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Faculty Conceptions of Tensions in PBL Implementation in Early Undergraduate Engineering Education*

ANGELA VAN BARNEVELD
Lakehead University, 955 Oliver Rd, Thunder Bay, ON P7B 5E1, Canada. E-mail: avanbar@lakeheadu.ca

JOHANNES STROBEL
University of Texas at El Paso, 500 W University Ave, El Paso, TX 79968, USA. E-mail: jmstrobel@utep.edu

Problem-based learning (PBL) is used in upper-level and increasingly in earlier years of engineering education. By implementing PBL, comfortable routines are disrupted for both educators and students, creating tensions. Using a methodological framework of phenomenography, this study explored the variation in engineering educators' conception and experience of the tensions when implementing PBL in the first two years of undergraduate engineering education. Results revealed that engineering educators' experiences of implementing PBL in the first two years are described by three predominant tensions. Faculty experiences of the key tensions associated with the implementation of PBL and their conception of these tensions (student, instructor, institutional) play a critical role in the development of instructional strategies for incorporating PBL into the engineering curriculum in the early years. The findings of this study can inform the development of support structures and teaching development programs for engineering faculty.

Keywords: faculty understanding; first-year engineering; phenomenography; problem-based learning; sophomore engineering; tensions

1. Introduction

Engineering educators are facing high demands as they are challenged to create learning environments that can not only better teach technical skills, but also incorporate process skills and foster other graduate attributes. Problem-based learning (PBL) and its variants have been deemed adequate for meeting the needs of educators and society in preparing the engineers of the 21st century. However, PBL inevitably disrupts the familiar flow and structure of classroom activity and forces both educators and students out of their comfort zone [8]). In addition to having to manage changes within their classroom processes and routines, engineering educators must also interact with and operate within the larger system of their college and university. The structure and culture of the college/ university may facilitate or hinder the teaching intentions and goals of educators, as this larger system can impose its own set of tensions.

Often, PBL (and variations) are implemented in later years of an engineering program so that students have the opportunity to apply the foundational engineering and basic science knowledge they acquired earlier in the curriculum [12]. However, engineering faculty have recognized and acknowledged the need to implement problem-based pedagogies earlier in the program [3] to provide early opportunities to develop and integrate technical skills, process skills (e.g., problem solving, communication, and teamwork); to demonstrate linkages between course content and real life engineering [38]; to prepare students to understand the role of engineers in society [26]; and to increase student retention in engineering programs [43].

This study investigated the qualitatively different ways in which engineering educators experience tensions related to the introduction of PBL into their own teaching practices. The research questions were (1) Based on their teaching practices, what are the predominant tensions encountered by engineering educators? (2) What are the qualitatively different ways in which engineering educators experience tensions with a PBL implementation in their teaching practices?

2. Literature Review

Engineering departments are challenged to better prepare engineering graduates for professional practice, and to help them transfer knowledge and skills to practice [51]. One of the learner-centered pedagogical models used in engineering is Problem-based Learning (PBL) [21]. In the context of this study, the definition of PBL is informed by Barrows [7] and Savery [44]), and remains intentionally broad and inclusive of other problem-focused pedagogies such as project-based learning (PjBL) [16], problem-oriented project-based learning (POPBL) [33] and design-based curriculum initiatives in engineering education [46]. Therefore, in the rest of this article, PBL is described as a supported learner-centered environment that makes use of ill-structured problems as the basis for learning technical and process competencies, and for developing pro-

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fessional attitudes. Problem-based pedagogies have been demonstrated as effective for long-term knowledge retention, skill development, student and faculty satisfaction [47] including in the domain of engineering [28], as well as increased motivation and engagement of students, increased self-directed learning skills, and an increased integration of theory and practice [42].

Most engineering educators implement PBL of their own accord and in an incremental fashion [11]. Schneckenberg [45] mentioned that as faculty consider adoption, they face tensions at the various levels of the systems and contexts in which they were embedded – common when implementing any new pedagogical innovation [15]. Barriers that impact adoption of innovations can be structural [6] or cultural [5]. Structural barriers are related to the status and priorities of faculty, while cultural barriers are related to the basic values of teaching and research within the institution [45]). Tensions exist between the desired outcomes of education and the affordances that actually exist within the institutional system. Researchers identified five tensions specific to engineering education reform including individual versus organization value assigned to teaching [14, 50], theory versus practice/application [49], well-structured classroom problems versus ill-structured real-world problems [2, 24] single-discipline versus interdisciplinary content [19], and problem-solving versus design [24, 41].

PBL implementation comes with its own set of five tensions [27]: (1) depth versus breadth of curriculum, (2) higher order thinking versus factual knowledge acquisition, (3) long-term effects versus immediate learning outcomes, (4) students' initial discomfort versus their positive attitudes, and (5) traditional role of instructor versus role of facilitator/guide. The paradigm shift required for PBL implementation in engineering education challenges conventional, familiar, and habitual perspectives held by educators and their discipline-specific teaching practices [31]. Additionally, the classroom system is nested within a larger system at the institutional level that carries its own goals, values, culture, structure, processes, and procedures. How engineering educators experience these tensions while implementing PBL remains largely unexplored.

3. Research Approach

The purpose of this study was to describe the variation in engineering educators' ways of experiencing and conceptualizing the tensions within PBL-type implementations in their teaching practice. As such we chose phenomenography-a methodological approach explicitly concerned with the ways in which people experience and conceptualize phenomena, and one that has been identified as an emerging methodology in engineering education research [10]. Phenomenography is a methodology emphasizing the variation in ways people experience phenomena, which are then organized into categories of description [1, 9, 22, 37].

4. Design of Study

4.1 Participants

We recruited participants via a survey distributed to engineering faculty in the US. In the survey, participants were informed that the definition of PBL was intentionally broad and inclusive, consisting of common criteria adapted from Savery [44] that focused on (1) use of real-world design, project, or problem scenarios, (2) multiple possible solutions (complex, open-ended), (3) role of the instructor is predominantly facilitator/guide, and (4) students are engaged in active learning. In the first stage of sampling, the inclusion criteria consisted of faculty who reported: (1) teaching at a degree-granting higher education institution in the United States, (2) holding a faculty position, (3) teaching in an engineering program, and (4) implementing PBL at least twice within the last 2 years. The survey respondents (n = 313) served as the population from which the interview participants were further sampled.

The second stage employed "purposeful sampling" [39], which resulted in the final selection of survey respondents invited to participate in semi-structured interviews. The criteria used to select and invite participants to be interviewed were: (1) PBL implementation in one's own course, (2) PBL implementation in Year 1 and/or Year 2 of undergraduate engineering programs. Lastly, to ensure a high probability that the selected sample comprised a range of differences in faculty conceptions of the PBL tensions, participants were chosen for maximum diversity across five criteria of variation: sex, geography, institution type, years of experience, and engineering domain.

To determine an optimal sample size, a review of 25 studies using phenomenography was undertaken [48], indicating that the sample size for phenomenographic studies tended to fall within a range of 12 to 28 cases. For this study, the final sample of the qualitative study of 14 was felt to be adequate.

4.1.1 Interview Participants

Male educators made up 57% (n = 8) of the sample while female educators made up 43% (n = 6) of the sample. The average age of the participants was 48.6 years (SD = 13 years) for male educators and

42 years (SD = 7 years) for female educators. With regard to years of experience teaching undergraduate engineering, 2 (14%) had between 1–5 years, 3 (21%) had 6-10 years of experience, 6 (42%) had 11–20 years of experience, and 3 (21%) had over 21 years of teaching experience. The participants represented 11 different states in the US.

With regard to faculty role, participants (n = 14) held the following ranks: full professor (4 or 29%), associate professor (6 or 42%), and assistant professor (4 or 29%). The engineering domains represented were Mechanical (6 or 42%), Civil (4 or 29%), Materials (2 or 14%), and Biological, Chemical, and Environmental/Ecological (each with 1 or 7%).

The majority of interview participants (7 or 50%) came from large research universities, while the rest came from Master's programs (5 or 36%) and special focus institutions like schools of engineering (2 or 14%).

4.1.2 Data Collection

The authors constructed a semi-structured interview protocol. Interview questions were piloted with five engineering educators for clarity and to ensure that responses were relevant for addressing the research questions. Interviewing is the main data collection strategy in phenomenographic research, where the intent is to capture and describe the participant's experience and conceptions of the phenomenon in their particular context [1]. The first author conducted hour-long semi-structured interviews with all 14 engineering educators. All interviews were digitally recorded, transcribed verbatim and verified for accuracy.

4.1.3 Data Analysis

Analysis of the transcripts served to develop pools of meaning, seeking to identify the variations in the experience of the phenomenon [23]. This was accomplished through a combination of deductive and inductive coding [18]). In this study, the 10 tensions – five engineering education reform (institutional) tensions [2, 14, 19, 24, 41, 49–50] and five PBL implementation tensions [27] mentioned earlier – were used as predetermined codes and deductive coding was used initially to identify and sort transcript utterances that reflected the tensions that engineering educators discussed. These utterances then served as the text upon which open coding was performed in order to establish an initial set of themes. The utterances were then grouped into themes and, once the themes were established, all transcripts were coded against the new themes. Modifications and revisions were made to themes as required in order to ensure uniqueness in the themes. Axial coding was used to further collapse the themes and develop categories of description of participants' experiences and understanding of tensions. As per phenomenographic research analysis, these transcripts and categories were reviewed iteratively to ensure that categories of description were defined as separate and distinct from each other, yet logically related [22]. Finally, the categories of description were hierarchically assembled to represent the outcome space, which represented the overall conceptualization of the phenomenon. When new tensions emerged, we predominantly reported nuances and "flavors" and provided a semi-hierarchical representation to provide structure and classification of the expanded set of tensions. (see Fig. 1 for visual of the data analysis process).

4.1.4 Trustworthiness – Validity and Reliability

Golafshani [20] suggested that within the qualitative research paradigm, trustworthiness in the form of validity and reliability should be addressed: In

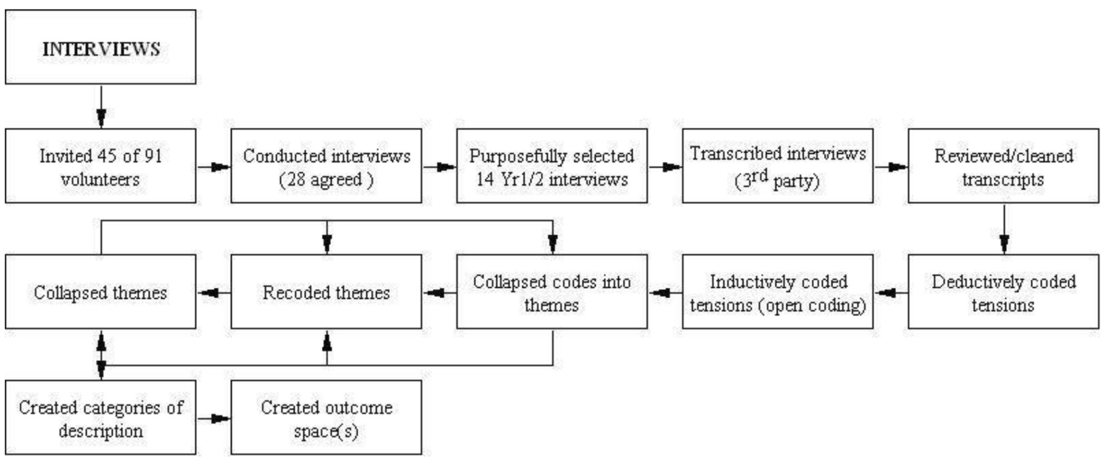

Fig. 1. Process of phenomenographic data analysis – Variation in experiencing tensions.

this project, validity was established with the use of multiple data coders, and member checks to validate researcher interpretations. Regarding reliability, the authors engaged experts at various points in the analysis of data. Experts were chosen as methodological experts in phenomenography and PBL implementation. The team shared research processes, themes, emerging results and early outcome space mapping for review and critical feedback.

5. Results and Discussion

Phenomenographic analysis resulted in three qualitatively different ways that engineering educators experienced and conceptualized tensions when implementing PBL in the first two years of the undergraduate engineering curriculum: student discomfort with the initial transition to PBL, the role of the educator as facilitator rather than teacher, and the value assigned to teaching by the individual and the organization. The perceived tensions and variations in conceptualizations of the tensions are presented next in summary and in detail (Table 1).

5.1 Conceptualizations of the Tension of Student Discomfort with the Transition to PBL Versus Positive Attitudes once the Transition is Made

Educators' conceptualization of this tension addressed student entry into, and expectations of, the higher education learning environment. The variations in their conceptualizations generated three categories of description that represented the increasingly complex ways of understanding the discomfort of students as they transitioned into a new way of learning and into higher education (see Fig. 2).

Category 1. Student Discomfort as a Lack of Readiness with Regard to Knowledge, Skills, and Attitude

Category 1 depicts the conceptualization of this tension as one of lack of student readiness with regard to entry skills from high school and foundational knowledge for engineering. Limited experience with self-directed learning, working in teams, and dealing with open-ended problems were key

Table 1. Summary of perceptions and conceptualizations of tensions

Perceived tensions	Variation in conceptualization of tensions
Student discomfort with the transition to PBL versus positive attitudes once transition is made.	Student discomfort as: • A lack of readiness regarding knowledge, skills, and attitude. • Dissonance of student expectations between their old learning environment and their new learning environment. • Transition to the new learning environment (PBL).
Individual versus organizational value assigned to teaching	Value assigned to teaching as: • Indifference. • Colleagues' skepticism about PBL. • A misalignment within the system.
Role as instructor versus facilitator	Educator role as: • Content provider – *what I know*. • Process advocate – *what I do*. • Learning (re)constructivist – *who I am*.

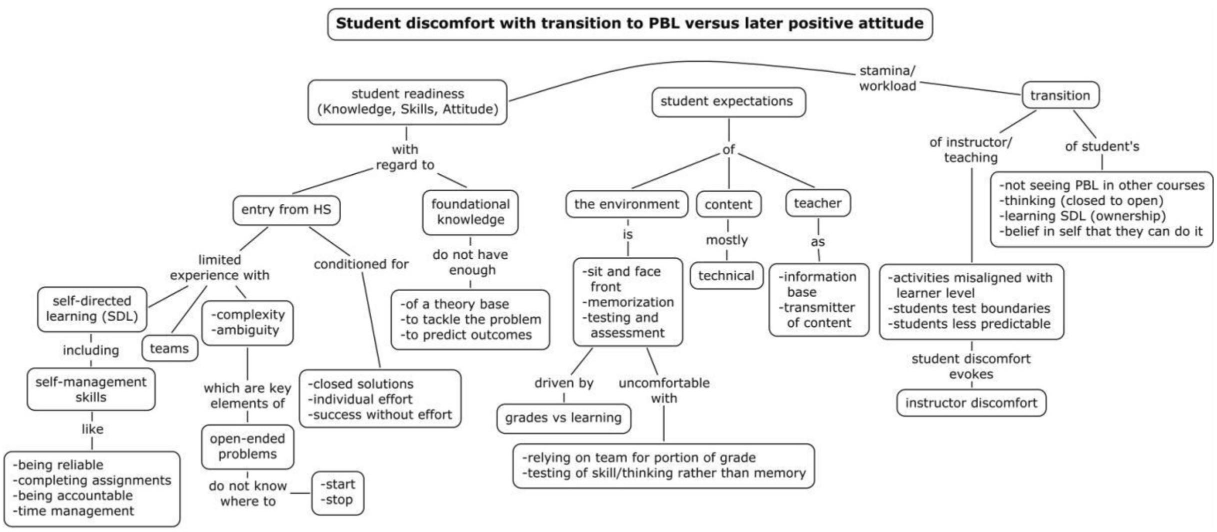

Fig. 2. Engineering educators' conceptualizations of the tension of student discomfort with the transition to PBL.

attributes related to entry skills from high school, as was the attribute of being conditioned to be a learner in the high school learning environment.

Self-directed learning, being able to manage and monitor one's learning are important skills that can be developed through engagement in PBL [43]. An initial understanding of the tension of student discomfort included this lack of experience with self-directedness and an element of student immaturity in being able to manage their time and efforts.

> Lisa: "They're freshman . . . the immaturity . . . they've never been given this kind of freedom to just do it on their own."

The conceptualizations of the engineering educators in this study with regard to student readiness are corroborated by research that looked at the students' perceptions of the transition into the first year of university, mainly that students felt under- and unprepared [32].

Limited exposure to open-ended problems, a key component in engineering design [41] was part of how the tension of students' initial transition to PBL was understood by these educators.

> Sam: "And if you get into open-ended problem-based project-based stuff depending on how open-ended you make it, they've just never seen anything like that before."

Additionally, part of the student discomfort was understood as the conditioning of the students to be learners in a high school environment. The predominance of single-solution, textbook problems and the prioritization of individual effort and achievement were understood to be the norm, rather than the open-endedness of problems encountered in engineering education and in the real world, and the greater significance placed on collaborative work. The other view of these educators was that students were conditioned to expect success in high school without the corresponding effort required. This, of course, is not the image or the reality of student workload or effort required in undergraduate engineering programs, where curriculum has been described as "extended and overloaded . . . congested beyond endurance" [46].

> Lisa: "It's a huge step because everything they've done so far has been so cookbook."

Finally, student discomfort was understood as a lack of foundational knowledge. Students did not have enough of a theoretical or experiential base to be able to work with open-ended problems.

> Hannah: "I can't give them free reign over it." They need some basic understanding of what the problem is because they don't have the background.

This perspective appeared to be disconnected from other research indicating that foundational content was acquired as part of the experience of engaging in PBL rather than being a precursor to PBL [29].

Category 2: Student Discomfort as Dissonance of Student Expectations Between Their Old Learning Environment and Their New Learning Environment

This category increases in complexity from Category 1 in that the conceptualization of tensions now moves from the readiness of the student before he/she gets to the program to their engagement in the engineering program where student expectations and contextual reality of being an engineering student may be dissonant. Student expectations may be, in essence, a product of their old learning environments. The three key attributes in this category are the students' expectations of the environment, the content, and the teacher.

Students may expect the engineering learning environment to require them to sit and face front and memorize technical content, all in a very teacher-centered setting [46]. The teacher may be expected to be the information base and the purveyor of content – the one who decides on the content and transmits it to the students. While this may be the case in more traditional approaches to engineering education, the PBL learning environment is more student-centered and focuses on both content and process skill development [17].

> Hannah: "The students are really resistant to problem-based learning. They come from traditional high schools where the teacher is the information base and they don't like having to learn for themselves."

With regard to assessment, understanding student discomfort may relate to students expecting that tests will focus on rote memorization as opposed to assessing their skills and thinking. Also, where students expected to rely on themselves for their grades, the introduction of team-based projects and team grades was uncomfortable.

> Hannah: "They're not comfortable with the fact that the test isn't the same and they don't just work the problems in order to get the grade. And they're also not comfortable with the fact that it's their skills being tested as opposed to 'can I memorize this equation.' "

Category 3: Student Discomfort as a Transition to The New Learning Environment (PBL)

This category differs from Category 2 in that the tension of student discomfort is now conceptualized as a transition into the PBL learning environment. The key attributes in the category were the transition of student and of the instructor/teacher. For the student, the process of transitioning required time and effort to modify one's thinking, accept greater ownership for one's own learning, and develop confidence in one's ability to learn in this new environment.

Sally: "But that kind of transition from close-ended thinking to open-ended thinking, it can be painful."

The conceptualization of this tension also seemed to encompass the educator's transition. Interestingly, in this category, there was the suggestion that student discomfort may evoke instructor discomfort, seemingly due to the unpredictability of behavior and questions.

Lisa: "With the freshman it's just . . . it's a little bit stressful every single week. You never know if it's going to happen."

The educator was asking the students to engage in a different type of learning, a deeper learning that was a departure from what was historically familiar to students coming from a high school setting.

To summarize, educators conceptualized the first tension of students' initial discomfort with the transition to PBL as (1) a lack of readiness with regard to knowledge, skills, and attitude at the time of their entry into the program from high school, (2) dissonance in student expectations between their old learning environments and their new learning environment, and (3) the transition to the new learning environment (PBL).

5.2 Conceptualizations of the Tension of Individual Versus Organizational Value Assigned to Teaching

Three categories of description emerged, each depicting variation in the experience of the tension as well as a relationship between categories that represented the increasingly complex ways of understanding the phenomenon – the tension between the individual and the organizational value assigned to teaching (see Fig. 3).

Category 1: Value Assigned to Teaching as Indifference

Category 1 depicted the educators' conceptualization of this tension as indifference to his/her innovative efforts on the part of others with regard to the use of PBL. The key attributes of this category included the perception of superficial support and a lack of acknowledgement of the time and effort required to implement PBL. While educators could make the personal choice to implement PBL in their teaching practice, they were not free of the constraints set by the larger context. A lack of interference could not necessarily be translated into a show of support when no measures were taken to facilitate the educators' use of innovative pedagogies.

Sally: "Some people don't want to do what I do and that's fine, but certainly no one is stopping me from doing what I am doing."

The implementation of PBL was to take place on the educators' own time and, as reported below, usually without acknowledgement or recognition [25]. Additional support (i.e., time, resources) was not evident.

Mike: "It takes a lot of time outside which I don't think others understand. But you know, if you teach a class, they think you're going to need an hour to prepare it but, in an hour to prepare, you're really not going to be able to plan some of these problems out."

Engineering educators were challenged by the time and effort required to design meaningful learning experiences for students. Clancy [13] found the same issue when conducting a professional development session for college educators and reported that educators expressed concerns about time, class size, developing appropriate problems, the assessment process, and support.

One area where educators felt the lack of support was in the preparation of PBL, particularly in the time it took to generate problems. The educators in this study acknowledged that the quality of the problems in their PBL courses was an important factor in meaningful learning for students. This perspective aligns with Clancy [13] and Leppävirta et al. [34].

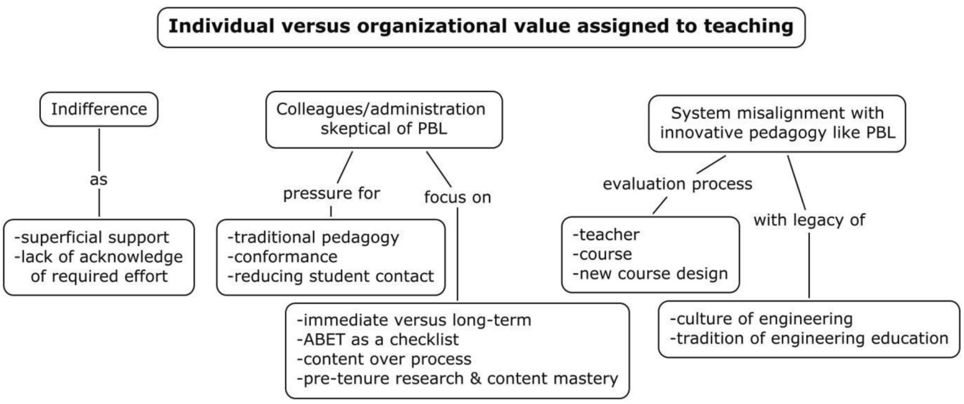

Fig. 3. Engineering educators' conceptualizations of the tension of individual versus organizational value assigned to teaching.

Category 2: Value Assigned to Teaching as Colleagues' Skepticism about PBL

This category evidenced the engineering educators' conceptualization of the value assigned to teaching as skepticism of fellow faculty and administration about PBL. This category had a broader focus on the conceptualization of the tension than in Category 1 which was situated at the individual level. Key attributes of this category included a focus on maintenance of the traditional educational setting, and pressure to conform to established teaching methods by colleagues who questioned why things needed to change.

> Simon: "I have in the past felt some pressure from administrators to stop trying new things, to stop putting effort into pedagogical and curricular innovation, and to shift my efforts elsewhere."

This difference in perspective on the conceptualization of the value assigned to teaching is similarly reflected in Anderson et al.'s [4] observation that "teaching load" often carries negative connotations.

Category 3: Value Assigned to Teaching as a Misalignment Within the System

This category differs from Category 2 in that it encompasses more than the individual and the faculty value assigned to teaching, and moves it into the systemic level, making it a more complex conceptualization of the tension. The key attributes included system legacy processes and legacy culture. The focus on research over teaching remained strong, while traditional processes for teacher and course evaluation were perceived to be ineffective in capturing the innovative approach to teaching used by the educators in this study. Study participants seemed to propose that the evaluation processes were not only misaligned with PBL and more aligned with lecture-based teaching, but were superficial at best.

> Colin: "It's the old story if you get teacher of the year at the research school, you can kiss tenure good bye."

The presented research here aligns with Wright [50] who found that the tension between individual instructor value assigned to teaching and the instructor's perception of the organization's value assigned to teaching was more evident in large research universities than it was in two or four-year institutions. In this study, 50% of the interview participants (n = 7) came from research-intensive universities and while not specifically analyzed for differences in conceptualizations based on classification type of institutions, the outcome space of engineering educators' conceptualization of this tension seem to align with Wright's findings.

In summary, engineering educators' conceptualizations of the second tension of the individual versus organizational value assigned to teaching formed the outcome space depicted in Fig. 3. The outcome space evidenced the increasingly complex interaction between the individual educator, his/her faculty/administration, and the larger legacy system of the university and the culture of engineering education.

5.3 Engineering Educators' Conceptualizations of the Tension of Traditional Role as Instructor Versus the Role as Facilitator

With regard to how engineering educators in this study understood the tension of instructor versus facilitator, three categories of description emerged. These categories demonstrated not only the progression from a narrower conceptualization of one's role (content provider) to a more evolved conceptualization (identity formation), but also demonstrated the hierarchical relationship between what one knows, what one does, and who one is (see Fig. 4)

Category 1: Educator Role as Content Provider

Category 1 depicts the role of the educator within the PBL environment as one of being a content provider. That is, the focus seemed to be not only on the imperative of content or subject matter mastery of the instructor, but also on being able to give the content to the student. The key attributes in this category include being a content expert and being able to answer students' questions at the time questions are asked. Here, the educator may understand his/her role as controller of content as well as deliverer of content.

> Lisa: "I think if I were a brand-new teacher, I would not feel confident enough in my knowledge level to do that. *Interviewer: Your content knowledge level or pedagogical content knowledge?* Content knowledge level – that I would be afraid that they would ask me something that I wouldn't know the answer and I would look stupid."

This category appeared to reinforce the "*what I know*" aspect of the conceptualization of this tension. Subject matter expertise was indeed critical to the role of the educator in that one needs to know engineering content in order to teach engineering content. The conceptualization of the role of instructor as content provider appeared to be teacher-centered. This perspective aligns with Prosser et al. [40] who indicated that where the conceptualization of teaching was more teacher-oriented, the discussion seemed to be more focused on delivery of content and gravitated toward information transmission.

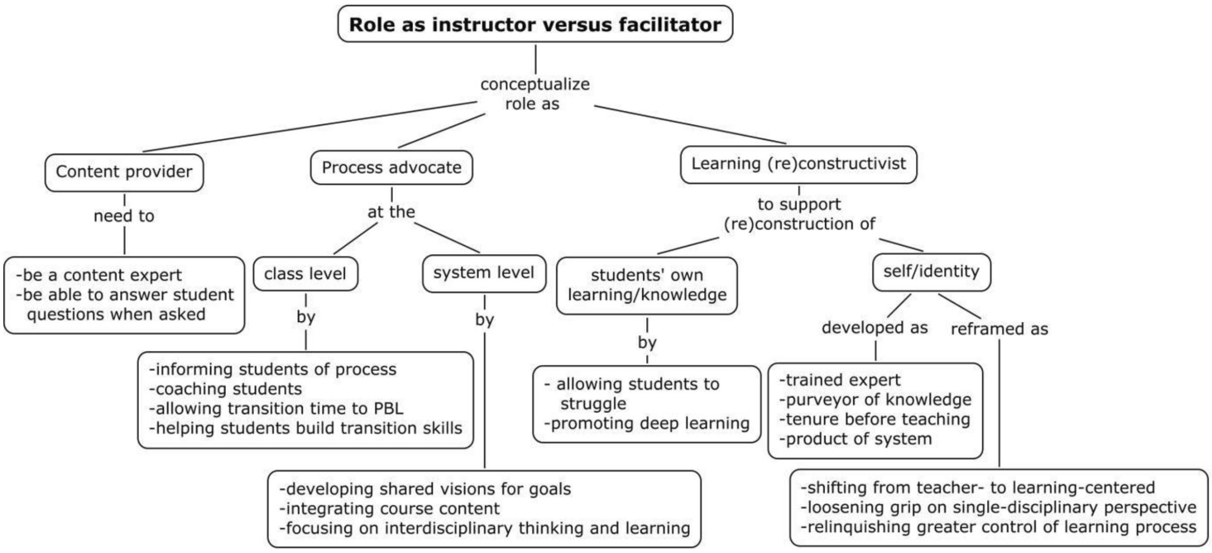

Fig. 4. Engineering educators' conceptualizations of the tension of their role as instructor versus their role as facilitator.

Category 2: Educator Role as Process Advocate

Category 2 represents the role of the educator in the PBL environment as being an advocate of the process of learning in a PBL environment. Key attributes included advocating and supporting process change at the classroom level, as well as at the system level. This category was different than the previous one in that the focus moved beyond instructor content knowledge and delivery being a requirement and now included pedagogical knowledge as a critical aspect of the role.

At the classroom level, educators continued to inform, coach, and support students in the PBL process, but also helped the students build transitioning skills (for the transition from non-PBL experiences into a PBL-centered class).

> Carla: "I put it on my syllabus. I'm a coach...But I don't think other faculty who have been in it [teaching engineering] for a long time see it the same way."

At the system level, educators attempted to promote the PBL process by engaging in efforts with other faculty to move beyond segmented content presented in disconnected fashion. While not always successful in actual execution, the effort to pursue and advocate for shared visions, integrated content, and interdisciplinary perspectives was evident in this category.

> Simon: "When we started putting faculty teams together and asking them to co-design and co-implement an integrated course block, you immediately saw this tension develop between the content-focused people or content-focused goals and more process-oriented people or goals . . . it created enormous tension."

This category reinforced the "*what I do*" conceptualization of the role, moving the educators' understanding of their role from the more static knowledge giver to a more active and engaged advocate of the PBL process with students and faculty. This conceptualization of process advocate and student-centeredness aligns with Prosser et al. [40] who found that educators who had a more holistic view of their subject matter content tended to focus their role as educator on helping students acquire conceptual knowledge rather than just having students be recipients of content delivered in a didactic format. It also aligns with Åkerlind's [1] work that revealed that educators experienced an increased sophistication of their understanding of their field by acquiring a greater comprehension of a particular teaching method. In this case, the commitment to working within a PBL environment and the perspective of student-centeredness seemed to be a co-evolution of the conceptualization of the role of instructor versus facilitator.

Category 3: Educator Role as a Learning (re)constructivist

This category is differentiated from Category 2 in that the conceptualization of the role was now focused on transformative aspects of instructor versus facilitator. Key attributes included support of students in (re)constructing their own learning, as well as an introspective reconstruction or reframing of the instructor's own identity as an engineering educator. The role of learning (re)constructivist aligns with Kember and Kwan's [30] view that a more sophisticated view of the instructor-facilitator role was that of facilitating students in becoming independent learners. The reframing of the educators' identity may reflect the change of perspective that being an educator goes beyond the content provided to or the concepts acquired by students.

While the educators in this study were trained to be engineering researchers, it may be that, by virtue of engaging and participating in innovative pedagogical practices, they started to reflect upon and reconceptualize their roles as engineering educators. An awareness of the different ways of being an educator was evident and, while the engineering researcher identity was borne of the education system that developed them, the evolution from an engineering researcher identity to an engineering educator identity was largely a personal journey.

The educators in this study demonstrated awareness of how their identity was initially formed, being trained in the higher education arena to be a domain expert, researcher, and a purveyor of knowledge.

> George: "It's not what we're trained to do – to be a kind of a moderator as opposed to professor. It's why traditionally for 400 years we've been called professors . . . We're trained to become an expert and then to sit there and tell everybody about it and professors love to talk."

And finally, one can actually reframe one's identity, perhaps moving from the identity-developed to the identity-transformed. It is understandable that one's identity as an engineering researcher is birthed in the specialized knowledge, skills, and expertise in a certain domain, and resistance to change may come when that identity is threatened (e.g., moving out of expertise – see Simon's comment below). In view of reframing one's identity, educators shifted their perspective from teacher- to learner-centered, established a comfort with working beyond their own disciplines, and relinquished control over some aspects of the students' learning experiences. By being in a learning environment where the educator challenged the students to engage in deeper learning experiences that required students to construct and/or reconstruct their own learning, relinquishing greater control to the students may be necessary in order for them to achieve the deeper learning goals. Margetson [36] noted that for deep learning to occur, critical components included motivational context, learner activity, interaction with others, and a solid knowledge base.

> Simon: "I think this might be the biggest hang-up for faculty. We all develop in a system that emphasizes disciplinary specialization and the knowledge and skills that go along with that. This becomes our identity – the disciplinary content or skills we have, define who we are, what value we can bring to our environment, and what we must pass on to our students. When you start integrating with other disciplines, and when you shift from teacher-controlled to student self-directed approaches, this identity starts to collapse. This is uncomfortable, even painful, for us faculty. Suddenly the thing that has provided our sense of competency – our disciplinary knowledge and skills – is no longer relevant. I think that most faculty respond by reverting, and trying to protect their disciplinary-based identity."

Margetson [36] also addressed the conception, or rather, the misconception of lack of control or authority in PBL and distinguished between authority and authoritarian attitudes.

This category reinforces the '*who I am*' conceptualization of the role where the essence of the engineering educator is not confined by how much they know and how much they can control the students and the learning environment, but embraces a transformed perspective of learning and of self and how the educator can be of service in supporting the students to construct their knowledge.

In summary, the educators' experiences and conceptualizations of the third tension of instructor versus facilitator formed the outcome space depicted in Fig. 4. The outcome space evidenced a hierarchical progression from content provider (what I know) to process advocate (what I do) to a reframed identity as an engineering educator (who I am).

6. Summary of Engineering Educators' Conceptualizations of PBL Tensions in Teaching Practice

In response to the second research question in this study, the experiences and conceptualizations of the predominant tensions encountered in teaching practice with the implementation of PBL were detailed above. For the tensions of students' initial discomfort with the transition to PBL, study participants conceptualized an outcome space as (1) a lack of readiness with regard to knowledge, skills, and attitude as part of their entry into the program from high school, (2) dissonance in students' expectations between their old learning environments and their new learning environment, and (3) the students' transition to the new learning environment (PBL).

For the second tension of individual versus organizational value assigned to teaching, participants conceptualized the outcome space as (1) indifference, (2) skepticism of colleagues towards PBL, and (3) system misalignment.

Lastly, study participants conceptualized the outcome space of the tension of role of instructor versus facilitator as (1) a content provider, (2) a process advocate, and (3) a learning (re)constructivist.

While the outcome spaces of the three conceptualizations of the tensions stand on their own, there is also a relationship between them that could inform a final, integrated outcome space. Two of the conceptualizations are PBL tensions

Value assigned to teaching

Tensions	PBL Implementation: Content-centered	Student-centered	Learning-centered
Instructor-facilitator	Content provider	Process advocate	Learning (re)constructivist
Student discomfort-satisfaction	Student readiness	Student expectations	Student transition

Fig. 5. The final outcome space of the variation in engineering educators' conceptualizations of the predominant tensions encountered with the implementation of PBL in their teaching practice in the early years of the program.

(student discomfort and instructor role), while the third is a system (engineering education reform) tension (value assigned to teaching). The key attributes of this outcome space were conceptualizations of the PBL implementation as (1) content-centered, (2) student-centered, and (3) learning centered. The final outcome space (see Fig. 5) depicted not only the variation in conceptualizations of the PBL tensions, but also the influence of the system-level tension of value assigned to teaching.

Category 1: PBL Implementation as Content-centered

The key attributes in this category included educators' conceptualization of their role as a content provider and more of a focus on filling the knowledge and theoretical gaps educators reported with regard to student readiness. This may be considered a traditional conceptualization of the interaction between educator and student within a PBL implementation, focused on information and content acquisition on the part of the student.

Category 2: PBL Implementation as Student-centered.

The key attributes in this category included the educators' conceptualization of their role as process advocates and their awareness of the need to address the students' expectations with regard to the new PBL learning process. This category differs from Category 1 in that, while content remained critical, the focus was more complex than simply *what* was to be acquired by the student and the educator oriented and supported students on *how* the concepts were to be acquired by them.

Category 3: PBL Implementation as Learning-centered

The key attributes in this category included the educators' conceptualization of their role as a learning (re)constructivist and the students' transition into the PBL learning environment. This category differs from Category 2 in that the interaction between the educator and the students is more focused on shaping the students' thinking, not only giving them more responsibility for the construction of their own knowledge, but also through the facilitation of and for deeper learning. This moves the focus of this category to an even more complex level beyond the *what* and the *how*, and creates learning experiences for students to integrate the *why*, and the *why not*.

While the conceptualizations of the tensions showed variation, where an educator actually finds him/herself on the continuum may be influenced by the system level tension of the value assigned to teaching [35].

7. Limitations

The context of this study focused on the implementations of PBL in the early years of the engineering programs. A limitation inherent with this population is that engineering educators, across their careers, rarely teach exclusively in the first and/or second year of the program. Therefore, while all efforts were made to focus interviews on the early years, it is unknown to what extent the full experience of these educators influenced their reported conceptualizations of tensions and management strategies. In addition, the majority of the participants in this study came from large research-intensive universities. This may have led to an over-representation of some tensions and can be considered a limitation of this study. Lastly, a limitation of this study is that the extent of transferability of these results to other contexts is unknown. In phenomenographic research, the determination of transferability is usually left to the reader of the research results. That is, it is to the reader of the research to determine the extent to which the results are applicable within their context.

8. Conclusion and Future Research

This work expands the body of literature investigating PBL in engineering education and specifically the ways engineering faculty experience and conceptualize tensions as they arise in the implementation of PBL and its variations in the first two years of the engineering curriculum. We present a novel outcome space that situates three qualitatively different ways for conceptualizing tensions ranging from students' initial discomfort with the transition to PBL and the educators' role as teacher versus facilitator. Additionally, these educators reported a system-level tension of the individual versus the organizational value assigned to teaching. Furthermore, the research shows the different nuanced variations educators experienced these major tensions leading into a final outcome space, in which conceptions of the tensions show variation across content-centeredness, student-centeredness, and learning-centeredness.

Future research may explore strategies of educators on how to manage these tensions and comparisons between tensions in PBL implementation between the first two years (this study) and other years of the engineering curriculum. Finally, supporting educators in managing these tensions is essential for appropriate PBL implementation – both in the classroom and on the system level: knowing these tensions might help administrators and instructional design staff.

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Angela van Barneveld , PhD, (ORCID: 0000-0002-0020-1000) is an Adjunct Professor at Purdue University and a sessional instructor at Lakehead University. Dr. van Barneveld received her PhD from Purdue University and, after a fulfilling career in learning and development in the private sector (IBM, Nortel, CGI), embarked upon an academic career. A seasoned facilitator, Dr. van Barneveld conducts faculty and industry workshops on topics such as learning design and learner engagement, especially in an online context; empathy in professional work contexts. She also designs online courses for different industries and teaches online courses for several universities. Dr. van Barneveld was on the Board of Directors for the Canadian Network for Innovation in Education.

Johannes Strobel, PhD, Professor, (ORCID: 0000-0002-2124-1116) is Associate Dean of Research and Graduate Studies at University of Texas at El Paso after working at SRI International and other institutes of higher education (Concordia University; Purdue University; Texas A&M and U of Missouri). Dr. Strobel's research focuses on STEM and defiance, empathy and care in engineering. He has published more than 170 papers in journals, proceedings and book chapters and co-edited five books. Dr. Strobel is founding editor of the Journal of Pre-College Engineering Education Research (J-PEER).