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Development of Critical Reflection for Transformative Learning of Engineering Educators in a PBL-Based Professional Learning Program*

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This study investigated how 35 Chinese university instructors developed and engaged in critical reflections in a six-month Problem-Based Learning (PBL) professional learning program in Denmark. Data sources included individual progressive portfolios, team-project reports, and focus group interview. Quantitative analysis indicated that participants developed significantly in content, process, and premise reflection in the domains of instructional knowledge and pedagogical knowledge. This result provides evidence for the effectiveness of using a PBL methodology to organize professional learning activities aiming for the development of critical reflection for transformative learning. Nevertheless, participants demonstrated little premise reflection regarding curricular knowledge, an area that demands more time and more systemic support. Qualitative analysis identified systemic, individual, and cultural factors constraining engineering teachers from critical reflection. The study also suggests that to facilitate premise reflection it takes longer than six months and demands more systemic support.

Keywords: critical reflection; university instructors; PBL-based professional learning; transformative learning; China and Denmark

1. Introduction

In response to the global demands for economic, political, and social changes necessary for sustainable development, higher educational institutes have undertaken the responsibility of providing students with competencies to manage professional problems that are both complex and interdisciplinary [1]. To reach these goals, not only students, but more importantly, universities are required to have the ability to communicate, collaborate, reflect, and transform their thinking within the context of change [2]. Shulman [3] advocated that university teachers should participate in the development and creation of distinctive bodies of knowledge that are composed of knowledge of subjects, pedagogy, curriculum, and beyond. Over the decades, scholars have argued that critical reflection is crucial for university teachers to provide quality education [4, 5] and that transformative learning should be the goal of professional development of university faculty [6], but a lack of conceptual clarity remains concerning how critical reflection can be defined and how its development can be analyzed [5–7].

Faculty development, considered essential in promoting innovation and excellence in higher education, has received growing research attention in terms of its practice and impact. While extensive research has reported on the changes university professors experience after receiving professional learning in terms of motivation, self-efficacy, attitudes, conceptions, and approaches to teaching [8–10], a large number of studies have also provided evidence that the changes teachers experience affect their students' approaches to learning, performance, and outcomes [11–14]. While reflective practice is an important intended outcome of professional learning activities and peer learning can be a useful resource, there is a need for more research on the process of teacher reflection [15, 16].

Problem and/or project-based learning (PBL) has been widely implemented in higher education and

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has proven to be an effective pedagogy for providing students with professionally-demanded skills, including communication, collaboration, and critical and reflective thinking [1, 11, 12, 17]. PBL's methodology can also be suggested to be an effective way of organizing pedagogical development activities for university teachers in the pursuit of transformative learning [1]. While several models that integrate PBL ideas into innovative professional learning programs for tutors in health and medical sciences [18–20], little is known about the resulting practices and impacts on teaching professionals. On a global scale, PBL is being increasingly implemented in engineering and other programs, leading to more studies on its results [21], but more attention is needed on how PBL can be used as a methodology to organize professional learning programs, and on the learning process of engineering instructors in PBL and how they experience changes. Additionally, evidence is needed regarding engineering instructors are engaged in the development of critical and reflective thinking, which may lead to transformative learning, particularly in a teamwork context.

This study first aims to understand the forms and levels at which university teachers develop critical reflection in a PBL-based professional learning program. It also aims to provide analysis and evidence for engineering teachers' engagement in transformative learning, and then looks to identify contextual factors that provide conditions and create challenges for university teachers' development of critical reflection. In the prevailing literature, the following terms, among others, are used interchangeably, such as "academic development", "faculty development", "staff development", "pedagogical development", and "professional development". With no intention of distinguishing between these terms, this study uses "professional learning" in reference to activities university teachers undertake that lead to the enhancement of teaching and learning [8].

2. Theoretical Framework

2.1 Transformative Learning and Critical Reflection

Transformative learning can be defined as "the process by which we transform our taken-for-granted frames of reference (meaning perspectives, habits of mind, mindsets) to make them more inclusive, discriminating, open, emotionally capable of change, and reflective so that they may generate beliefs and opinions that will prove more true or justified to guide action" [22, pp. 7–8]. Stemming from Habermas' [23] theory of knowledge-constitutive interests which identifies three domains of learning – the technical, the practical, and the emancipatory – Mezirow's [24] theory of transformative learning distinguishes between three forms of learning: instrumental, communicative, and emancipatory. Instrumental learning involves a learning process to control and manipulate the environment or other people with informed consensus by empirically demonstrating the results. Communicative learning, instead of testing hypotheses, is focused on understanding meanings, values, and feelings through communicating with others and in-context interpreting. Emancipatory learning, the most significant learning form, involves a critical analysis of the taken-for-granted processes, norms, and conditions for premises and consensus.

Reflecting on experiences serves as an important tool for intellectual development and supports the grounds for constructing belief and knowledge [25]. In particular, critical reflectivity is essential in inquiry-driven processes [7]. Mezirow [21] identified three forms of reflection: content, which addresses questions of what the problem is and how to solve it; process, which asks the questions of how effective the problem-solving strategy has been; and premise reflection, which questions the presupposition of the present knowledge, questions why the problem has been posed in the first place, and seeks alternative solutions. The three types of reflection can be seen as a taxonomy representing levels of reflection and are related to the three forms of learning – instrumental, communicative, and emancipatory, respectively. Through these three forms of learning, the validity of reflection may be tested. Premise reflection is the level regarded as critical reflection and has the potential to lead to transformation of meaning perspectives, which involves criteria for making value judgements and for influencing one's belief system [4, 26]. For university teachers, critical reflection is a key aspect for constructing teaching knowledge [15] and should be closely linked to premise reflection on higher education (HE). This type of reflection is the only avenue that can lead to emancipatory learning, and consequently, fundamental changes in HE [4, 6, 7, 15].

2.2 Developing Teaching and Learning Scholarship

Reflection is associated with experiences [24, 27, 28]. Kreber [5] articulated that there are two important sources of reflection on teaching: teaching experiences and theoretical knowledge. University teachers tend to rely on their personal knowledge, which is based on teaching experience, as a valuable source of reflection because it is useful in the context in which they teach [29, 30]. However, different types of reflection are needed to determine the relevance and usefulness of theoretical knowledge and apply it to one's situational teaching practice

[27]. Therefore, there are three equally important domains of teaching knowledge relevant to university teachers: meaningful goals and the purpose of higher education (curricular knowledge); student learning and development in relation to these goals (pedagogical knowledge); and teaching and instructional design processes needed to bring about student learning and development (instructional knowledge) [31].

A framework for teaching and learning scholarship has been proposed by several authors (see, [5, 6, 15, 31]) that links three types of reflections for university teachers (content, process, and premise) to their learning about three important domains of teaching knowledge (curricular, pedagogical, and instructional). University teachers may be engaged in different levels of reflection on their teaching practices. When reflecting on content, or asking questions about what the problem is and how to solve it at the end of a teaching activity, instructors may ask questions such as "What happened during the course?" and "What did I do and what were the outcomes?" Instructors often use current knowledge (conceptions that are already held) to identify a problem and come up with solutions to solve it without questioning their presumptions. When reflection on process, or asking questions about how effective the problem-solving strategy has been, an instructor may ask things like, "Did the new strategy affect students and how did it work?". The instructors may validate their assumptions in order to reach consensus when communicating with students and peers. When premise reflecting, asking questions about the presupposition of present knowledge, why the problem has been posed in the first place, and whether there are alternative solutions, the instructors may ask, "Why it is important to use such a strategy and are there any alternatives?"

These three levels of reflection serve to explain how engineering instructors may construct knowledge in three different domains: in the domain of curricular knowledge, where the teachers reflect on the goals and purpose of teaching; in the domain of pedagogical knowledge, where teachers reflect on how students learn; and in the domain of instructional knowledge, where teachers reflect on instructional design and process. In each of the domains, the teachers may be involved in one or all three levels of reflection. Therefore, the framework yields nine forms of reflection in relation to teaching knowledge that draws on teachers' experiences or educational research [15]. Accordingly, teaching and learning scholarship is an essential component in university teachers' professional learning when they "engage in content, process and premise reflection on research-based and experienced-based knowledge in the areas of instruction, pedagogy and curriculum in ways that can be peer reviewed" [32, p. 153].

2.3 Critical Refection in Professional Learning Activities

As individuals develop intellectually, they encounter events that cannot be interpreted through their existing mental frames of reference. Professional learning activities can provide opportunities for university teachers to reflect through social interaction and feedback [16]. While substantial research has been conducted on evaluating the effectiveness of professional learning programs, systematic reviews in the field (see [9, 33] have reported ambiguous conclusions on program impact because studies have primarily focused on the features of the professional learning activities, such as format and duration, and have paid little attention to the core characteristics such as goals, theoretical foundation, and content of the programs. Therefore, future research should offer qualitative insights into the theoretical foundations of professional learning [9]. Furthermore, while it is suggested that professional learning programs should target critical reflection as an essential goal [34] and that the content and form should focus on emancipatory learning instead of solely emphasizing how to train participants on teaching strategies [6, 35], further evidence is needed to fully understand the processes and results of such engagement.

Thus, the current study is embedded in the framework of teaching and learning scholarship which involves critical reflection on educational goals and purposes – whether they appropriately address the various political, social, cultural, environmental, and economic constraints of our time [15]. Thus, the context of professional learning deserves attention [36], and it is necessary to explore what sociocultural contextual factors support or constrain university teachers' engagement in critical reflection on professional learning activities.

Centra [37] provided an operational model of transformation, highlighting four conditions for university teachers to evolve through professional learning activities. First, it is necessary for individuals to acknowledge a gap in knowledge and feel the need for acquiring new knowledge about teaching and learning. Second, they must value the opportunity for professional learning and view it as professionally relevant and potentially beneficial. Teachers must also know how to change, and finally, they must be motivated to change at both intrinsic and extrinsic levels. Recent literature has emphasized the significance of value and relevance as "tipping points towards change" [38]. The importance of the contexts in which the teachers are situated is also highlighted since these settings

define and distinguish the teachers' perceived needs and support structures [10, 39]. The model also suggested that a lack of certain conditions may result in constraints on change. Further research has identified "dilemmas" that hinder university teachers from changing their practices; for example, individuals may be hindered by a lack of conceptual and pedagogical knowledge [40], or due to cultural concerns and institutional policies (e.g., lack of support) [39, 40].

2.4 PBL in Transformative Professional Learning in Engineering Education

A variety of strategies have been employed in professional learning activities, including providing theoretical backgrounds such as constructivism and interactive and collaborative activities [36]. For the purpose of facilitating critical reflection, suggestions have included facilitating critical theories, supporting reflective practices, and creating action plans [7]. In particular, in engineering and science education, while an increasing number of universities and programs are implementing problem and project-based learning at philosophical and practice levels [21], the method can also serve as an approach to professional learning. Kolmos, Du, Dahms, & Qvist [41] reported the benefits and effectiveness of using the PBL philosophy and methodology to organize an online Master Program to support engineering and science teachers in implementing PBL. However, there is a need for more research on university teachers' experience as learners. With this in mind, this study aims to gain insight into the process of university teachers' engagement in critical reflection and provide evidence of transformative learning through a PBL-based professional learning program. The following research questions have been formulated to shed light on professional learning:

1. In which forms do engineering instructors develop critical reflection through a PBL-based professional learning program?
2. What are the factors constraining their engagement in critical reflection?

3. Methodology

This study is designed to explore how professional learning programs, based on PBL principles and characteristics, are implemented and what outcomes occur. It takes special care to document the process of university teachers' engagement in critical reflection. The research design focuses on the internal connections of the goals, theoretical bases, activities, and outcomes, as suggested by Stes, Min-Leliveld, Gijbels, and Petegem [9].

3.1 Program Design and Participants

A University (AAU) is internationally recognized for its use of a PBL-based pedagogical model. Starting in 2017, a six-month professional learning program was provided and hosted by A University in collaboration with China Scholarship Council, with an overall goal of pedagogical development through implementing PBL in China. Each year, a group of 35 Chinese university teachers from engineering and science backgrounds participates in this program on a full-time basis. The 35 (11 female and 24 male) participants in the 2018–19 program participated in the current study. Participants held PhDs in engineering fields and worked as assistant (n = 17) and associate professors (n = 18) in their home universities, with little prior experiences of professional learning for teaching. Their ages ranged from 30 to 43, and their teaching experiences ranged from half a year to 20 years.

Objectives of the program included: (1) to critically reflect on university teaching and learning; (2) to develop pedagogical knowledge and skills to support student learning; (3) to develop teaching plans and strategies to enhance student learning in China through PBL; (4) to evaluate self, peers, and students critically and constructively.

Program participants attended academic activities worth 30 European Credit Transfer System (ECTS) (the equivalent to 900 study hours) over six months. The following activities and assessments were designed (see Table 1 for details). Instruction was carried out using the principles of constructive alignment [42]. Participants worked in seven self-formed groups, each supported by a pedagogical facilitator (an expert in pedagogy and an individual experienced in facilitating professional learning programs) and a subject supervisor (an expert in the engineering and science fields and an individual familiar with AAU-PBL practice).

3.2 Data Generation

3.2.1 Individual Teaching and Learning Portfolio

A teaching portfolio is often used as a tool in educator development through which teachers' self-reports, including formative and summative evidence of teaching effectiveness for the purpose of teacher growth and assessment, are recorded [43]. It is also seen as useful for documenting engagement in various reflective processes associated with teaching and learning scholarship [15]. The program at AAU invited participants to write an individual teaching and learning (T&L) portfolio as a tool to promote teacher growth, based on the premise that pedagogical development is not only for teaching but also a meaningful learning process for the teachers [43]. The T&L portfolio provided guideline

Table 1. Learning Activities and Assessment (1 ECTS = 30 study hours)

Major learning activities	Credit (ECTS)	Study hours	Assessment
10 courses (in the forms of workshops, lectures, and assignments) (months 1–4)	10	300	Course assignments (essays, reflective discussion, portfolio, etc.)
Individual teaching and learning portfolios (months 1–6)	5	150	Monthly reflection tracked through a progressive portfolio
Two team projects on teaching and learning issues (1) Mini test projects (month 2) (2) Major project (months 3–6).	15	450	• Two team-based project reports • Analysis of team process • Oral presentation and defense
Guided observation of AAU-PBL model in practice throughout (months 1–4)			Reflective discussion and portfolio
Design of a PBL course that could be implemented in one's home university after the program (individual or collaborative) (months 5–6)			Course design and portfolio

questions and was designed to promote a progressive process of reflection, with each participant submitting their reflective writing on a monthly basis for a total of six entries per participant.

At the program's start, participants were invited to describe and discuss their teaching philosophy, backgrounds, and prior experiences, and analyze challenges in current teaching and learning practices. This aided them in identifying students' learning needs and developing new initiatives in order to better support student learning. Throughout the program, participants were expected to reflect on their understanding of alternative teaching methods such as PBL and report on their participation in the program courses and observation of AAU activities. They were also asked to reflect on the process of developing, planning, and evaluating suitable PBL-inspired teaching and learning activities in relation to general and specific teaching objectives, subjects, contexts, and students' backgrounds. They were also invited to discuss diverse educational theories and teaching and learning methods relating to their own practices and contexts. Finally, they were given the opportunity to develop their own action plans for what they would do differently in the future. At the end of the program, participants reviewed and revised their complete version of the portfolio before final submission. English was the primary language for writing the portfolio throughout the program, and participants were asked to add elaborations in Chinese in the final version if it was necessary for them to express themselves fully.

3.2.2 Team Project Reports

During the program, participants worked on two team projects: (1) a one-month mini project aiming to understand the AAU-PBL model and try out working in a team, and (2) a four-month main project researching a teaching and learning issue with support of educational theories. The team reports were also used to provide recommendations and create action plans for PBL-based alternative teaching methods. In total, each participant was involved in two collaborative projects and the writing of two reports. To support their first PBL experiences, in the pilot project, the groups were predesigned according to participants' diverse backgrounds, and each group was given a topic to guide their projects. The majority of participants worked in different teams for the two projects. The current study mainly reports analysis of the major project reports in that they followed the AAU-PBL model structure, including problem identification and analysis, formulation of research questions, theoretical framework and literature review, research design, empirical data generation, analysis and discussion, and conclusions containing recommendations and action plans. For the major project, participants formed groups and chose topics on their own based on their interests. Each report was expected to be between 20–30 pages for mini project and 30–50 pages for the major project. All project reports were written in English.

3.2.3 Focus Group

To reach a higher degree of trustworthiness and validity in the interpretation of indicators from the portfolios, talking to the university teachers to confirm meanings and exploring further critical reflection is suggested [15]. Focus group interviews were conducted at the end of the program, providing a session of evaluation and promotion of further reflection. Each focus group involved participation of the major project group members (ranging from six to eight in various groups). Each interview lasted 4–5 hours and was audio-recorded. The sessions included presentations and explanation of the project, semi-structured questions, and discussion of emerging topics that fostered further reflection. The interviews were conducted bilingually, meaning the participants could elaborate in Chinese to support their use of English in order

to gain deep insights. The conversations were transcribed and translated to English by the first author (the interviewer).

During the interviews, the authors listened to participants' feelings and experiences gained from participating in the PBL professional learning program, their thoughts and analyses of what they had learned, their beliefs and belief changes throughout the program, and their future action plans. These questions followed interviewing techniques suggested by Kvale and Brinkmann [44]. In addition, confirming questions were asked, allowing opportunities for the participants to elaborate on what they wrote in their reports and portfolios. Initial interpretation and analysis of their levels and forms of reflection were triangulated through the conversations and discussions. Furthermore, the authors also explored the concerns and constraints participants described in their writing regarding the potential of implementing PBL in their home contexts. This information helped analyze the conditions, challenges, and contextual factors influencing the outcomes of the professional learning activities.

3.3 Data Analysis

An integrated approach was employed for data analysis comparing multiple sources of qualitative data, combining both a theory-driven approach [45] and a thematic approach [44]. Several procedures were implemented in the analysis process. First, a theory-driven deductive content analysis was applied using the Critical Reflection Framework for Scholarship for Teaching and Learning [15] (See Table 2 for coding guideline). The authors also read the individual portfolios that followed their evolving thought process. We used the first two monthly portfolios to explore the levels and forms of reflection the participants were involved in at the program's start, which were primarily based on their previous experiences. We reviewed the portfolios at month 3, 4, 5 and 6 (which is the final version) to explore the levels and forms of reflection participants engaged in at different points in the program. Participants were expected to engage in more critical reflection later in the program through the support of the activities the participants were exposed to in the program. Thus, in the analysis process, we paid particular attention to the participants' development and evolving impressions during the program. The contextual analysis was also important to the analysis in order to identify condensed meanings and interpret what the participants meant in their given contexts.

With the hope that a team environment could support engagement in critical reflection, we also analyzed the team project reports following the same framework (Table 2) as the portfolios. Although we reviewed the first team-produced mini-project reports at the end of the second month, we found that the participants mainly reflected on the mini-projects in their individual portfolios, and the first team-produced project reports were thin reports that mostly answered the questions posed in the guidelines. We interpreted this as a lack of understanding of the purpose of the team project and a lack of previous experience participating in such activities. We then adjusted the program by providing additional sessions that supported participants with teamwork skills. Given this experience, we primarily had to rely on major project reports for the analysis of this study, which included not only the major report process and outcomes, but also the collective reflection on the entire program process and the particular lessons learned from the mini projects.

Initial analysis results of the individual portfolios and team project reports were triangulated through focus group discussions. Further analysis of focus group discussion outcomes explored the reasons behind the identified gaps between individual and team reflections and the factors constraining the participants from projected levels and forms of critical engagement. Then, all texts were analyzed against emerging themes and compared to the literature. A collaborative approach to analysis was also used, with the authors spending several rounds comparing, discussing, and negotiating their interpretation, categorization, and findings before an agreement was reached.

Finally, a ''quantifying qualitative data''

Table 2. Coding Guidelines for Levels and Forms of Reflection Three Types of Knowledge Domains (Adapted from [15])

	Instructional knowledge	**Pedagogical knowledge**	**Curricular Knowledge**
Content reflection	What teaching strategy shall I use?	What do I know about how students learn and develop?	What are the goals?
Process reflection	How effective are these strategies in terms of reaching the goals?	How I have helped students to reach these goals?	Are these goals possible and feasible to reach?
Premise reflection	Is this strategy the most appropriate? Are there any alternatives?	Why is what I have done to help students important? Are there any alternatives for my role?	Why are these goals important? Are they aligned with overall outcomes of the educational program and the needs of the profession and society? Are there any alternatives?

approach [46] was employed to compare the states of the individual portfolios between the beginning and end of the program in order to calculate the degree of change in each participant. This method has been well-used in cognitive sciences and was recently introduced to educational studies [17, 47]. The participants' entries of portfolio month 1–2 were counted as program's start and a blended result of reviewing month 3–6 was counted as program's end. We calculated the percentage of participants who provided indicators in each form of reflection and then conducted a z-test [48] to analyze individual reflection development, comparing their engagement with different forms of reflection at the program's start and end, respectively.

4. Findings

4.1 In which Forms do Engineering Instructors Develop Critical Refection Through a PBL-Based Professional Learning Program?

Following the Critical Reflection Framework for Scholarship for Teaching and Learning [15], an overview of the deductive analysis outcome of team project reports and individual progressive teaching and learning portfolios is presented in Table 3. The findings are reported and discussed following the structure of three types of knowledge with which the university teachers are expected to engage. Results from individual reflection through progressive portfolios comparing the program's start and end are also discussed in relation to group reflections based on team project reports. Indicators were used to make inferences about the type of learning or reflection the instructors engaged in and to also provide both formative and summative information for the authors to interpret each recorded instance and determine whether the participants engaged in content, process, and premise reflection [15].

4.1.1 Instructional Knowledge

At the program's start, the participants were asked to write their reflections on their teaching philosophy, prior experiences regarding preferred methods by which to learn and to teach, and what types of students they had. As presented in Table 3, all participants demonstrated their reflection at a content level, reporting that lecturing was the major method by which they were used to experiencing both as students and engineering instructors. The main reason for this shared experience, according to them, is the history of the Chinese educational system, which focuses on the important role of a teacher as a knowledge giver and transmitter. Process reflection was partially addressed; all participants believed that their role as a university teacher is to help students learn important subject-specific knowledge and get good grades. As one of them wrote, "it is important that I help them to get good grades so that they can get a good job in the future." All participants also identified characteristics such as lack of engagement and motivation from their current students, seeing these problems as the major barriers to their teaching and the seemingly low quality of university teaching and learning in China. Few participants reflected at the premise level; although most expressed their willingness to learn more pedagogy during their participation in the program, only five participants expressed doubts about lectures being the most useful way to teach.

Throughout the program, the participants demonstrated progressive improvement in engaging in multiple levels of reflection. At the program's end, the majority of participants wrote their reflections at not only the content level, but also the process level, combining more aspects of engagement with instructional strategies and with ideas they had gained through reading about and comparing theories from the literature, consulting with experts, and discussing options on their teams. At the premise level, the majority of the participants questioned lectures as being the primary teaching method, and more than half of them questioned the common memory-based and grade-oriented methods of assessment; nevertheless, only around one third (n = 12) of them provided alternative and multiple strategies for teaching and assessment.

All team project reports submitted at the program's end included nearly all the items (except one) of the listed indicators at all levels of content, process, and premise, as shown in Table 3. This indicates participants' engagement with the instructional knowledge and teamwork in the program were high.

During focus group discussions, the participants reflected on their own improvements in engagement at all three levels of reflection. In particular, they specified their engagement in critical reflection related to instructional knowledge; for example, all groups questioned the usefulness and effectiveness of relying on lectures as the major teaching methods. One group pointed out:

> "Through this program, we experienced real student-centered learning and we can now see that what we thought was student-centered learning back home was still lecture dominated. By having teachers talk so much in classes, we may not be ensuring students learn." (Group 5)

Similar to the individual portfolio results, only two groups, in both team project reports and focus group, reflected further on the assessment issues

Table 3. An Overview of Reflection Indicators in the Three Forms of Knowledge Identified by Both Teams and Individuals

Domains	Overall indicators of reflection in three forms identified from both team projects reports and individual portfolios	Team project reports (teams who mentioned the referred items by team numbers)	Individual Teaching and Learning Portfolios				
			Program' start		Program' end		
			Number of indicators	%	Number of indicators	%	Additional value comparing program' start and end
Instructional knowledge	**1. Content reflection**		60	86%	70	100%	14%
	☐ Discussing teaching methods that one is used to	T 1, 2, 3, 4, 5	35	100%	35	100%	0%
	☐ Explaining history and sources of the often used teaching methods	T 1, 2, 3, 4, 5	25	71%	35	100%	29%
	2. Process reflection		148	47%	231	73%	26%
	☐ Explaining why the methods were used	T 1, 2, 3, 4, 5	25	71%	32	91%	20%
	☐ Explaining student backgrounds	T 1, 2, 3, 4, 5	30	86%	35	100%	14%
	☐ Identifying student issues/problems (e.g., lack of motivation and needed skills)	T 1, 2, 3, 4, 5	30	86%	35	100%	14%
	☐ Viewing role of teacher as a subject expert and knowledge transmitter	T 1, 2, 3, 4, 5	30	86%	30	86%	0%
	☐ Using grades to evaluate the outcomes of teaching and learning	Not mentioned	30	86%	29	83%	–3%
	☐ Comparing different teaching strategies and relating them to one's own context	T 1, 2, 3, 4, 5	2	6%	18	51%	46%
	☐ Consulting experts on teaching strategies	T 1, 2, 3, 4, 5	0	0%	19	54%	54%
	☐ Discussing teaching strategies in your team	T 1, 2, 3, 4, 5	0	0%	30	86%	86%
	☐ Writing an article on teaching strategies	Not mentioned	1	3%	3	9%	6%
	3. Premise reflection		5	4%	65	46%	43%
	☐ Questioning the usefulness and effectiveness of teaching methods	T 1, 2, 3, 4, 5	5	14%	30	86%	71%
	☐ Recommending alternative or combined teaching strategies	T 1, 2, 3, 4, 5	0	0%	23	66%	66%
	☐ Questioning the usefulness and effectiveness of assessment methods	T 2, 3,	0	0%	12	34%	34%
	☐ Recommending alternative and multiple assessment methods	T 2, 3,	0	0%	0	0%	0%
Pedagogical knowledge	**4. Content reflection**		30	21%	79	56%	35%
	☐ Describing characteristics of ones' students	T 1, 2, 3, 4, 5	16	46%	26	74%	29%
	☐ Explaining student characteristic backgrounds	T 1, 2, 3, 4, 5	14	40%	25	71%	31%
	☐ Discussing student learning needs	T 1, 2, 3, 4, 5	0	0%	23	66%	66%
	☐ Questioning one's own knowledge of student learning	Not mentioned	0	0%	5	14%	14%
	5. Process reflection		3	1%	135	64%	63%
	☐ Relating literature on educational theories and findings of previous studies to teaching practices	T 1, 2, 3, 4, 5	0	0%	14	40%	40%
	☐ Relating what one has learned in the program courses to one's own teaching contexts	T 1, 2, 3, 4, 5	NA	NA	29	83%	NA
	☐ Relating what one has observed from AAU teaching and learning activities to one's own context	T 1, 2, 3, 4, 5	NA	NA	35	100%	NA
	☐ Relating what has been observed from AAU students to one's own students	T 1, 2, 3, 4, 5	NA	NA	35	100%	NA
	☐ Comparing different approaches to learning and relating to one's own context	T 1, 2, 3, 4, 5	0	0%	25	71%	71%
	☐ Viewing teacher as learning facilitator	T 1, 2, 3, 4, 5	3	9%	32	91%	83%
	☐ Consulting experts to discuss student learning	T 1, 2, 3, 4, 5	0	0%	29	83%	83%
	☐ Discussing ideas about student learning in a team	T 1, 2, 3, 4, 5	0	0%	32	91%	91%
	☐ Writing an article on how to facilitate learning	Not mentioned	0	0%	3	9%	9%

NA = Not applicable.

Table 3. (*continued*)

Domains	Overall indicators of reflection in three forms identified from both team projects reports and individual portfolios	Team project reports (teams who mentioned the referred items by team numbers)	Individual Teaching and Learning Portfolios				
			Program' start		Program' end		
			Number of indicators	%	Number of indicators	%	Additional value comparing program' start and end
Pedagogical knowledge	**6. Premise reflection**		0	0%	60	57%	57%
	☐ Comparing different educational theories related to PBL	T 1, 2, 3, 4, 5	NA	NA	32	91%	NA
	☐ Comparing teaching and learning strategies related to PBL and beyond	T 1, 2, 3, 4, 5	NA	NA	28	80%	NA
	☐ Relating different aspects of student learning reported in research articles to ones' own students and contexts	T 1, 2, 3, 4, 5	0	0%	0	0%	0%
	☐ Recommending alternative methods to understand and document student learning	T 1, 2, 3, 4, 5	0	0%	35	100%	100%
	☐ Creating a new action plan (e.g., PBL teaching design)	T 1, 2, 3, 4, 5	0	0%	25	71%	71%
Curricular knowledge	**7. Content reflection**		10	14%	50	71%	57%
	☐ Discussing course goals	T 1, 2, 3, 4, 5	10	29%	25	71%	43%
	☐ Discussing knowledge, skills and competences related to the program one is teaching	T 1, 2, 3, 4, 5	0	0%	25	71%	71%
	8. Process reflection		0	0%	79	38%	38%
	☐ Relating the learning goals to student learning outcomes and professional demands	T 1, 2, 3, 4, 5	0	0%	13	37%	37%
	☐ Questioning how the goals can be reached within the current system	T 1, 2, 3, 4, 5	0	0%	13	37%	37%
	☐ Questioning the current system of assessing student learning and evaluating teaching effectiveness	T 1, 2, 3, 4, 5	0	0%	11	31%	31%
	☐ Questioning how to support students to develop the necessary competencies in the current system	T 1, 2, 3, 4, 5	0	0%	15	43%	43%
	☐ Discussing HE philosophies	T 1, 2, 3, 4, 5	0	0%	10	29%	29%
	☐ Discussing and debating the goals of education in a team	T 1, 2, 3, 4, 5	0	0%	17	49%	49%
	9. Premise reflection		0	0%	0	0%	0%
	☐ Discussion the overall educational system and changing competencies over time	T 3, 4, 5	0	0%	0	0%	0%
	☐ Discussing the gaps and anticipated connections between higher education and societal needs in China	T 4	0	0%	0	0%	0%

NA = Not applicable.

and provided alternative approaches to support their anticipated implementation of PBL.

4.1.2 Pedagogical Knowledge

At the program's start, less than half of the participants addressed two aspects of content reflection in their portfolios, mentioning the characteristics of their students (n = 16) and the explanation of student backgrounds (n = 14). Except that three participants wrote about their role as facilitators without further elaboration, their writing indicated neither process nor premise reflection.

At the program's end, approximately two-thirds of the participants reflected on the characteristics of their students (n = 26) and gave an explanation of their students' backgrounds (n = 25). Additional indicators were also identified, such as discussing their students' learning needs (n = 23) and questioning one's own knowledge about student learning (n = 5). At the process level, nine indicators were identified in process reflection, with two items addressed by all participants and six items addressed by more than two-thirds of participants. In addition, three participants wrote academic articles on learning during their study in the program. At the premise level, four items were raised by the majority of the participants, including searching for alternatives and providing new action plans.

All three levels of reflection were addressed in all five team project reports, aligning with the items listed from the individual portfolios (sees Table 3) and indicating a synchronous development of growth. The engagement in all levels of reflection on pedagogical knowledge was further confirmed during focus group discussions. All groups elaborated on their mindset change that came about as a result of their PBL experiences. Through the real-life based projects, they learned to focus on how students learn and how to facilitate learning through diverse methods. They learned to question what was taken for granted about goals of teaching and learning (subject-knowledge transfer). They began to think how to motivate student learning and facilitate deep learning through alternative avenues, and accordingly, how their roles as teachers multiplied and demanded alternatives. One group reported:

> "When we started this program, we could not see the point of learning about educational and learning theories; we are just engineers, so how could these theories be relevant to us? However, after our first project, we realized that although we are experts in our subjects, we knew nothing about how to do research on student learning, and we even did not know how to work together as a team ourselves. . . Now the educational and learning theories make sense when we can relate them to our own learning in the PBL. In the future, we will know to start designing a teaching activity from thinking about learning theories and how students learn. . ." (Group 3)

Similar discussions were observed in all focus groups, indicating a visible development of critical reflection on pedagogical knowledge as a learning outcome of their participation in the PBL program.

4.1.3 Curricular Knowledge

At the program's start, less than half of the participants (n = 16) described the course objectives in their portfolios, an indicator of content reflection, and there was no indication of process or premise reflection being present.

At the program's end, an increase of both content and process level indicators was observed in the portfolios, albeit without individual reflection on the premise level.

Team reports identified several indicators at both content and process levels, as presented in Table 3. At the premise level, three groups (T3, T4, and T5) discussed the overall educational system and how the competencies the profession and society demanded had evolved over the last few decades. Only one group (T4) discussed the gaps between higher education and the societal needs in China. This finding indicates a limited level of critical reflection on curricular knowledge.

During focus group discussions, the participants questioned the knowledge-education gaps at the system level, such as a gap between the competencies demanded by engineering professions and what students have been taught within the curricula, engineering students' lack of readiness for workplace after four years' of study, and the need for alternative ways to organize curricula. The focus group discussions also shed light on the critical reflection on curricular knowledge. Although all participants were enthusiastic about how they had learned and benefits from the PBL program, and most of them expressed their readiness to implement PBL when they returned to their home universities, they foresaw many obstacles to changing the curricula in general. As one group discussed:

> "Now we learned about PBL, and we are convinced that it is certainly useful for students in Denmark. It should ideally be useful for our students in China because our students are too weak in terms of many industry-requested competencies. Even graduates from top universities do not satisfy the companies' needs from their point of view. We seriously need change, but it is also difficult. . ." (Group 4)

4.1.4 A Summary of Development and Change Level

Table 4 reports results of the z-test analysis of individual reflection development by comparing participants' engagement in forms of reflection at the program's start and end, respectively, by calculating the adding percentage value from participants providing reflection indicators before and after the program, as illustrated in Table 3. The values of the z-test show significant differences between the start and end of the program, registering at = 0.05 for six of the nine dimensions. Three dimensions (6, 8, and 9) were not included in this calculation due to a lack of indicators at the program's start. The overall results indicate that participants demonstrated significant development of individual reflection in eight of the nine dimensions of reflection. The only dimension that was not found to be reflected was that of premise reflection regarding curricular knowledge.

Despite the overall significant improvement in individual reflection, fewer than half of the participants reflected at higher levels, including premise reflection regarding instructional knowledge (46%), premise reflection regarding pedagogical knowledge (57%), and process (38%) and premise (0%) levels of reflection regarding curricular knowledge. Comparatively, a higher representation of indicators can be observed in team projects than in individual portfolios in all above-mentioned dimensions. This indicates the benefit of team environments in the promotion of higher levels of reflection. Nevertheless, both sources of data reported only

Table 4. Individual Reflection Development at the Program's Start and End *(NA = Not applicable)

Types of knowledge	Forms of reflection	Program start (n = 35)		Program end (n = 35)		Adding value from program start and end	Z-test	P-value
		Number of indicators	Percentage of participants providing the indicators (n = 35)	Number of indicators	Percentage of participants providing the indicators (n = 35)			
Instructional	1. Content reflection	60	86%	70	100%	14%	2.915279	0.004
	2. Process reflection	148	47%	231	73%	26%	12.65248	0.000
	3. Premise reflection	5	4%	65	46%	43%	3.429269	0.001
Pedagogical	4. Content reflection	30	21%	79	56%	35%	6.595534	0.000
	5. Process reflection	3	1%	135	64%	63%	4.291385	0.000
	6. Premise reflection	0	0%	60	57%	57%	NA	NA
Curricular	7. Content reflection	10	14%	50	71%	57%	5.46056	0.000
	8. Process reflection	0	0%	79	38%	38%	NA	NA
	9. Premise reflection	0	0%	0	0%	0%	NA	NA

NA = Not applicable.

limited indicators of premise reflection regarding instructional knowledge and curricular knowledge.

4.2 What are the Factors Constraining the University Teachers' Engagement in Critical Reflection?

An inductive thematic analysis of the data sources identified several factors that challenge participants' engagement in critical reflection, including hurdles at three levels: systemic, individual, and cultural. The three levels are interrelated and mutually influence each other.

At the systemic level, participants wrote about and discussed their concerns about the national higher education system. They referred to this as a "paradox" since universities are expected to provide students with the necessary professional and societal competencies, while at the same time, following rigid and structured curricula. Boundaries between disciplines are strictly sustained and there are few opportunities to conduct cross-disciplinary projects because the teachers are only responsible for specific courses. A project design that demands resources beyond a course can generate issues among colleagues. Approximately one-third of participants had no say in deciding on their course assessment and grading system, making it more difficult to reflect critically on the premise level. In addition, the university evaluation system for teachers was mainly based on their research outcome and success in attracting grants, demotivating factors for prioritizing teaching. Furthermore, the large class sizes, most teachers have between 40–100+ students), and curriculum standards were challenging aspects for implementing a change in how they taught when they returned. As discussed in one focus group:

> "We are supposed to help students develop competencies needed for engineering profession, but our universities also want us to teach the textbooks chapter by chapter."
>
> "If we do something different (from lectures), we don't know what students will think about it. If we have them spend class hours for projects work, we would not be able to finish the required curriculum."
>
> "In a big classroom of over 100 students, if I ask them to work in teams during the class, it would be too chaotic. If Observation Supervisor of the university happened to see this chaos in the class, they would think I am incompetent."

Although participants made action plans on implementing PBL as requested by the program, most of them expressed worries about integrating PBL into their classrooms due to the above concerns. A dilemma was identified between rationales and boundaries to change. In addition, while many participants reported a change in their teaching and learning beliefs, which shifted from teacher-centric to student-centric, other instructors' beliefs remain essentially the same. Some instructors still held beliefs that disciplinary knowledge should be prioritized over pedagogical thinking. As one participant stated in a focus group:

> "I think PBL is a good methodology, maybe it is more useful for engineering courses in year 3 and 4; for my course which is focused on engineering basics focusing on physics, it is not easy to use PBL because students need to know the basic concepts first."

The concerns, worries, and dilemmas can also be related to cultural values. The historical and traditional ideology of teachers as the master of subject knowledge is still a prevailing value among university teachers in China. In addition, society views students as customers and teachers as service deliverers. This dual role was still reflected in their portfolios and discussions even after they experienced a learner-centered professional learning program. In their final versions portfolios, more than half of the participants noted that they were struggling among different roles. As one teacher wrote:

> "I feel I have changed dramatically during this program, which was really an eye-opener for me. This is what university teaching and learning should be, like here, students are motivated to learn. I wish to do the same home and I will try PBL certainly; I should facilitate students by motivating them instead of forcing them to learn. . . but in China if I don't tell them what is correct, students may blame me for not being a good teacher, and if students send formal complaints, I will be in trouble. . ."

5. Discussion

This study has aimed to investigate the ways in which 35 Chinese engineering instructors engaged in and developed critical reflections through a six-month PBL-based professional learning program in Denmark. Using the framework of Critical Reflection for Scholarship of Teaching and Learning [15], an analysis of individual progressive portfolios, team project reports, and focus group interviews was conducted, both qualitatively and quantitatively, distinguishing nine forms of reflection, namely content, process, and premise levels in aspects of instructional, pedagogical, and curricular knowledge.

Regarding the levels and forms of reflection, the study found that at the program's start, participants primarily engaged in content reflection on instructional knowledge, with some connection to pedagogical and curricular knowledge. Only half of the participants were able to integrate process reflection on instructional knowledge. These characteristics are indicators that these university teachers were focused on themselves as transmitters of subject knowledge [49]. According to Kreber [50], content reflection is primarily related to beliefs of knowing without questioning validity and articulating one's beliefs about teaching does not necessarily lead to student learning. Although half the participants addressed process reflection of instructional knowledge, they mainly saw themselves as masters of subject knowledge and information transmitters, conceptions which are related to a lecture-based learning environment. At the program's end, regardless of the knowledge domain, the majority of participants demonstrated indicators of content reflection (the highest percentage of participants), immediately followed by process reflection (with the highest number of total indicators), and premise reflection (only moderately addressed). This is in line with the previous studies suggesting that university faculty engage primarily in content reflection on teaching, followed by process reflection to a lesser extent; premise reflection across all three knowledge domains was not consistent [50].

In terms of domains, the study found that at the program's start, participants primarily engaged in reflection on instructional knowledge, involving elements of pedagogical knowledge but very little curricular knowledge. At the program's end, the demonstrated reflection rated highest on instructional, followed by pedagogical knowledge, while more indicators were identified in pedagogical than instructional knowledge. Curricular knowledge was least addressed, both by number of indicators and participant percentage. This result is slightly different from what was found in Kreber's study [49], in which most indicators were identified to take place in the domain of instructional knowledge, followed by pedagogical knowledge, and considerably fewer indicators of curricular knowledge were found. The significant increase in the number of indicators for pedagogical knowledge may be because the program design prioritized reflection on student learning and development, which is an essential aspect of a PBL-based professional learning program [41].

This study has contributed to the framework of Critical Thinking for Scholarship of Teaching and Learning [15] by providing evidence of significant change and development through a longitudinal study in a PBL environment. Results suggest that these university teachers demonstrated significant development in individual reflections in a PBL-based environment; nevertheless, only fewer than half of the participants were able to engage at the highest level of reflection which is regarded as critical for transformative learning [6, 7, 15]. In addition, a few indicators reported in previous studies were not identified in the current study, an example being that engagement with a research-based approach to teaching and learning improvement [52] remained little recognized by the participants even by the program's end, possibly because research on teaching and learning is still not recognized in participants' evaluation systems. In addition, although many participants reported changing how they saw their role as a university teacher – from master of knowledge to a learning facilitator – none stated their role as being that of an active catalyst and leader for HE changes [53]. Furthermore, no one provided alternative recommendations for the system or outlined a plan for

communicating with institutional leaders to discuss goals related to curriculum and evaluation change as suggested by Kreber [15]. This may be because the curriculum design and revision system use a top-down approach, as was discussed in focus group discussions.

These results are compatible with outcome of previous studies in that engineering instructors seldom change the goals and essence of teaching (premise reflection), and changes most often involve the resources used, sequencing, and the instructional process [54]. The results of this study suggest that the development of transformative learning through critically questioning and reflecting on one's own beliefs often takes longer than is expected [6]. Nevertheless, the study also suggested that a team environment may provide good opportunities for university teachers to together discuss, reflect on, and understand their shared experiences in order to challenge their frame of reference for understanding the world and seek alternatives to their long-held values, assumptions, and beliefs.

This study offers evidence for the effectiveness of using a PBL methodology to organize professional learning activities [20]. Instead of evaluating instructors' learning outcome through the format and duration [33], we focused on their engagement with and development of critical reflection and documented how the 35 Chinese engineering instructors improved their critical reflection. Thus, a team-based PBL methodology that aims to contribute to transformative learning can be a useful way of developing university teachers' involvement in scholarship for teaching and learning [15]. Instead of learning a new software or a new strategy for increasing student participation, meaningful professional development encourages educators to critically examine what they believe and value by bringing their preconceived notions about teaching into awareness [35]. Critically questioning the current practices and reflecting upon how these practices work and why they are important, as well as seeking alternatives, are essential steps for launching transformative learning and should be the focus of professional learning activities [4, 7, 16, 34, 53].

A few constraining factors were identified in this study that encompass systemic, individual, and cultural levels. While the participants were excited about learning through a PBL model, they experienced a dilemma in terms of them implementing these pedagogical changes due to cultural concerns and institutional policies (e.g., a lack of support) [39, 40, 55] and a lack of conceptual change [40, 55]. In a system where university teachers are mainly evaluated based on their disciplinary expertise rather than pedagogical competencies, it is hard to motivate teachers to focus on teaching and learning pedagogy. Thus, when providing university teachers with transformative learning opportunities, it is essential to provide a systemic level of support, including motivation and ability to change [37, 53], a demonstration of the value and relevance of change through trigger events [38, 56], and a new institutional culture through changes of the evaluation system and other needed support [10, 39]. In addition to these factors, we also found individual motivation a key factor in change; for example, a few participants seemed to be more interested in the idea of traveling abroad than participating in the professional learning program itself. The lack of intrinsic motivation and appreciation for professional learning opportunities makes transformative learning difficult [37].

This study has the following significances and limitations. First, although the study provides insight into engineering instructors' development of critical reflection during their six-month experience in a PBL-based professional learning program, the results of the study remain provisional because the study was conducted in the context of participants' experience in Denmark, and they may change their beliefs and perceptions when the context is changed [10, 36, 39] and they return to their home environments where the constraints they reported are in full effect. Therefore, longitudinal studies to observe these instructors' practices in relation to critical reflection and the outcome these reflections have on their teaching and their students' learning would be meaningful. In addition, while the design of this research offered an opportunity to gain insight into how participants reflections based on their team project experiences, we did not investigate if instructors would develop similar reflections through professional learning activities based on individual work. A comparison of these two formats deserves further research attention. Moreover, previous research results suggest that university teachers may report more declarations of reflection rather than demonstrating concrete indicators through self-report data. While the current study filled in the field's empirical research gap by yielding longitudinal and multiple sources of data from both quantitative and qualitative analysis, there may still be bias given that researchers interpreted the portfolios and team reports. Therefore, the results of the study should be compared with other sources of evidence such as observations and questionnaire surveys.

6. Conclusion, Limitations and Future Perspectives

Supported by multiple qualitative data sources including individual progressive portfolios, team-

project reports, and focus group, the current study explored how 35 Chinese engineering instructors engaged in and developed critical reflections in a six-month Problem-Based Learning (PBL) professional learning program in Denmark. Quantitative analysis indicated that participants significantly developed reflection in all the three forms, namely content, process, and premise reflection within the domains of instructional knowledge and pedagogical knowledge. To conclude, the study provided evidence for the effectiveness of using a PBL methodology to organize engineering educators' professional learning activities, focusing on pedagogical development that aids in implementing PBL, and facilitate critical reflection for transformative learning.

Nevertheless, participants demonstrated little premise reflection regarding curricular knowledge, which can be attributed to systemic, individual, and cultural factors constraining engineering teachers from critical reflection. The study also suggests that to facilitate premise reflection it takes longer than six months and demands more systemic support.

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