from those experiences.

3 | RESEARCH DESIGN

Phenomenography is a qualitative, second-order, relational research approach, the purpose of which is to understand the "qualitatively different ways in which people experience or think about various phenomena" (Marton, 1986, p. 30). Second-order research does not try to make objective statements about reality but instead tries to understand conceptions of reality mediated by people's experiences (Marton, 1981). This fits with our aim, as we seek to study variations in students' conceptions of PBL. In phenomenography, the focus is relational—not human experience, as in phenomenology (Larkin et al., 2006) or the object being experienced, as in grounded theory (Glaser & Strauss, 1967)—but the relationship between the two. We focused neither on students' internal state of mind in a psychologically subjective sense nor on PBL as an objective practice. Instead, we looked at the experienced relationship between students and PBL.

One of the fundamental tenets of phenomenography is that there is a limited number of ways in which experiential relationships, known as conceptions (Marton, 1981), manifest around a particular phenomenon. We sought to identify this finite variation of conceptions of PBL and categorize them into an outcome space (Åkerlind et al., 2005). This approach to categorization is unique to phenomenography: it comes with an explicit mandate to hierarchize emergent categories. Marton originally employed hierarchization to organize conceptions of physics theorems, for which there are correct and incorrect conceptions. However, he acknowledged early on that not all phenomena are so clear cut. More open phenomenographic research questions could aim at "mapping conceptions of the world and relating categories of description to one another" (Marton, 1986, p. 150)—that is, conceptions that are not inherently right or wrong but reflect diverse apprehensions of a phenomenon. For instance, conceptions of the second law of thermodynamics can be explored using a closed phenomenographic design, while conceptions of culture can be explored using an open phenomenographic design. The open approach, therefore, does not create a hierarchy-based "on value judgements of better and worse ways of understanding, but on evidence of some categories being inclusive of others" (Åkerlind et al., 2005, p. 111). In engineering education, phenomenographic studies have mostly looked at open phenomena such as design (Daly et al., 2012; Zoltowski et al., 2012), entrepreneurial learning (Täks et al., 2016), tutor-automated feedback (Calvo & Ellis, 2010), and ill-structured problems (Dringenberg & Purzer, 2018) rather than closed-type phenomena of the Marton tradition (e.g., Ebenezer & Fraser, 2001). PBL is an open phenomenon in the sense that there is no correct conception of PBL, but there are more or less complex or broad conceptions, which may yield more or less beneficial learning outcomes.

3.1 | Data collection

Sampling in phenomenography is always purposive (Etikan, 2016) and comes with a mandate to sample for maximal variation (Åkerlind et al., 2005). Our goal was to examine conceptions of PBL contextualized by broad immersion into PBL, to yield a comprehensive set of conceptions of PBL in the outcome space. Given the paucity of systemic PBL implementations, we opted to maximize variation within the previously mentioned Danish university by sampling across four different engineering programs. Students from universities in other countries were not included in this study. The four chosen programs were:

- *Mechanical Engineering*—an undergraduate program that includes constructing, manufacturing, and controlling machines and production systems.
- *Electronic Engineering*—an undergraduate program that focuses on developing innovative electronic products and improving existing ones.
- *Medialogy*—an undergraduate program focused on the interaction between humans and machines and the science and technology behind interactive digital systems.
- *Urban, Energy, and Environmental Planning*—an undergraduate program that aims to address transportation challenges, environmental responsibility, and urban planning challenges, such as gentrification and climate change.

These four programs offer a broad sweep of the experience of engineering education in a systemic PBL environment, from disciplinary to interdisciplinary. They offer differing epistemological accounts of what counts as knowledge in engineering: mechanical and electronic engineering educations espouse a more essentialist epistemology, broadly following the view of the science of Karl Popper (1972), whereas medialogy and planning tend toward a constructivist epistemology informed by Science and Technology Studies (STS) (Jamison et al., 2011). An essentialist epistemology posits the existence of objective scientific knowledge, translating into curricula that focus on scientific facts and theories. A constructivist epistemology claims that scientific knowledge is the product of social processes, translating into curricula that focus on social actors within the sphere of knowledge production. It should be noted that constructivist epistemology in STS is not the same as constructivist epistemology in PBL: the former is a theory of social processes involved in knowledge production in the scientific arena, while the latter is a theory of knowledge construction inside the learner's mind.

In terms of the sample composition, Daly et al. (2012) suggest that "while the distribution of participants whose experiences comprise each category of descriptions and the representation of the sample group to their larger populations cannot be generalized, the range of variation in the sample is expected to reflect the range of variation in the population" (p. 194). We, therefore, sampled women and men reflecting the range of variations within their respective programs, within a wide age range (18–33 years old). Limitations on gender sampling in this study are addressed in the limitations section of this paper. Sample sizes in phenomenography vary between 15 and 25 participants. Fewer would not be representative enough, and more would be redundant.

We planned to sample between five and eight students in each program. We sent e-mails to the program coordinators for each of the four undergraduate studies and then went door-to-door in relevant student project rooms to recruit participants. Where representative diversity of age and gender could not be achieved by door-to-door recruitment, the first author e-mailed the program secretary requesting permission to directly e-mail students who matched the required characteristics (female students in medialogy and electronic engineering were approached this way). Some participants who initially signed up during door-to-door recruitment dropped out before the start of the interviews. However, 16 participants constitute a sufficiently large sample to minimize the risk of any commonly occurring conception being missed.

In addition to participant characteristics mentioned in Table 2, some of the participants revealed during the interview process that they were neurodiverse. They revealed this of their own accord, with no prompt from the interviewer. However, the interview process had a built-in follow-up question to deal with such an occurrence or any other unique characteristic revealed in situ: the interviewer asked participants to indicate how this divergent feature contributed to their experience and apprehension of PBL. To protect participants' privacy, their age and neurodiversity information are not listed in Table 2. But as neurodiversity was relevant to the results, diagnoses, including dyslexia, autism, depression, ADHD, and anxiety disorder, were reported.

TABLE 2 Participants in the study

Pseudonym	Gender	Study program
Casper	Male	Mechanical Engineering
Harald	Male	Mechanical Engineering
Asbjorn	Male	Electronic Engineering
Rune	Male	Electronic Engineering
Sanne	Female	Electronic Engineering
Hella	Female	Medialogy
Jorgen	Male	Medialogy
Knud	Male	Medialogy
Poul	Male	Medialogy
Lasse	Male	Medialogy
Mohammed (international student)	Male	Medialogy
Elise	Female	Planning
Erling	Male	Planning
Lykke	Female	Planning
Brigit	Female	Planning
Line	Female	Planning

We interviewed all participants at the start of P3 (refer to research framework), which is a "sweet spot" in the development of their understanding of PBL in the undergraduate curriculum. At this point, participants have just come out of two semesters with a focus on PBL processes and skills, have been asked to reflect on their PBL practices, and have had the opportunity to put this into practice in a full semester-long scientific project. As students progress to P3 and beyond, the PBL process fades into the background of their experience (Boelt et al., 2021). P3 is, therefore, an interesting time to look at how conceptions of PBL vary among students who have completed their induction into systemic PBL. It should be noted that two participants went through P0 and P1 twice, as they quit their previous programs and started over again in a different discipline the following year. However, this was not assumed to impact their conceptions of PBL in a significant way, since they still followed the same P0–P3 progression during their second attempt.

3.2 | Interviews

Participants received an invitation to participate from their program coordinator with a slide deck summarizing the research project during P0. During P2, participants who signed up during door-to-door and e-mail recruiting met up with the interviewer to obtain participation consent and explain the research approach.

Participants were invited to wait for the interviewer at the entrance of the engineering building, allowing for a short informal chat unrelated to the research between the entrance door and the interview room. This process was crucial in creating a sentiment of psychological safety for the participant and "realness" on the part of the interviewer (Rogers, 1951, 1969) and set the tone for a nondirective style of the interview rather than a formally structured process.

The interviews were conducted in English by the first author. There were several reasons for this choice of language: first, there was a pragmatic reason—neither the interviewer nor all participants spoke Danish fluently (there was one international student), while all students and authors spoke English fluently enough to comfortably converse. Second, the use of English subtly reinforced participants' feeling of psychological safety during the interview, positioning the interviewer as a friendly "outsider" in a very tangible way. Doing the interviews with an interpreter would have been detrimental to the active-listening approach adopted by the interviewer. Koulouriotis (2011) reported that interviews done in English with non-native speakers could yield positive experiences for participants who feel empowered to share their experiences with a broader audience. However, special care should be given to clarify meanings and develop a common understanding of what is being said between the participant and interviewer. This care was provided by the Rogerian nondirective, active-listening approach to the interviews (Lee, 2011).

The interviews, lasting about 30–45 min each, were recorded with the consent of the participants. The interviews all started with the same open question about the participant's experience with PBL over the P0–P3 period: "How did you experience PBL over the last few months?" After this, a series of follow-up questions were asked in response to what was said, with the following themes explored more specifically in each interview:

1. The learning process.
2. The group work process.
3. The choice to study in PBL versus not PBL.
4. Specific aspects of the experience of PBL related to specific characteristics of the participants (e.g., being female, being older, being in a particular study program).

The first three themes were chosen based on salient themes of PBL student experience in the literature, outlined in Section 2.4. The final theme made room to draw out variations of conceptions linked to sampling variation. The interview themes focus on student experiences of PBL (second-order questions) rather than asking directly, "What is PBL?" (first-order questions) (see Ebenezer & Fraser, 2001). Because participants had just received two semesters of PBL training, there was an elevated risk that even asking second-order questions linked directly to definitions of PBL such as, "Can you explain what PBL is," would have yielded textbook answers, where participants recite what they learned about PBL in their training, rather than how they actually conceive it. The experience-centric approach emphasizes drawing out phenomenographic conceptions in the analysis rather than interviewing phase.

We chose a semi-structured format with the themes listed above for the follow-up, rather than rigid questions (Waller et al., 2016), and a nondirective interview process (Lee, 2011) in which the participants directed the interviewers to the aspects and directions that were most important to them. The interviewer reacted to the participant with questions like: "Could you please explain what you just said?" or "Could you please elaborate on what you just said?"

In most cases, themes were brought up by the participants themselves. For instance, a participant would mention the social aspect of PBL while describing their experience. Instead of stopping the participant and enforcing a specific order of themes, the interviewer followed the participant and asked them to elaborate. If the participant did not mention one of the themes of their own accord, an open prompt would be given, such as "We didn't talk about the group aspects of your PBL experience yet. Could you tell me something about that?" If participants brought up a theme that was not on the researcher's list, they were asked to elaborate. Even so, Åkerlind (2005) notes that the choice of statements for requesting elaborations is a form of directivity—it is impossible to be completely nondirective in a semi-structured interview process.

The advantage of this approach over a highly structured one is threefold: first, it creates a feeling of psychological safety for participants in which they feel empowered to share their perspectives freely, rather than responding to the expectations of an interviewer. Setting the pace, moving rigidly from one question to the next, breaking the flow of the conversation by enforcing a scheduled order of questions, and pausing to thumb through a long interview schedule do not contribute to an open interview atmosphere. Instead, the interviewer kept the themes in a notebook on the table and could cast a sideways glance without interrupting the conversation. Second, an open approach has been shown to create space for marginalized perspectives to come to the fore (Sochacka et al., 2018). In this study, it allowed female and neurodiverse participants to feel comfortable sharing their struggles with PBL in ways that a rigid interview schedule could have discouraged. From a phenomenographic perspective, researchers are encouraged to uncover "nondominant" conceptions (Larsson & Holmström, 2007), which are more likely to emerge in a nondirective approach. Third, a nondirective, active-listening approach is an effective parry against the imposition of the interviewer's assumptions onto the participant. The interviewer builds the interview around participants' contributions rather than the reverse.

There are limitations to our approach: first, the researcher has significantly less control over the interview process, which requires more experience with interview facilitation compared with working through a structured protocol. Second, this approach makes it harder to compare like-for-like different transcripts. Whereas comparing like for like is important in developmental phenomenographic analysis where transcripts are taken as wholes (i.e., one participant yields one conception; Bowden & Green, 2005), this is not the case in pure phenomenographic analysis, where transcripts are chunked; conceptions are attached to excerpts from transcripts and one participant yields multiple conceptions (Booth, 2001; Marton, 1986; Marton & Booth, 1997).

The approach to interviewing in phenomenography is "not prescriptive" (Booth, 2001, p. 171), and we, therefore, hope that the arguments put forward in this section will also contribute to a discussion about structured protocols versus nondirective interviewing in phenomenography.

3.3 | Analysis

The interview recordings were pseudonymized, then passed to a research assistant who transcribed them verbatim. The transcripts were checked by the first author for discrepancies against the audio recording and shared with the second author.

First, both authors read through all transcripts thoroughly while listening to the audio recordings to get a sense of the data as a whole. Then, the first author parsed through the transcripts to reduce the data (Marton, 1986; Marton & Booth, 1997). This means "identifying and grouping ways the subject experienced, or conceptualized the phenomenon" (Stolz, 2020, p. 8)—this is different from the open coding approach used by other qualitative research (Waller et al., 2016). Thus, all codes were labeled as follows: "PBL as … [insert conception]." This stage of the analysis was carried out by the first author from the vantage point of their outsider perspective because the second author's expert insider relationship to PBL might have burdened the coding process with prior assumptions about PBL.

We then conducted pure phenonemographic analysis (Booth, 2001; Marton, 1986; Marton & Booth, 1997) rather than developmental phenomenography (Bowden & Green, 2005). We chose this approach because we were interested in unpacking different conceptions within the accounts of participants, as well as across participants, thereby identifying nondominant conceptions within transcripts. Therefore, rather than sorting the transcripts as units of interpretation, which would have masked differentiations within the transcripts, the first author broke down transcripts into meaningful quotes that were coded separately.

In using the code manager function of Atlas.ti (Version 8; Hecker, 2022), which allows the aggregation of quotes tagged with the same code, the first author looked at the excerpts as interpretive units in piles of quotes tagged with the same code. The coded piles of quotes were then harmonized by the first author—when the conceptions identified in some piles were very close, they were merged, after which 14 conceptional codes emerged. These 14 codes, grouped together, constitute the pool of meanings (Marton, 1986; Marton & Booth, 1997), which can be found in the supplemental information (Data S1).

The emergent meanings, taken at the level of the individual quotes from different participants, constituted the variations in the ways of conceptualizing PBL (Stolz, 2020). From here, the first and second authors critically reviewed the coding process, playing devil's advocate, where the second author felt that a particular characterization could be better illuminated with insights from the expert insider perspective. From the pool of meanings, we distilled critical attributes and distinguishing features of each code, and from there, produced categories of descriptions (Stolz, 2020). We then sought a logical relationship between these categories—and found several similarities and contrasts—in the scale at which conceptions were expressed, the domain to which the conceptions referred, and finally, whether these conceptions related to positive or negative experiences.

3.4 | Mapping the researcher's positionality

Sochacka et al. (2018) noted the importance of incorporating sensitivity to the researchers' positionality in the qualitative research process. Increasingly, interpretive qualitative research is doing away with the axiological neutrality of quantitative research: moral, ethical, and political commitments cannot be completely bracketed but rather acknowledged and mitigated through interpretive awareness as part of the research process (Walther et al., 2013).

The authors share a commitment to constructivist education principles. However, they differ markedly in their experience and interest in PBL research: the first author has more experience with problem-based learning than problem-oriented project work, while the second author has more experience with systemic PBL. In addition, the authors come from different disciplinary backgrounds: the first author comes with an education in psychology and the second author with an education in engineering research. Finally, the first author worked with the university only for the duration of the research, while the second author has been working at the university for several decades. These differences were harnessed to improve the quality of the research process: they allowed for a broad perspective in the research design and analysis, bringing insights from disciplines outside of engineering education while facilitating translation to communities of practice in engineering education in the second half of the analysis and write-up. In this way, the first author was chosen to conduct interviews, to present participants with a friendly outsider: the interviewer's relative lack of experience with engineering education was put to participants up-front, thereby allaying potential fears that participants would say something wrong or that critical perspectives on PBL would be passed on to their teachers and supervisors. While the outsider position can create an empathy barrier (Gair, 2012), our nondirective active listening approach was designed to overcome this (Lee, 2011; Rogers, 1951, 1969).

The authors agreed on an epistemological stance that could be qualified as "light constructionism" (Eatough & Smith, 2006, p. 485). This epistemological position emphasizes the unique position of individuals within a socially constructed world (Anh & Marginson, 2013). Such a position gives space to the experiential perspectives of participants while recognizing constitutive influences of social reality on their experience of particular phenomena. It also recognizes that the interview process is not neutral but forms a space where the experiential accounts of participants and the interviewer are dialogically evaluated and transformed: "the researcher is always connected to and to some degree influences and is influenced by the social institution under investigation" (Walther et al., 2013, p. 633). Therefore, through the interview process, the outsider perspective of the interviewer became dialectically entangled with the experiential insider perspective of participants, blurring what were neater lines at the start of the research. In this regard, we disagree with some phenomenographers who claim that it is possible to investigate the relationship between the participant and the phenomenon without tainting it with the relationship between the interviewer and participant (refer to Bowden & Green, 2005). As such, the version of social reality presented in the findings is not the correct version but a version co-constituted with the participants, as seen from the vantage point of the researchers through the process of a double-hermeneutic. Quality assurance measures were, therefore, required to ensure that the version of reality presented in this paper is valid, relevant, and insightful to community practitioners.

3.5 | Quality considerations

In assessing the quality of our research process, we used Walther et al.'s (2013) framework for quality assessment. Phenomenographers have noted the particular importance of communicative and pragmatic validation for phenomenography (Åkerlind, 2011; Dringenberg & Purzer, 2018; Zoltowski et al., 2012). To strengthen the relevance of our work to various stakeholders involved, our nondirective, participant-focused interview approach, combined with an open discussion of the data between the coauthors and the broader research community, bolstered our communicative validity. To ensure a good fit between our findings and the reality of engineering education, we used the insider/outsider positions and the pure phenomenographic design, focusing the write-up on the explanatory power of the results and their implications for practice, thereby effecting pragmatic validation. In addition, we paid close attention to phenomenographic methods and procedures advocated in the literature, with the sampling, interview, and data sorting design mapped according to reported best practices in the field, adding theoretical validation and process reliability to our quality considerations. Finally, we took the extra step of mapping our own positionality and accounting for our biases and respective positions in the design of the data collection and analysis, strengthening the procedural validity of our research.

4 | FINDINGS

The purpose of this study is to identify conceptions of PBL among engineering students and to organize these into meaningful phenomenographic patterns.

In this section, we identified conceptions of PBL ranging from the individual to the society level. Within these levels, we organized conceptions of PBL as a process for negotiating personal growth and group dynamics or as a structured educational method.

4.1 | The outcome space

The outcome space describing conceptions of PBL includes the phenomenographic categories we developed at the individual, group, and society levels. The higher levels are inclusive of lower levels. Variations within these overarching categories of description are defined in Table 3 as Variations A, B, and C. The hierarchical nature of the outcome space is represented in Figure 2 and described in more detail in the sections that follow.

In all the direct quotations featured in this section, (…) is used to denote omitted content, while … is used to denote a pause. Where a pronoun has been used in a direct quotation instead of the noun it refers to, we have added the noun in brackets for clarity.

4.1.1 | Individual-level conceptions of PBL

The first category comprises individual-level conceptions of PBL. This means that participants conceive of PBL as primarily geared toward individual learners. We arrived at this category by observing the language used by the participant: participant referring to PBL using primarily "I" pronouns, describing PBL in relation to individual or personal spheres of experience, positioning the participant–phenomenon relationship (student-PBL, in this case) as bilateral.

TABLE 3 The categories of description within the outcome space of students' conceptions of problem and project-based learning (PBL)

	Categories of description		
	Individual-level conceptions (1)	**Group-level conceptions (2)**	**Society-level conceptions (3)**
Variation A (unsupportive process and hostile environment)	PBL as a stressful process and environment	PBL as an arena for interpersonal conflicts	–
Variation B (supportive process and safe environment)	PBL as a process for supporting personal growth	PBL as a source of social support	–
Variation C (structured learning method)	PBL as a structured method for personal academic development	PBL as a structured method for interpersonal academic development	PBL as a structured method for developing real-world skills development

Within that category, three variations appear. First, some participants conceive of PBL as a process that supports personal growth.

For some participants, particularly those from minority groups (gender, neurodiversity, nationality), PBL was also conceived as an opportunity to explore their identities as engineers:

> Sanne: I think fundamentally, I've become more comfortable being a woman in this field of study. (…) There's been some major ups and downs but generally I'm feeling more confident and becoming more and more comfortable.

> Mohammed: I thought I was an engineer, a programmer—sit down at a computer and code there for hours. But now I'm starting to focus on the human part. I want to know what people want. Because anyone can sit down and program something amazing, but not everyone can get someone to use that, and that's what I want to focus on—I want to understand the interaction between person and device, and then try to make that interaction better, to get them to use whatever it is I'm going to program.

These thoughts on engineering identity development were part of a broader pattern of conceiving PBL as a process and environment that supports self-reflection and personal development, growing self-confidence, and emotional equanimity:

> Mohammed: PBL handed me the tools to look back at myself and make the proper conclusions, and fix myself, in a way. It also taught me how to be calmer, to sit down and look at something, and think—not be as erratic as I was before.

> Hella: after I've been in a social situation and things like that, I pin-point every single little thing that I feel like I did wrong, and then I keep thinking about that. And then I only see how I'm not likeable, and then tell myself that other people see the same. But I'm trying to reflect on how I don't see that in everybody else, and then why would they see the same in me?

> Knud: PBL's a great thing to help you grow personally, not just to change your own perspective but also to grow stronger in some perspectives that you hold.

In these reflections, participants relate how experiences with PBL triggered them to reflect on self-perceptions, and behaviors toward others, in search of personal growth. This is not the same as reflecting on academic competences.

For other participants, particularly neurodiverse participants with dyslexia, social anxiety, and autism spectrum disorder, PBL was conceived as an emotionally unsupportive process and hostile environment. This conception led participants to perceive PBL as a source of stress that is harmful to learning, as shown in this quote:

> Asbjorn: The group things weren't going well, and I was also worried that I wouldn't pass anything, and that everything would just … well, collapse for me.

> Elise: I haven't been comfortable enough in this group to actually share some of the very intimate stuff, well, I haven't shared some intimate stuff but in some way I just feel like this diagnosis or this thing will not be accepted.

A third conception shared by most participants sees PBL as a structured methodology for developing content and process skills related to academic scholarship and disciplinary knowledge. This includes connecting theoretical engineering knowledge with practical skills, developing time-management skills, writing skills, learning new practical skills such as coding, welding, design, and so forth. This is illustrated in the following quotes:

> Rune: I've evolved as a writer on the project. I've sort of gotten the methods now to write more effectively and in a higher formal state.

> Sanne: doing the things I learn by reading a book—doing that in practical things, I get from the PBL groupwork. So, I have to get the fundamental knowledge by myself and then I can go and apply it with my group.

4.1.2 | Group-level conceptions of PBL

The second category of conceptions relates to PBL as a group-based process. PBL is seen as a social support process within the university experience. We arrived at this category by observing the language used by the participant: participant referring to PBL using collective nouns like group or people, describing PBL in relation to the group sphere of experience, positioning the participant–phenomenon relationship (student-PBL, in this case) as multilateral. For many participants, the PBL group was where friendships were forged, where support could be found when one was not doing well academically, and the primary source of social interaction in and out of the classroom, as shown by these quotes:

> Lasse: PBL has helped me get some, like, social bonds with people, and helped start like—it helped me very far.

> Casper: I know these people I'm studying with now in it (my PBL group) would probably be the best people I could study with ever, so that's a motivation that I don't want to drop out.

For a large group of participants, however, PBL was conceived more as an arena of interpersonal conflict; a space where personalities and ideas inevitably clash, and a process that ignites tensions around a learning problem:

> Lykke: I feel it's very frustrating when we have jobs to do and people are just sitting there, just like "Oh I don't know what to do," and of course they can ask for help but there's no original reflection or analysis—they basically just copy from a page, and I have to rewrite it, and add comments—it's just such a struggle, oh my god.

Sometimes, interpersonal conflicts play out in ways that can be emotionally harmful to some participants, especially those marginalized by neurodiversity, gender, or nationality.

> Elise: Right now I'm in a group, where I can't say that I am adapting well to it. I … I'm not well. Some people, I can't figure out how they express themselves and somehow I just become desperate to have any kind of response no matter what it is or what mood.

In this conception, disruptive social processes take precedence over disciplinary problem-solving and become the object of the learning focus.

The majority of students conceived of PBL as a structured participant-directed method for learning interpersonal, academic, and professional skills in a way that is not possible in a traditional pedagogical environment. In particular, participants cited collaborative learning skills, the ability to compromise with one another and work with different opinions and competences, to find their place and role in a group, with each other but also with teachers.

> Knud: When you're co-dependent with others you have a much—I kind of want to say a much greater pool of knowledge that you're also, like, using, right? Because now it's not just your own experience, but the experience of everyone else within your group, and if you want to go further than that and talk with some people from other groups they might also have entirely different experiences and perspectives, as well.

> Harald: every time we have a discussion in our PBL group and something ticks in the back of my head, and I just want to control the situation. And I have to hold back not to do that—the other guys have to make their decisions, as well. And yeah—it's become better, but I think in the beginning it was very hard to leave control in other people's hands.

> Mohammed: During the first semester, when our supervisor walks in and gives us his opinion, I would take that as—it's not an opinion. Do it this way. And I think that it shows in our project, that half of it is us and half of it is just very strictly our supervisor, and it didn't mix well together, because we had different opinions, obviously. While, now I am more of the—ok, he's giving us his advice. Consider it. But we don't necessarily have to do it. It's been a huge jump for me.

This conception of PBL focuses mainly on PBL as a learning method that structures interpersonal learning, including teacher–student learning relationships, to render meaningful learning experiences from the group space and problem-solving process. The social process is still important but is subordinate to constructive academic learning outcomes that come from collective problem-solving.

4.1.3 | Society-level conceptions of PBL

The final category of conceptions describes PBL as a structured method for learning real-world skills. We arrived at this category by observing the way collective nouns like group or people were used in an abstract or hypothetical sense, describing PBL in relation to a more general collective experience in which the people in the collective are not (yet) known, positioning the participant–phenomenon relationship (student-PBL, in this case) as neither bilateral nor concretely multilateral, but rather as an abstract multilateral. Being abstract, the participant–phenomenon relationship at this level of conception tends toward the universal, where participants derive from PBL more general, universally applicable lessons. In this conception, PBL is seen as a structured educational method that readies students for future careers as engineers, in jobs that will be team-based, problem-based, and interdisciplinary:

> Erling: The appeal of the PBL model that this university is driving is, due to my own reasoning, that ok, once you're going to work in real life, you will again be in groups with other people and you'll have to still cope with, you'll have to come to agreement with other people even though they might have different views than you, and you'll have to argue with them to find a common base.

> Sanne: I can't imagine that I'll be working alone once I'm an engineer—I'll be working in a group, probably, on some projects with many other people and having to coordinate everything, and all that stuff that seems really stressful and exhausting and I think it's really good that we learn to do it now. And … yeah. Because it is something you have to learn to do.

Participants could give very specific examples of real-world engineering related to their projects, but these examples were narrow: building an app, developing bicycle paths in the city, building a sterling engine, and so forth. Thus, PBL was conceived as an inductive learning method to train engineers for the real world: one project at a time, students build a repository of real-world problems and induce what an engineering career entails from this. PBL was not referred to as a vehicle for taking social responsibility or other more socially-oriented, deductive conceptions.

4.2 | Hierarchy of categories within the outcome space

Having organized the categories according to breadth and inclusivity, we suggest that they relate to each other as follows:

- When PBL is conceived as a hostile environment and unsupportive process (Category 1.A in the outcome space), this causes stress at the individual level. When paired with a conception of PBL as an arena for interpersonal conflict (Category 2.A), this creates a vicious cycle where conflict feeds stress, and stress feeds conflict. PBL is conceived primarily as a process for learning to navigate these difficult personal and social situations, at the expense of learning technical, disciplinary content and academic skills.
- When PBL is conceived as an unsupportive process at the individual level (Category 1.A) but a safe space at the group level (Category 2.B), students can escape the vicious cycle with the support of their group, which can lead to conceiving PBL as a structured method for learning academic skills and contents (Category 1.C).
- When PBL is conceived as a supportive process at the individual level (Category 1.B) but a hostile space at the group level (Category 2.A), students might close in on themselves and focus on PBL as a process for personal growth (Category 1.B), and personal academic development (Category 1.C).
- When PBL is conceived as a supportive process at the individual level (Category 1.B) and a safe space and supportive process at the group level (Category 2.B.), students can focus on developing academic skills and technical knowledge. With this focus, the conception of PBL as a structured method for learning around relevant real-world problems may develop (Category 3).

Finally, our pure phenomenographic approach revealed that there was little mutual exclusivity in the variations of the conceptions. This shows that our participants had nuanced conceptions: those influenced by negative experiences were capable of seeing that PBL is other things beyond a stress trigger or an arena for interpersonal conflict.

5 | DISCUSSION AND IMPLICATIONS FOR PRACTICE

The purpose of this study was to map qualitatively different conceptions of PBL among engineering students into a phenomenographic outcome space. In summary, our study uncovered a hierarchy of conceptions of PBL ranging from individual to societal levels and from a process with a focus on personal and social dynamics to a structured educational method.

The discussion centers on how student conceptions of PBL fit within the broader literature on PBL, particularly around PBL competences, the shortcomings of PBL in handling social processes, and the role of societal issues in PBL.

5.1 | Conceptions of PBL and PBL intended learning outcomes

Systemic PBL curriculum designers have particular competences in mind when they design an undergraduate program (Holgaard & Kolmos, 2019). They might expect that students who follow the P0–P3 induction into PBL hold conceptions of PBL that are broadly compatible with this competence framework. It is, therefore, interesting to evaluate this against our findings.

Our study shows that the conceptions of PBL held by the majority of participants did indeed align with the ILOs of the PBL induction track. Interpersonal and meta-cognitive competences related to optimizing individual learning, motivation, formulating individual and collective learning strategies, and structural project competences fit well with our findings. This indicates that participants understood and experienced the potential of PBL to expand their interpersonal and metacognitive skillset. Some participants for whom negative conceptions of PBL dominated justified persevering with PBL on the basis of the benefits of acquiring these interpersonal competences. Looking at the processes that participants went through as learners, those holding conceptions of PBL as a structured educational method could be said to have experienced a change in their understanding of knowledge similar to that observed in the personal epistemology literature (Elby, 2009; Hofer, 2001; Hofer & Bendixen, 2012). As their grasp of PBL increased between P0 and P3, participants may have experienced a change from viewing knowledge in dualistic terms of right and wrong to relativistic terms that tolerate ambiguity. However, the conceptions of PBL pertained to PBL as a process, environment, and learning methodology; none of the participants referred to the nature of knowledge per se. This is likely because the phenomenographic design of the study focused on the relationship between participants and PBL rather than the mental processes of participants regarding learning and epistemology (which are two distinct constructs, see Elby, 2009). A study of personal epistemologies in students working in a systemic PBL environment using a phenomenological design might shed further light on this subject.

We found that participants' conceptions of PBL sat outside of the ILOs of PBL on two counts: first, the ILOs of PBL, as defined by Holgaard and Kolmos (2019), do not integrate competences pertaining to personal development and do not reflect the social process conceptions held by participants. Second, participants' conceptions of PBL fell outside the scope of the ILOs in terms of structural competences and problem-oriented competences discussed in the research framework.

5.2 | PBL as a social process, engineering identity, and reflection

The ILOs of PBL cover a broad range of academic and professional skills but do not include personal development or negotiating dysfunctional group dynamics. For instance, reflection is generally discussed in the PBL literature in light of Kolb's theory of meta-cognitive competences (Holgaard & Kolmos, 2019; Illeris, 2002; Vos & De Graaff, 2004). In this approach, practice and metacognition feed into each other to enhance learning. However, the type of reflection included in Kolb's metacognition remains at the cognitive level. The literature does not include questions of personal or emotional development, particularly linked to engineering identity, with some peripheral exceptions (Du, 2011; Servant-Miklos et al., 2020). Yet we found widespread conceptions of PBL as a process for personal development and an arena for interpersonal conflict. One might argue that interpersonal conflict is simply the flip side of the interpersonal competence coin. But unless active attention is given to self-reflection, including reflection on emotions, personal growth, and group dynamics, students may never cross the bridge from interpersonal conflicts to collaboration. This has important consequences on the types of engineering identities that evolve from the PBL process—seeing how conceptions of PBL as a process for personal growth are tied into engineering identity development (Section 4.1.1). For instance, if students see PBL as a supportive social process, this might support the development of more collaborative engineering identities, whereas seeing it as an unsupportive social process and a hostile environment may create competitive engineering identities. We would argue that in systemic PBL, dominant conceptions of PBL play an important role in the campus culture. Given the impact of campus culture on determining engineering identities (Tonso, 2006), this reinforces feedback loops that determine the engineering identities that emerge.

The specific feedback between PBL, campus culture, and engineering identities would merit a deeper investigation that sits outside the scope of this phenomenography. Perhaps systemic PBL universities could investigate the experiences of Alverno College in terms of integrating campus culture into the learning process through reflection (Diez et al., 2010). In this American college, the curriculum emphasizes the moral purpose of education as part of students' self-assessment and feedback practices. This makes students reflectively aware of dimensions of learning that fall outside the strictures of the Kolb cycle, pertaining to the question of identity and culture instead.

Based on the results of this study, we suggest that facilitating a more structured reflection on the emotional impact and group dynamics involved in systemic PBL may mitigate conceptions of PBL as an unsupportive process and hostile environment. This would challenge current educational practices around PBL in engineering education, wherein such reflection competences are not commonly considered. Our findings show that the potential for such reflection is already included among the most prominent conceptions of PBL that students hold. In practice, it would be unlikely to meet much resistance from students.

If a broader definition of reflection were included in the engineering curriculum, this could address conceptions of PBL at all three levels identified in this study. This would be particularly fruitful if it included reflection on a theoretical level linked with concrete practices of PBL. One might draw inspiration from the Articulated Learning Reflection process drawn up for service-learning by Ash and Clayton (2004). In Articulated Learning, students formulate reflections as learning experiences, following what, how, why, and goals questions, upon which a critical thinking framework is applied (accuracy, clarity, relevance, depth, breadth, logic, significance) to articulate reflections between practical and conceptual levels. This could de-dramatize conflictual interpersonal situations by reframing them as part of a learning process from which students stand to gain personally and as a group. Another approach for assembling reflection at all three levels of conceptualization is to utilize the concept of exemplarity that sits at the heart of the original intent of PBL (Christiansen, 1999), to help students make the link between individual experience and collective phenomena. Exemplarity is an inductive learning approach pioneered by Oskar Negt in the 1970s that consists in engaging with theoretical and structural concerns through concrete examples grounded in the lived experience of learners (Servant-Miklos & Guerra, 2019). Project problems were originally meant to provide an exemplary springboard toward broader theoretical and societal issues (Servant-Miklos & Spliid, 2017).

5.3 | Limited society-level conceptions

We studied conceptions of PBL at the start of the P0–P3 induction period. This is an interesting time when PBL is most consciously present in participants' minds, but it also comes with limitations. It may be that student conceptions of PBL change at the postgraduate level, for instance, to emphasize societal issues and professional outlook, whereas our participants' societal-level conceptions of PBL were limited to seeing PBL as a structured method for developing real-world engineering knowledge and skills. They did not really think of PBL as a conduit for investigating broader societal problems. That is not to say that they were not interested in these problems, but such concerns were not seen as integral to PBL.

One issue with PBL as it is applied in engineering education today is the tendency to focus on disciplinary problems at the expense of interdisciplinary issues and complex challenges (Guerra, 2014; Kolmos, 1996). If engineering educators feel that designing pedagogies that stimulate broader societal thinking is an important part of future engineering education practices, then engineering students could be exposed to situations where they apply and integrate their discipline and subdisciplines into real-world problem situations from the start of their studies. It has been suggested that emphasizing exemplarity could help engineering students to see the relationship between their studies and wider societal issues, particularly sustainability issues (Servant-Miklos & Guerra, 2019). Through exemplarity, the importance of collaborative skills in working together toward common solutions to complex problems becomes apparent. Within a systemic PBL environment, teachers could harness the potential of PBL as a supportive social process to stimulate feelings of communal belonging through team efforts to tackle complex societal problems. This could be done in line with the United Nations Sustainable Development Goals (UNSDGs), which provide a simple framework for engineering education to break down sustainability issues into manageable chunks while retaining a sense of the whole system (Mann et al., 2020).

Staff and faculty have a role to play in creating campus cultures focused on real-world relevance and social responsibility—through the choice of problem themes, course contents that run alongside projects, project supervision, and the integration of exemplary reflection practices. The literature indicates that societal impact is a key feature in the future of engineering education (Duderstadt, 2008). However, it might be interesting to investigate whether educators hold societal conceptions of PBL through a phenomenographic study.

6 | LIMITATIONS AND FUTURE WORKS

This study was subject to certain limitations. First, our study was done at one university in Denmark, which may have given the answers a certain cultural bias, including a bias in terms of campus cultures. Second, our study only looked at conceptions held by students, not faculty and other staff. As we mentioned, it is possible that conceptions of PBL depicted by PBL scholars in the literature differ from the conceptions held by on-the-ground teachers. Third, although we found the period at the start of P3 to be a particularly interesting moment to look at student conceptions of PBL, one might repeat the experiment with students at a higher level of study to gain insights into conceptions of PBL at the postgraduate level. Fourth, our study assumed participant gender along a binary—this should be read in the cultural context of Northern Jutland, where this study was conducted. Discussions on gender self-identification have not yet permeated the regional culture and would have come across as uncomfortable or hostile to participants. We left space for participants to discuss gender in any direction they chose during the interviews, but we realized that the discussion on gender identity is moving research methodologies toward more pro-active engagement with gender self-identification.

Future works on student conceptions of PBL might, as suggested, take a phenomenological design to investigate students' personal epistemology. Another possibility is to investigate personal epistemology in PBL using a deductive approach, such as theory-led thematic analysis (Braun & Clarke, 2014). In such an approach, the researcher would not be looking for new categories but rather testing to what extent and how theoretically derived categories manifest in the interview data.

There are practical implications of this study: structured reflection practices and exemplarity could be included in faculty development programs for PBL. This could be done within the regular faculty development tracks of individual universities or centralized through international conferences and international engineering education centers. These practices could also be included in the growing body of open online resources for PBL practitioners (Holgaard et al., 2020).

7 | CONCLUSION

We performed a phenomenographic study of the qualitative variations in students' conceptions of systemic problem-oriented project work in engineering education. Through this research, we uncovered categories of descriptions of PBL organized from individual to societal level. Our findings showed that there are interesting parallels between conceptions of PBL held by participants and the ILOs of PBL proposed in the literature. But there are also several conceptions that raise new issues for PBL scholars and educators. The conceptions of PBL as a structured educational method echo the interpersonal competences ILOs of PBL that are developed through the P0–P3 period. However, students crave more attention to personal growth and conflictual group dynamics processes that are not sufficiently developed in the current practice of PBL. At the same time, students largely do not see societal issues as integral to PBL beyond the set of real-world skills they acquire through project work. Yet encroaching global threats such as climate change and pandemics suggest that it might be important to raise a more social angle on problems in PBL at all levels of engineering studies, in line with the UNSDGs.

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