Strength in Diversity: Future-proofing PBL Research and Practice
Special Issue

Ginie Servant-Miklos, Xiangyun Du, Jette Egelund Holgaard, and Nikolaj Stegeager *

EDITORIAL

Problem-Based Learning (PBL), a student-centred learning approach that focuses on real-life problems in higher education, has been around for more than fifty years (Servant-Miklos, Schmidt & Norman, 2019). It originated in 1969 at McMaster University's medical school in Canada and spread to other academic disciplines including engineering (Guerra et al., 2017), law (Cleassens, 2020), humanities (Kloeg, 2023), and psychology (Wiggins et al., 2016), becoming a well-recognized approach in universities worldwide. This wide-ranging diversity of applications has yielded, on the one hand, a rich body of theory and practice, with different PBL models emerging to meet diverging curricular requirements and learning objectives (Savin-Baden, 2003). On the other hand, it has also created some confusion, wherein the differences in philosophical understanding, didactic basis, and concrete practice between the academic disciplines have not been discussed thoroughly. At the same time, PBL is facing a host of new challenges from emerging global threats and opportunities, such as climate change, biodiversity loss, socio-economic inequality, and technological progress, including artificial intelligence, with a commensurate rise in ethical challenges. Faced with the rapidly evolving environmental emergency, some PBL scholars have recently called for PBL to "change or risk irrelevance" (Servant-Miklos, Dolmans & Ryberg, 2023), advocating for the development of more socially engaged, transdisciplinary, and sustainable approaches to PBL.

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*   Virginie Servant-Miklos, Erasmus School of Social and Behavioural Sciences, Erasmus University
        Rotterdam, Netherlands
        Email: servant@essb.eur.nl
        Xiangyun Du, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of
        UNESCO, Department of Planning, Institute for Advanced Study in PBL, Aalborg University, Denmark
        Email: xiangyun@plan.aau.dk
        Jette E. Holgaard, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of
        UNESCO, Department of Planning, Institute for Advanced Study in PBL, Aalborg University, Denmark
        Email: jeh@plan.aau.dk
        Nikolaj Stegeager, Department of Culture and Learning, and Institute for Advanced Study in PBL, Aalborg
        University, Denmark
        Email: nikolaj@ikl.aau.dk

In line with this call to action, in this special issue, we brought together scholars from a range of disciplines to share their perspectives on how disciplinary, methodological and pedagogical innovation can help future-proof PBL practice and research. Our special issue includes expertise from the fields of medicine (Reinsch et al., 2023), engineering (Servant-Miklos, Holgaard & Kolmos, 2023), humanities (Kloeg, 2023), and three interdisciplinary perspectives (Duchi et al., 2023; Guerra et al., 2023; Scholkmann et al., 2023), to provide a well-rounded gathering of voices from the most prominent areas of application of PBL. In this editorial, we consider the methodological, disciplinary and future-oriented contributions of these papers before reflecting on what the future of PBL might look like in the light of current events and future uncertainties.

Methodologies

One of the aims of this special edition was to showcase the variety of research approaches that can be deployed in investigating PBL. In the past, PBL research was heavily skewed towards quantitative research designs, particularly under the influence of McMaster and Maastricht's cognitive psychology research departments (e.g. Strobel & Van Barneveld, 2009). This has changed in recent years, and all the papers in our special issue feature qualitative research designs. Some borrow from traditional PBL research methods, like the case study approach, but add a novel comparative element (Scholkmann et al., 2023). Others offer new approaches to PBL research, like the combination of Education Action Research and phenomenography proposed by Duchi et al. (2023) – a combination which had been suggested by phenomenographers in the past (Cherry, 2005), but not put into practice until now. Likewise, Servant-Miklos, Holgaard & Kolmos (2023) combined Braun and Clarke's (2012) Theory-led Thematic Analysis with a longitudinal qualitative study design; a methodological innovation that adds not just to the PBL research toolkit, but to education research methodologies more broadly. Reinsch et al. (2023) showed with their randomized cross-over design that it is a possible nod to experimental research strategies within participatory qualitative research processes, while Guerra et al. (2022) also used structured qualitative research methods, including surveys, that build on quantitative epistemologies. Both papers challenge the traditional binary divide between qualitative and quantitative research without explicitly crossing over into mixed-methods research. The collection of papers assembled in this special issue shows the need and possibilities for methodological innovation in PBL research beyond traditional quantitative approaches on the one hand, and descriptive qualitative case studies on the other. There is scope for creatively adapting existing qualitative methodologies to broaden the epistemological scope of PBL research beyond an essentialist / constructivist binary. Thus, phenomenological, phenomenographic, critical and participatory traditions, can, among others, not merely inform PBL research, but also help to rethink practices within the PBL classroom. This depends on our capacity to borrow PBL perspectives from different disciplines to spur innovation.

Disciplinary contributions

Although PBL was originally billed as an interdisciplinary educational approach (Servant-Miklos, Schmidt & Norman, 2019), PBL research and practice since the 1970s has been largely confined to disciplinary contexts, particularly in Medical and Engineering Education (Scholkmann et al., 2023). In fact, most PBL scholarship has been published in medical and health professions education research journals, or in engineering education journals. While international conferences like the Pan-PBL conference and journals like this one have tried to bring together educators and researchers from different disciplinary backgrounds under the same roof, we wanted to go further with this special issue and ask PBL scholars to reflect on the contribution of their discipline to the field of PBL studies.

For instance, Guerra et al. (2023) discuss the usefulness of PBL tools developed within engineering education for broader international teacher training programmes, which can help develop PBL outside of engineering education. Reinsch et al. (2023) move beyond the traditional medical PBL tutorial setting to look at the potential of PBL within the formation of communities of practice, while Kloeg (2023) encourages PBL practitioners to look beyond "how" questions asked within the social sciences and address "why" questions posed by the humanities. Duchi et al. (2023) and Scholkmann et al. (2023) discuss issues at the cross-over between disciplines. Duchi et al. look at novel forms of student reflection within project-PBL as a way to integrate disciplinary input in a multi-dimensional reflection framework that toggles students' epistemological assumptions. Scholkmann et al. provide a case study in how Kloeg's call to include hermeneutical thinking in PBL could work in practice – by integrating social sciences and humanities thinking within STEM PBL programmes (while also cautioning of the potential pitfalls!).

These papers reflect an increasing appetite within the PBL community to make good on the promise of PBL to break down disciplinary silos. This is especially important in light of the chaotic, transdisciplinary nature of global challenges. As we head into unchartered climate waters, present global geopolitical and environmental instability is likely to increase, urgently calling educators to break out of disciplinary confines and put forward robust educational methods that can prepare students for present and future challenges and uncertainties.

Future-proofing

To paraphrase the former United States Secretary of Defense Donald Rumsfeld, the future consists of known knowns, like the inevitable consequences of warming the world by at least 1,5°C (IPPC, 2023) and destroying 70% of animal life on Earth (World Wildlife Fund, 2022), known unknowns, like the final extent of climate warming, which depends on emissions pathways and system feedback loop sensitivities (Steffen et al., 2018), and unknown unknowns, including potential socio-economic, geopolitical and nuclear risks, or what Nassim Taleb (2005) called "Black Swan" events. In this context, we use the term

"future-proofing" with a degree of irony: the idea that any educational method, let alone a method from the 1960s, could shield us or be shielded from events of such magnitude makes little sense. Nonetheless, as Servant-Miklos, Dolmans and Ryberg (2023) pointed out, there is a real risk of PBL becoming irrelevant if it does not rise up to the challenges coming in hard and fast into our classrooms, affecting the learning process, including difficulties in heating learning spaces, emergency remote teaching caused by the pandemic, and the rise of artificial intelligence, and the learning contents by challenging traditional disciplinary perspectives. Four papers in this special issue suggest avenues for increasing PBL's relevance and resilience for the future. Duchi et al. (2023) and Kloeg (2023) propose PBL as a process of personal sense-making, in which students are invited to reflect on personal and social meaning-making. This requires moving away from purely cognitive perspectives on PBL that focus solely on problem-solving, collaborative and professional competences, the relevance of which has been in doubt in the literature since at least the 1980s (Servant-Miklos, 2019). It also calls to move away from viewing PBL purely as a tool for increasing learning and knowledge retention efficiency, focusing instead on personal hermeneutics and a sense of who students are in the world. Duchi et al. (2023) propose that student agency for action can be born from the "sweet spot" in this reflection process. Servant-Miklos, Holgaard and Kolmos (2023) looked at the factors influencing students' awareness, interest, and engagement with environmental sustainability issues, and found that professional identity construction within PBL engineering education can act as a barrier to broader social and political engagement, confining engagement to the personal and professional realm. The paper discusses ways in which student concern about sustainability might usefully be channeled towards institutional forms of engagement within universities, in a way that would circumvent identity barriers towards forms of engagement that are viewed as more contentious.

Finally, Scholkmann et al. (2023) call for a reversal of decades of increasing disciplinarity in PBL, particularly through the framework of "Mega-projects" and Techno-anthropology, that ambition to foster cross-disciplinary thinking within STEM education. However, the authors caution that both projects have faced difficulties – Mega-projects were placed on hold in 2021, while the largest part of the Techno-anthropology programme was also shut down. These case studies show how difficult changing PBL to meet present and future needs will be. We would like to highlight the authors' conclusion that the capacity to *keep experimenting* will be crucial to PBL's capacity to adapt. Some of the experimental pedagogies highlighted in Duchi et al. (2023) show the potential in combining PBL with other approaches like serious gaming, jigsawing, and more experimental approaches. In Dutch and Danish, the terms "*proef*" / "prøve" mean to try, to experiment. Perhaps we might end on this play-on-words from our Northern European colleagues to suggest that what we're really calling for is future-experimenting with PBL.

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The "Sweet Spot" for Reflection in Problem-oriented Education: Insights From Phenomenographic Action-research

Lorenzo Duchi, Virginie Servant-Miklos, Loïs Kooij, Liesbeth Noordegraaf-Eelens *

ABSTRACT

This paper examines the impact of a structured, multi-dimensional reflection track of a 16-week pilot programme in experimental pedagogics (XP) in The Netherlands. XP is an elective undergraduate programme in which students investigate socially relevant educational problems in local communities and design educational interventions to address these issues through problem-oriented project work (PPL). To accompany the learning journey, students follow a reflection track structured with workshops, learning diaries, and articulated learning essays, that cover cognitive, phenomenological, relational, social, and global dimensions of reflection. The design of the track was informed by an interdisciplinary reflection framework combining inputs from cognitive and critical paradigms. To evaluate and improve the impact of this novel approach to reflection in problem-oriented education, the authors undertook an Education Action Research (EAR) process with the 17 participating students. The evaluation phase of the EAR was conducted using a phenomenographic design to draw out qualitative variations in conceptions of reflection among students who participated in the pilot. Focusing on variations of conceptions allowed the teachers-as-action-researchers to gain a fine-grained understanding of reflection within the XP problem-oriented setting. The findings reveal an outcome space comprising seven increasingly complex reflection categories. A phenomenographic analysis of the categories led us to conclude that

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*   Lorenzo Duchi, Erasmus School of Social and Behavioural Sciences, Erasmus University Rotterdam, Netherlands
Email: duchi@eur.nl
Virginie Servant-Miklos, Erasmus School of Social and Behavioural Sciences, Erasmus University Rotterdam, Netherlands
Email: servant@essb.eur.nl
Loïs Kooij, Erasmus University Rotterdam, Netherlands
Email: kooij.lois@gmail.com
Liesbeth Noordegraaf-Eelens, Erasmus School of Philosophy, Codarts Rotterdam, Netherlands
Email: noordegraaf@esphil.eur.nl

there exists a reflection "sweet spot" inside which there is growth in reflection breadth and depth. Outside the sweet spot, students either do not reflect at all, or become so entangled in reflection that an infinite reflection regress appears to derail learning. We conclude by discussing the contributions of these findings to strengthening critical, socially relevant reflection in problem-oriented project work in the context of current global crises, focusing on the role of supervisors in fostering productive reflection.

INTRODUCTION

Reflection skills have been an important objective of problem-oriented learning in higher education since the earliest days of these pedagogies (Servant, 2016). Whether in problem-based learning (PBL) or in problem-oriented project work (PPL), in all fields ranging from medical and engineering education to social sciences and humanities, educators report on problem-oriented learning's capacity to get students to introspect on their learning trajectories (e.g. Gibbons, 2018; Hmelo-Silver, 2004; Seibert, 2021).

For clarity's sake, we use problem-oriented learning as an umbrella term covering different pedagogies that share common principles of student-centred learning, constructivist learning principles, and where the learning process begins with an ill-defined problem (Servant, 2016). Within that umbrella, different expressions of problem-oriented learning appear with markedly different implementations. Problem-based learning (PBL) refers to a method of learning in which students tackle (usually written) problems designed by content-experts, in sessions guided by a tutor. Although students are encouraged to form learning objectives, course learning objectives and literature are contained within a tutor manual that serves as a reference (Barrows & Tamblyn, 1980; Moust et al, 2021). Problem-oriented project work (PPL) refers to a method of learning in which students work in group of 3-7 on a larger, real-world problem, which they investigate over an entire semester. Students define the problem themselves, guided by a project supervisor (Andersen & Heilesen, 2015; Kolmos et al., 2004).

The scope of reflection within problem-oriented learning has generally focused on a cognitive interpretation, with the ideas of Dewey, Kolb, Schön, Piaget and Vygotsky as prominent sources of inspiration (De Graaff & Kolmos, 2003). This can be explained, firstly, by the strong constructivist roots of problem-oriented learning, in both its PBL and PPL iterations (Schmidt, 1993; Servant, 2016). Secondly, the majority of renowned

reflection models in education offer variations on the cognitive paradigm, with a strong focus on problem-solving (Rogers, 2001).

In the early days of PPL in Germany and Denmark, reflection was also understood through the critical lens of C. Wright Mills' "sociological imagination", which placed individual reflection within a broader historical and sociological context. Mills' work, as interpreted by the German critical pedagogue Oskar Negt (1974), was instrumental to the Danish PPL founders' understanding of project work (Hansen, 1997). A psychoanalytic and existential view of learning was implicit in the assumptions underlying critical reflection at that time. However, as PPL moved away from its critical roots from the 1980s onwards, cognitive interpretations of reflection superseded other paradigms (Servant, 2016).

Critical reflection is undergoing a revival in the light of the enormous challenges the world faces today (e.g. Biesta, 2020; Dahl & Kennedy McFoy, 2022; Giroux, 2018). Institutions that had previously moved away from critical learning approaches under political pressure to compete in the global marketplace at the height of the neoliberal era (1991-2008) are now attempting to revive them (Andersen & Heilesen, 2015). Following this revival of socially conscious education, we developed an extra-curricular, project-based (PPL) educational programme in Experimental Pedagogics in Spring 2021. Twenty students from different social sciences undergraduate programmes enrolled for this 16-week course comprising three tracks. First, a project track in which teams of students researched and addressed a real-world educational problem by designing an educational intervention which they targeted at their project problem. An education track provided students with the tools and knowledge they needed to design their intervention. The third track offered a multi-dimensional, structured approach to reflection, in which four dimensions of reflection were explored: cognitive, phenomenological, relational, societal (and global).

The teaching team for Experimental Pedagogics ran an Educational Action Research (EAR) process alongside the educational activities to inform and improve the educational practices (Mertler, 2019). EAR is embedded in the critical educational tradition as a way to include educational stakeholders in the educational design and improvement process. It was first described as an emancipatory educational tool in Freire's *Pedagogy of the Oppressed* (1968), and has since become a mainstay of critical pedagogy practices (Miskovic & Hoop, 2006). As part of the EAR process, we investigated the impact of the Experimental Pedagogics programme on students' conceptions of reflection.

Research Questions:

1. After participating in a 16-week Reflection Track as part of the course Experimental Pedagogics, what are the qualitatively different ways in which

> *students understand and practice reflection in a problem-oriented learning environment?*
> 2. *What practical lessons can the problem-oriented learning community draw from the insights gained from this?*
> 3. *How does this insight contribute to steering the action-research cycle for the course Experimental Pedagogics?*

A unique feature of our action-research approach was the integration of a phenomenographic research design (Cherry, 2005; Marton, 1986) in the evaluation phase of the action research. This means that instead of focusing on common themes, we uncovered variations emerging from the student experience of reflection. We chose this approach to map out possible different experience categories that our unique approach to teaching reflection could trigger. With such a map, we hoped to understand how different conceptions align (or misalign) with our programme objectives, what educational outcomes they trigger, and what pathways students take to reach their conception. This paper will review the literature on problem-oriented learning and reflection, present the EAR methodology enhanced with a phenomenographic evaluation design, and discuss findings on reflection and problem-oriented education.

LITERATURE REVIEW

Although there is abundant literature on reflection in the educational field, there is no consensus on a clear definition and approach to the concept (Ottesen, 2007). The first mentions of reflection in teaching stem from John Dewey's experiential learning philosophy in the 1930s (Liu, 2015). In the 1980s, these intuitions were further developed by Donald Schön, focusing on the link between action and reflection (Ash & Clayton, 2009; Liu, 2015; Rogers, 2001). In the decades that followed, reflection solidified itself as a crucial tool in teaching (Liu, 2015). Schön's work was used to develop increasingly sophisticated models (Ottesen, 2007; Rogers, 2001).

Reflection scholars seem to agree that the reflective process is at least in part a cognitive endeavour (e.g. Kuk & Holst, 2018; Ottesen, 2007; Rogers, 2001). This does not mean that reflection is a mere act of describing, summarising or repeating learning content. Reflection is defined as a process of carefully examining one's personal beliefs and individual behaviours and a willingness to adapt them if they are not in line with the desired outcomes. As this process can be challenging, the best place to start is often bringing awareness to the obstacles that may interfere with these aims (Gay & Kirkland, 2003, Ottesen, 2007). When implemented correctly, the process leads to a richer understanding from which the learner is able to consider and adapt to the insights acquired in the process.

Reflection has always been at least tacitly present in the practice of problem-oriented education (Servant, 2016), within which different paradigmatic understandings of reflection have emerged.

Cognitive Reflection

The cognitive paradigm frames reflection as a means to reinforce the learning process, and create new learning strategies. For example, Ash and Clayton (2009) see reflection as an essential step of the learning process: to solidify new knowledge, we must first take a step back to reflect on the new information. When this is not done, learning can be superficial and unpredictable. Similarly, Hmelo-Silver (2004) stresses the importance of reflection in stimulating PBL student's ability to combine new academic information with prior experience. This approach to reflection in PBL, which mostly takes the form of auto-and-peer-feedback, promotes the learner's ability to self-regulate and rectify the shortcomings in their learning process (e.g. Hmelo-Silver, 2004, p.247; Savery & Duffy, 1994, p.6; Hendry, Frommer & Walker, 1999). While these approaches suggest promising outcomes in learning, the benefits of reflection are not expected to transcend the classroom. The value of reflection in these conceptions is purely performance-based, in the sense that its function is to improve student performance measured in quantifiable results and course grades. Servant-Miklos and Kolmos (2022) identified the negative impact of focusing exclusively on cognitive reflection in PPL students. They found that when personal motives, social dynamics and societal factors are excluded from reflection practices, students can develop unproductive conceptions of problem-oriented work. For example, neurodiverse students experienced problem-oriented work as hostile social arenas. The lack of psychological safety within the project group impeded learning and led students to attribute their distressing experiences to the pedagogical format. They were unable to reflect on group dynamics and how to improve them.

Critical Reflection

The term "critical reflection" has been used in problem-oriented learning literature to mean reflection that leads to changing one's teaching and learning practice (e.g. Du et al., 2020). In a similar way, the term "critical thinking skills" is often used to refer to thinking that challenges current educational practices and contents. However, in this paper, "critical" refers to a social-transformative educational paradigm (Servant-Miklos & Noordegraaf, 2021), in which reflection is conscious of socio-economic disparities and wider historical processes that govern social change.

Critical theory contributed to early discussions on reflection in problem-oriented education in the PPL approach (Andersen & Heilesen, 2015; Illeris, 1974; Servant, 2016). Illeris' (1974) seminal work on the subject built on Negt's historical materialist and psychoanalytic critical pedagogy (Negt, 1974). Negt translated Mills' sociological imagination into experience-based emancipatory project work, following the concept of

critical exemplarity (Servant-Miklos & Guerra, 2019). Although the critical approach was side-lined in PBL and PPL literature and practice in favour of cognitive reflection in the 1980s, there has been renewed interest in last decade. For instance, Noordegraaf et al. (2020) critiqued the dominance of the cognitive paradigm in PBL, suggesting that it cuts students off from the world at a time of heightened global crises. Servant-Miklos and Kolmos (2022) came to similar conclusions regarding PPL. They also found that an exclusive focus on cognitive reflection can be harmful to social dynamics in project groups, impacting students' identity formation processes by leading them to develop more individualistic professional identities.

Borrowing from Bourdieu's sociology, psychoanalysis and existential phenomenology, Feilberg (2014, 2016) argued that the formation of a professional and scientific *habitus* in project work requires reflective practice surrounding social and emotional processes in the group work, uncovering internal psychological processes such as (unconscious) motives and drives, and interpersonal psychological processes such as group dynamics. He also argued that supervisors play an important role in guiding productive student self-reflection of intrapersonal psychological processes in project work (Feilberg, 2016). In doing so, he developed the existential-phenomenological and psychoanalytic underpinnings of critical reflection but stopped short of exploring its implications for a learning in a world destabilised by crises. Taking this added step, Servant-Miklos and Noordzij (2021) noted the importance of integrating a praxis of action and reflection in problem-oriented sustainability education to steer students away from unproductive strategies of denial, bargaining and despair.

Most reflection research and practice follows either one or the other reflection paradigm. This paper offers a reconciliation of cognitive and critical approaches, presenting the impact of a multi-dimensional reflection programme in the Experimental Pedagogics programme in The Netherlands.

METHODOLOGY

Reflecting on Educational Action Research with Phenomenography
This paper presents the evaluation phase of EAR cycle in which we collected and analysed data using a phenomenographic design. We will briefly present EAR, describe the initial phases of our EAR cycle, and explain how we designed our evaluation phase with phenomenography.

Educational Action Research. Educational Action Research is a participatory, cyclical research approach, where practitioner-researchers aim to improve their own educational practices (Mertler, 2019; Olin et al, 2016). An EAR cycle typically comprises an

investigation, action, and an evaluation phase that informs the next cycle by suggesting improvements to practice (McAteer, 2013; McNiff & Whitehead, 2006). What makes our research fall under EAR rather than other forms of action-led investigations like practitioner-research and pedagogical action research is our dual aim to improve practice *and* develop new methodological and theoretical insights for the problem-based research community (Capobianco & Feldman, 2006).
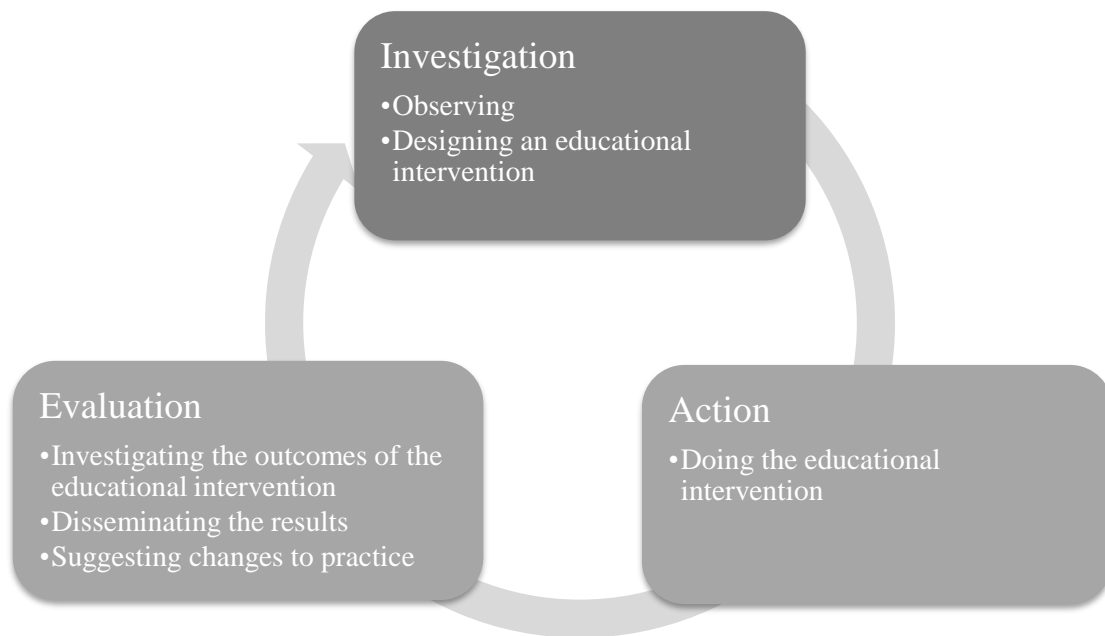

Figure 1. The Educational Action Research Cycle.

In our research, the investigation and action phases were led by the second author, while the evaluation phase was led by the first author. The third author supported the research by transcribing the interviews and performing the literature review. The last author had a supervisory role.

Investigation. The investigation phase lasted six months, from the start of the academic year in September 2020, until the start of Experimental Pedagogics in February 2021. The investigation phase was initiated in response to a request from the University's Diversity and Inclusion Office (DIO) to develop a training programme to sensitize university students to early outreach issues in socio-economically deprived areas of Rotterdam. When the coronavirus pandemic hit, working with primary and secondary schools in Rotterdam became fraught. The DIO's mandate was therefore broadened to sensitizing students to diversity and inclusion issues in education. In the months that followed, the authors led informal consultation sessions with key players in diversity and inclusion and education innovation, at the University and outside the university, to obtain insights into

what might be included in the training design. The authors designed a 16-week extra-curricular training programme, as described below.

Action: Experimental Pedagogics. The pilot programme in Experimental Pedagogics (XP) ran as an inter-faculty extracurricular for undergraduates at Erasmus University Rotterdam in The Netherlands in the Spring semester of 2021. Due to pandemic lockdowns, the entire programme ran online as shown in Table 1.

Week	Project Track	Education Track	Reflection Track
1	Introduction Project Work Training		Intake Interviews
2	Topic Selection Group Contract	Lecture: Cognitive levers of learning	
3	Research Design	Problem-based learning: Scaffolding	Reflection Diary 1
4	Initial Problem Analysis	Lecture: Individual Levers of learning	
5	Initial Problem Analysis	Jigsaw classroom: group-based learning methods	Reflection workshop 1: cognitive & phenomenological reflection
6	Problem Reformulation	Lecture: Group Levers of learning	
7	Problem Analysis	Case-based learning: successful classroom experiments	
8	Problem Analysis		Reflection Diary 2
9	BREAK	BREAK	BREAK
10	Finalize the Problem	Lecture: Societal Levers of Learning Workshop: Build Blocks of Educational Experiment	Reflection workshop 2: group & societal reflection
11	Experiment Design	Object-based learning: writing the implosion	
12	Experiment Design	Lecture: Global Levers of Learning	Reflection Diary 3
13	Experiment Design	Design-based learning: Education for 2100.	
14	Experiment Design		Deadline Articulated Learning Reflection
15	Deadline Project Report		
16	Group Project Presentations		Exit interviews

Table 1. Week-by-week, Track-by-track Structure of the XP Programme.

Project Track. The project track closely follows the Roskilde Model of PPL (Andersen & Heilesen, 2015). The step-by-step approach listed in Table 2 is adapted from Holgaard et al. (2017). We developed scaffolded worksheets to accompany each step. Students formed groups of 3-5, and identified a real-world educational problem on the theme of diversity and inclusion in an educational setting of their choice. Due to access constraints caused by coronavirus lockdowns, we did not further restrict their choice of problem: two groups worked with higher education, two groups with high school and one group with primary school problems. Three groups worked with Dutch institutions, two with institutions in the home country of one of the team members (Poland and Bulgaria). The problems covered LGBTQ issues, racial-ethnic diversity, the urban-rural opportunities gap, neurodiversity and xenophobia directed towards Roma children. The project deliverable was an education intervention plan, with a background research report on the problem (literature review and stakeholder interviews or surveys), and a detailed outline for a classroom experiment to address the problem.

Education Track. The education gave students the theoretical knowledge and skills to design their educational experiment, structured into five levels of increasing scope and breadth.

- The cognitive level covered traditional educational sciences and cognitive theories of learning, including constructivism, self-determination theory, information processing, and instructional design (Ryan & Deci, 2020; Sweller et al., 2019).
- The individual level addressed the existential and phenomenological importance of learning, using existential and embodied phenomenology to introduce students to concepts of agency, purpose, choice and self-authoring (De Beauvoir, 1947; Merleau-Ponty, 1945).
- The group level drew upon psychodynamic understandings of group work and the Karpman triangle to uncover how classroom group interactions can function or malfunction (Bion, 1968; Emerald, 2016).
- The societal level covered classic and modern critical pedagogy (Arendt,1961; Biesta, 2020; Freire, 1968; hooks, 1994; Negt, 1974).
- The global level situated education within a broader technological, socio-economic and environmental threats and opportunities (Dumit, 2014; Haraway, 2016).

Within the education track, classes were taught using an array of problem-oriented, student-centred pedagogies including problem-based learning (Moust et al., 2021), jigsaw method (Aronson & Patnoe, 2011), case-based learning (Ellet, 2018), object-based learning (Dumit, 2014) and other bespoke workshop formats tailored to developing specific skillsets such as constructive alignment and educational design.

Reflection Track. The reflection track mapped onto the education track, with levels of reflection corresponding to the different educational levels covered in the education track, ranging from cognitive reflection to critical and intersectional reflection.

The reflection track comprised the following learning moments:
- 30-minute individual intake interview: students were asked about their background, their motivation for joining, and formulated programme learning goals for themselves.
- Individual learning diaries: students wrote personal reflections using written prompts adapted from Ash and Clayton (2004) (refer to Appendix 2). There were three hand-in moments for learning diaries, spaced out to give students time to absorb their learning experience, process it in the workshops, and grow from experience before writing the next one.
- Reflection workshops: workshops took place at strategic moments of the programme, after students handed in a learning diary. In the workshops, students used their diaries as primary sources for meta-reflection exercises using different theoretical lenses to help them interpret their experiences. The four levels of reflection were:
  - Cognitive: students interpreted their diaries through the lens of the Kolb learning cycle (Kolb, 1984).
  - Individual: students interpreted their diaries through the lens of phenomenological analysis (Eatough & Smith, 2017; Feilberg, 2016).
  - Relational: students interpreted their diaries through the lens of Karpman's drama triangle and the empowerment dynamic (Emerald, 2016).
  - Societal and Global: students interpreted their diaries through the lens of the sociological imagination, focusing on exemplarity (Mills, 1959; Negt, 1974).
- Written Articulated Learning Reflection: we adapted Ash and Clayton's (2004) Articulated Learning to cover all three learning moments of the diaries, instead of one discreet event. Students were asked to trace a learning arc across their learning experience for the whole programme, and interpret that arc at all four levels of reflection covered in the programme.
- 30-minute individual exit interview: students were asked about their experience and key takeaways of the programme, and to assess the outcomes of their learning goals. The interviews for this study were performed immediately afterwards.

Evaluation: using phenomenography in EAR. Although Cherry (2005) suggested more than fifteen years ago that phenomenography might be a useful tool for action researchers, Beaulieu (2017) noted that the call had not been heeded by action researchers. He argued that phenomenography's emphasis on divergence and variation might make a powerful

contribution to diversity and inclusion in action research. He stated: "infused by phenomenography, action research can lead to a deeper understanding of diverse views and inspire solutions for addressing the educational disparities we continue to experience" (p. 64). We harnessed the second author's prior experience with phenomenography to design our evaluation with phenomenographic principles in mind.

While most qualitative research approaches seek common themes underlying the studied phenomenon, phenomenography investigates variations in conceptions of the phenomenon (Bowden & Green, 2005; Marton, 1986; 1986). That is, it tries to grasp how people can interpret the same phenomenon differently. As Marton and Booth suggested (1997, p.111), there is a strong relation between how one experiences a given situation and how one acts upon it: "To make sense of how people handle problems, situations, the world, we have to understand the way in which they experience the problems, the situations, the world, that they are handling or in relation to the way they are acting (…). You cannot act other than in relation to the world as you experience it". An approach focused on variation rather than common themes provides an opportunity to bring uncommon or marginalized perspectives to the fore and consider them on an equal footing with more common perspectives. Therefore, we believe that phenomenography can enrich the critical pedagogical toolbox by challenging educators to understand and situate different conceptions of the educational experience in relation to each other.

The outcomes of a phenomenographic analysis are a series of categories that define an outcome space. This space is a graphically represented map of all identified conceptions, such that the relationship between the different categories, and between the categories and educational objectives becomes apparent. In our case, different categories or conceptions emerged from the data based on the different way in which participants experienced reflection. The outcome space describes a hierarchical, logical relationship between emergent categories. Phenomenography posits that categories of conceptions ought to be logically connected since different conceptions represent different relationships between the studied phenomenon and how people experience it (Åkerlind, 2005). Categories in the outcome space are organised hierarchically, which does not imply a value judgement on conceptions, but denotes that some categories are more complex or broader than others (Åkerlind, 2005; Marton & Booth, 1997). The aim is to describe the qualitatively different ways participants experience a phenomenon in a useful and meaningful way for practice, showing what would be needed for a student to move from a less complex to more complex ways of understanding a classroom phenomenon (which could be related to classroom content or process). Therefore, there is a continuous iteration between defining the categories and clarifying the logical relationships between them (Bowden & Green, 2005). As phenomenographic research explores the variation of students' experiences of a given phenomenon, this allows for a way of looking at the

collective experience of the phenomenon holistically (in contrast to the individual experience each person might have about the phenomenon).

This research method has been used to explore the impact that educational programs might have on students' experiences of certain classroom phenomena. Phenomenographic analysis has been conducted to explore, for example, students' experiences around engagement and creativity (Reid & Solomonides, 2007) or around programming (Stamouli & Huggard, 2007). In problem-based education, Dringenberg and Purzer (2018) studied variations in conceptions of ill-structured problems, Servant-Miklos and Kolmos (2022) examined variations in conceptions of problem and project based learning, while Mohd-Ali et al. (2016) used a PBL setting to explore methodological questions in phenomenography. In the area of reflection, Prinsloo, Slade, and Galpin (2011) explored how students experienced online reflection diaries. Given the popularity of phenomenography as an educational research method, we were able to adapt existing research tools towards an EAR framework, including interview protocols, sampling procedures, interview approaches and analysis.

Interview protocols. We developed a two-part semi-structured interview protocol modelled on existing phenomenographic protocols by Dringenberg et al. (2018) and Zoltowski et al. (2012), adapted to the EAR framework. The first part focused on descriptive elements of participant experiences in XP. The second part focused on reflection, divided into experiential questions, and what Zoltowski et al. called "summative questions" (2012, p. 58), i.e. questions that elicit more explicit formulations of participants' conceptions of reflection. The key adaptation to the protocol made for EAR is the context-boundedness of the questions, rather than more general or abstract experiences of reflection. The full protocol is provided in Appendix 1.

Participants. In EAR, sampling is purposive and context-bound (Etikan, 2016), i.e. researchers sample participants according to their proximity to the educational phenomenon being investigated. In phenomenography, sampling aims to maximise variations in demographic characteristics within the target group (Åkerlind et al., 2005). To resolve this, following Daly et al.'s contention that sampling should reflect variations occurring in the target population (2012), we sampled the entire population of XP. Of the 20 students who signed up for XP initially, 17 stayed until the end. We therefore utilized the data of 17 participants for this study, which is within the range of participants required in phenomenography to avoid any common conceptions being missed (Servant-Miklos & Kolmos, 2022). Following the norms on ethical research, all students were given an option to opt out of research participation without affecting their enrollment in XP. However, none chose to opt out. Before the start of XP, all students signed an informed consent form detailing the research process, the data collection points and the storage and use of data.

Pseudonym (randomly assigned)	Faculty	Nationality (Dutch / International)
Ada	Social Sciences	Dutch
Carol	Economics	International
Catherine	Social Sciences	International
Chima	Liberal Arts & Sciences	Dutch
Cornelia	Liberal Arts & Sciences	International
Daphne	Philosophy	Dutch
Freya	Social Sciences	Dutch
Felicia	Liberal Arts & Sciences	International
Gabriele	Media & Communication	Dutch
Hetti	Liberal Arts & Sciences	International
Iria	Liberal Arts & Sciences	International
Jessica	Social Sciences	International
Livia	History	International
Pia	Social Sciences	Dutch
River	Liberal Arts & Sciences	International
Sadie	Social Sciences	International
Samira	Social Sciences	Dutch
Sandra	Social Sciences	International
Valentine	Liberal Arts & Sciences	International
Yuri	Social Sciences	International

Table 2. Participant Table.

Interviews and Transcripts. As indicated in Table 1, we conducted the interviews during the last week of XP. The first and second author split the student group randomly and each conducted half of the interviews. Due to the lockdown measures in place at the time, all interviews were done online. Interviews lasted about one hour each, and were all conducted in English as this was the language of XP. The interviews were recorded with the permission of the participants, then the audio recordings were given to the third author who transcribed them. All transcripts were pseudonymized.

Analysis. There are two schools of thought on analysis in phenomenography: pure and developmental. Pure phenomenography looks for conceptions within sections of transcripts and across different transcripts (Marton, 1986; Marton & Booth, 1997). Developmental phenomenography assigns one conception to one transcript as a whole unit, then groups transcripts that display similar conceptions (Bowden & Green, 2005).

Pure phenomenography is used when researchers are interested in variations within transcripts. Developmental phenomenography is useful when researchers are interested in a broader view of variation across the group of participants. We used the developmental approach. We began by reading repeatedly the entire set of transcripts in an iterative and comparative process. The transcripts were then sorted into piles with similarities and differences outlined. From there, categories related to each transcript as a whole emerged from the content of the interviews, rather than any theoretical framework from the literature. After several iterations, the categories were clarified and refined. This allowed for the development of the structural relationships between the categories which laid the foundations for the two axes forming the outcome space. The first author played the lead in the categorization process, with the second and third author playing "devil's advocate". Although there is no prescribed way to visualize the outcome space, we followed Zoltowski et al (2018) and Dringenberg and Purzer (2018) in designing a matrix outcome space in which categories follow an upward, rightward trajectory (Figure 2).

FINDINGS

The Outcome Space
The analysis revealed seven qualitatively different ways in which participants understood and practiced reflection within XP. An overview of the categories can be found in Table 3.

Categories	Summary
Category 0 Hetti, Yuri, Sandra, Valentina, Samira, Pia, Iria (all prior to XP)	Reflection is for the teacher and for the course, not for the students. Reflection is being forced upon and does not add to the learning experience of the students. It is deemed irrelevant and of no added value.
Category 1: Personal Reflection Ada, Frida, Helen, Livia, Sadie, Youri	Reflection is for personal growth and development. The focus is on the individual and on self-awareness. A depth in the reflection starts to emerge in comparison to previous experiences. Yet, it lacks appreciation for other perspectives and for deeper level of analysis.
Category 2: Relational Reflection Jess, Sandra, Valentina	Other people's inputs and experiences start to become a crucial component of the reflective process. Interacting with others begins to become an integral part of the reflection. It can be that close friends or family help with the reflection or that other inputs are being considered. Nevertheless, the focus is still on the self, the goal is still self-development.

Category 3: Societal Reflection Carol, Cornelia	Reflection has become critical in so far as other perspectives and actors are being taken into consideration. Other people's insights, perspectives, values are seriously included in the reflection process. The goal and focus of the reflection have moved outside of the individual to include others and society at large.
Category 4: Metacognitive Reflection Catherine, Pia, Samira	Reflection gains a deeper level of analysis. Gaining a stronger and deeper sense of self-awareness in relationship with other people helps to build the foundations to develop this meta-understanding of reflection. Connections start to become visible. The focus is still on the self but the meta level allows for one to direct and guide one's development.
Category 5: Critical Reflection Gabriele, Iria	Reflection has gained both depth and breadth. The deeper level of analysis moved beyond the self to include and take into consideration their contexts, the community, and society at large. Reflection becomes critical, deep, and societally engaged.
Category 6: Fractal Reflection Daphne	Reflection has become too complex and chaotic. Complexities and confusions emerge when exploring deeper and broader elements of reflection. Without sense-making frameworks, reflection can turn into an inefficacious, self-destructive tool.

Table 3. Categories of Description of Students' Experience of Reflection.

The seven categories formed an outcome space with two distinct, yet related, axes: "Depth of Reflection" and "Breadth of Reflection", as shown in Figure 1. The former describes the depth of students' reflection across different levels, moving from a more superficial self-reflection towards a more profound level of reflection, then tipping into downward, regressive spiral of continuous reflection on reflection. The second axis outlines the extent to which students' reflection involves other actors, ranging from being self-referential to include others and the society at large.
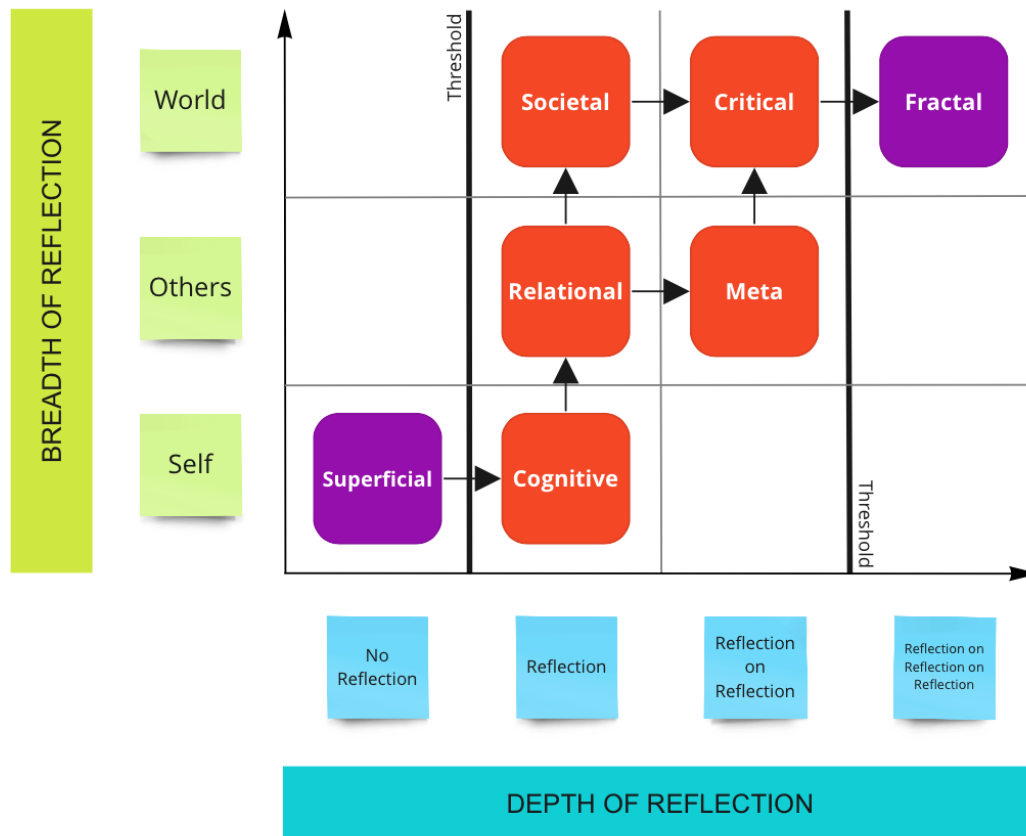
Figure 2. The Outcome Space of Conceptions of Reflection in a Problem-based Environment.

The Categories of Experience

Each category is ordered in such a way that subsequent categories describe a more comprehensive way of understanding and practicing reflection. The qualitative differences between the different categories enabled us to develop the hierarchical structure shown in the outcome space. Five of the seven categories, namely Category 1 to 5, were related in such a way that each subsequent category represented a more sophisticated and comprehensive way of experiencing reflection. Although logically related to the other ones, Category 0 and 6 do not fall in that group. This shows the existence of a reflection "sweet spot" in the outcome space. Inside of the "sweet spot", students go one or two levels deep in one or both axes. Outside the "sweet spot", students either do not reflect at all (as shown by students' experiences prior to this project - Category 0), or become so entangled that an infinite regress appears to derail learning (Category 6). Inside of this "sweet spot", categories that are more sophisticated contain elements that are unique to them as well as elements that are present in less comprehensive categories. Category 0 emerged in conversations with the students as the most common understanding and practice of reflection before entering the programme.

Category 0: Superficial reflection. Many students described how they previously disliked the idea of reflecting, deeming it of no value. It was experienced as imposed and geared towards knowledge and facts, which compounded a feeling of detachment and alienation. Hetti and Samira best described the transition away from this form of reflection during XP.

> Samira: My view of reflection really went from something that you have to do, and that I would write in half an hour because you have to do, to make something out of it, to really think about what you write, what you did, what you learned.
>
> Hetti: guess before I would just have answered that reflection is more for the teachers, but I now see it as something more for myself

What helped students to move through this transition was certainly the time and space in the programme devoted to reflection. However, something that was of particular importance was the creation of a psychologically safe environment.

> Youri: When I realised it is not judgmental, I felt a bit released and accepted. I think that I realised it is a safe space in which I can put my thoughts, instead of a place where I need to spill out my personal life. I think that in the first reflection I was very protective. Later I built trust and realised the importance of it.

This transition was experienced by many students, regardless of what categories they fell into later.

Category 1: Personal reflection. Participants in this category developed a view on reflection which revolves around their own personal growth and development. They claimed to have experienced a greater sense of self-awareness as they developed more open and exploratory mindsets. Moving beyond a view of reflection as shallow, teacher-centered, and content-oriented, now students started to regard it as an integral and meaningful part of their own development.

> Ada: Reflection is thinking back of an experience, and trying to... Yeah, maybe almost like relive it. But relive it from different aspects, or relive it from the cognitive level, or the phenomenological level and really evaluate it and work out details, so you can make it more meaningful and learn from it. Because I think that when you experience something you are so caught up in the moment and you, you... because you are in the moment, you have to act on it. And when you reflect on it afterwards, you don't have to act on it anymore because the moments is past. So that gives you, I think, a little room to look back and really learn from it.

Students in this category started to appreciate the distinction between experiencing and learning from the experience. It is this focus towards meaning and learning that defines this category, transitioning away from the previous one. Personal growth and

development became crucial in their understanding and practice of reflection. They started to reflect on how their everyday experiences related to each other and to themselves, how they could derive learnings and incorporate those learnings in their own lives, in line with their own goals and actions. Felicia framed this in her own way when pondering on how self-reflection can become a tool to know one's strengths and weaknesses.

> Felicia: I don't think there's like a wrong or right way to do it, of course. But yeah, I think it helps you see where your strengths and weaknesses are. (...) It does allow you to I don't know, to not to get I mean, certainly like to get to know yourself, but it's not that deep. I think. Yeah, I mean, it does help, it does help you to see your strengths and weaknesses.

Yet, these students were still focused on their own personal growth and development, without taking into account other perspectives or taking a step back to re-evaluate or re-examine their viewpoints. Their conception revolves around bettering themselves, improving their weaknesses and leveraging their strengths. Their reflections, while beginning to show signs of depth and awareness, were still very much self-centered and solution-oriented.

Category 2: Relational reflection. Participants in this category developed a view on reflection that started to include other people and other perspectives. They started to see how reflection could be beneficial for the group process. Being able to share, talk, and discuss with others became a crucial component of the reflection process. In describing an important moment in her development, Sandra reported how feedback and other people more generally played a valuable role in her learning.

> Sandra: The feedback really helped me I think. Even if it was just like, oh, wow, that sounds a bit depressive. I don't know, it just it really, maybe it's my personality type. But I really like getting other people's view on things, even if it's a view I disagree on. But still, I think it adds so much value.

Within the outcome space, students in this category moved up the axis "Breadth of Reflection" as they developed a more critical view on reflection that includes and considers other inputs and perspectives. Being able to reflect with others becomes more meaningful and exciting.

> Valentina: In my group projects, we had to reflect sometimes about how the interviews we were carrying out went and I got much more enthusiastic, because then you get, I don't know, triggered by other people, other people's experiences and what they say and, and my reflection felt much more complex when I was doing with people than on my own.

However, the focus of their reflection is still around self-development and growth. Ultimately, students in this category still saw others as a way to improve themselves, seeing self-development and personal growth as the purpose of reflection. Moreover, students started to show signs of a deeper level of reflection, although they cannot yet be qualitatively defined as having reached a metacognitive level of reflection.

Category 3: Societal reflection. At this level, students showed a wider understanding and practice of reflection, regarding the spectrum of actors involved. Students in this category started to seriously consider other people's perspectives, backgrounds, and values when reflecting on certain learning moments. They discovered how the center of their reflection can move outside of themselves to encompass people, communities, and larger societal issues. In contrast to the previous categories, the focus was no longer solely on personal growth. Here the purpose and meaning of reflection had a more critical and engaged tone. In defining what reflection is to her, Carol clearly explained this new level of engagement in her reflection.

> Carol: I always thought that reflection was like a very personal thing, like, takes a personal approach. So additionally, now I see that it can also be through someone else's eyes. Now I understand reflection, also, the ability to connect your experience or situation to something much wider, like societal issues.

One can see an application of Carol's definition in how Cornelia described one of her reflection moments. By being critical and aware while taking diverse perspectives into consideration, Cornelia tapped into the relationship between a set of systemic issues and her own project work.

> Cornelia: I tried to feel empathy for the people who are discriminating against Romani people. At the same time, I also feel empathy for Romani people as well. So, I was looking at different perspectives, like how they look at Romani people, how Romani people look at Bulgarian people. It was like I was being Romani people. And I was like, okay, they see us as criminals, which is making me act upon it more, you know, the way that, like… I feel like I'm an outcast, and the country that I live in is making me… I don't know, do impulsive stuff, probably I wouldn't like to be a minority in the country that I'm living.

While this showcases a radically different level of analysis than in the previous categories, students in this category still have not yet been able to tap into the depth of their reflection, the second axis of the outcome space. This other dimension begins to emerge in the subsequent categories.

Category 4: Metacognitive reflection. The main difference between this category and the previous ones relates to the axis "Depth of Reflection". While previous categories showed an increased level of sophistication in relation to the axis "Breadth of Reflection",

the following categories explore how the change across the two axes show an increasingly comprehensive view of reflection. Students in this category did not necessarily develop the broad analysis found in Category 3. Nevertheless, their understanding and practice of reflection is built upon Categories 1 and 2, as shown in Figure 2. Participants in this category developed a more comprehensive idea of reflection that revolves around self-awareness and personal growth. They also started to appreciate other people's input in the process. It is thanks to these two developments that participants engaged in a deeper level of reflection. Catherine outlined her reflection process and showed how being metacognitive was the most crucial component in allowing her to create connections and depth in her learning.

> Catherine: I think the most difficult part is just before the last step, you have to reflect on your reflection. So don't forget it, don't just like, do it once, and then put it away and never read it again. But read it, and then do it on a frequent... like do it frequently. And then finally, try to, to link it together, try to link your different, like, critical moments in life together. Just try to link it together to see, is there any common things between those moments? So by seeing the similarities and the differences, you maybe can learn a new thing about yourself.

This metacognitive perspective in the reflection process enabled students in this category to develop a clearer sense of self-direction. Reflection became a pivotal tool for awareness and action. Students took initiative for their own education: they started to identify their learning needs and goals and to initiate, monitor, control and evaluate their learning process to reach their goals and meet their needs.

> Pia: It makes you more aware of the learning moments, and also makes you more aware of how much you've already learned. And yeah, also to be able to see what learning goals you could set for further process. Because when you're looking back at where you're at, right now, you're also able to set a goal for where you want to be.

As with Category 2, students were able to position themselves outside of themselves, to include others in their own reflections and evaluations. That is, they developed a more in-depth reflective process while starting to open up to others' inputs and perspectives. However, the focus of their reflection still revolved around self-development and growth. It is with the next category of experience that the students were able to combine both metacognitive and societal elements to their reflection to develop a critical view on reflection.

Category 5: Critical reflection. Participants in this category experienced a more sophisticated reflective and critical perspective on reflection. Alongside the two axes, they started to include a wide variety of actors and perspectives in their reflection while acknowledging the importance of stepping back to develop in-depth understandings and

practices. Students' perspectives became critical in so far as they took into consideration the world and the context around them, questioning their identity and positionality in society. That is, they were able to take a metacognitive perspective on their experiences which was informed by people and societal factors. This can be seen in Iria's words when she reflected on her project work and how that made her develop a more critical stance towards herself and society.

> Iria: I started to question my position in this project, with, like, I don't know, stepping into the foot of a different country and a community that is completely unrelated to me in some ways. I think that those critiques based on yourself are super valuable. And if you do not leave time to for this reflection, so maybe you don't even realize, and you think you're actually doing something positive, which might not be positive. So yeah, I think that was a point where I realized like, okay, like, think twice about what you're doing.

Students in this category considered other people's inputs, perspectives, situations in their thinking and reflecting. They also understood the importance of reflecting on reflection, on taking step backs and reconsider or re-evaluate the situations further. When asked why she found reflecting with societal and critical lenses to be striking and interesting, Gabriele gave the following explanation:

> Gabriele: You can really articulate in a deeper way, think about what you're doing. And why you're doing it, and also be critical on things that you shouldn't do, or the way you're doing it.

Category 6: Fractal reflection. In this last category, participants reached beyond the sweet spot of reflection by getting entangled in an infinite reflection regress. They developed a broad sense of awareness, which allowed them to question themselves and their positionality in society. However, they also entered a regress which made it harder for them to reflect in a meaningful and constructive way. Students in this category were no longer able to make sense of their reflection, derailing their learning process. Thus, an internal conflict emerged between a sense of development in their critical practice and understanding of reflection and society against a sense of complexity, loss, and confusion. This tension can be seen in Daphne's words as she described how her view of reflection changed over the course of the program.

> Daphne: Yeah, I think I did a lot more reflection than I thought of the first time. And, it also made it harder to reflect (…) Because I was thinking about thinking about thinking about thinking. On and on. That makes it hard to just write something.

This created a sense of chaos and derailment. It became impossible to make sense of the complexities and nuances of learning. When one cannot stop reflecting and enter an

infinite reflection regress, life becomes overwhelming and ungraspable. The more they explore, the harder and more complex it becomes.

Relationship between the categories. Table 4 clarifies the main relationships across the different categories.

Categories	Relationships
0 ->1	Having the time and the space to properly reflect becomes vital in the transition from a shallow reflection to experience a more meaningful and personal dimension.
1 -> 2	Finding a stronger sense of personal growth and development in the reflection process is conducive to start appreciating others' inputs and perspectives.
2 -> 3	Considering other people's inputs in the reflection process is a first step towards taking seriously into account the insights, opinions, and values of others and the society at large.
2 -> 4	Having a stronger sense of self while learning to appreciate the others can lay the foundations for a metacognitive understanding of reflection.
3 -> 5	Becoming more aware of the way others and society at large can affect one's experience and reflection is necessary to develop a critical and in-depth view on reflection.
4 -> 5	Developing a deeper sense of oneself and one's experience is conducive to becoming engaged in a critical and socially engaged reflection.
5 -> 6	Engaging in both the breadth of the possibilities and the depth of the layers of reflection might lead towards a fragmented, confused, and complex view of oneself and the world.

Table 4. Relationships between Categories of Description.

DISCUSSION

The category descriptions and the relationships between the different categories that make up the outcome space reveal a number of important points for the practice of reflection in a problem-oriented environment.

Firstly, we related the experience of reflection to two dimensions: breadth and depth. This means that reflection can be interpreted along two independent, yet interconnected aspects. On the one hand, students can engage with aspects of reflections that take into account a larger set of actors. On the other hand, students can experience a type of

reflection that taps into deeper levels of thinking. Secondly, the categories are nested hierarchically with clear relationships and dependencies between them. In particular, categories 1 to 5 show a development of reflection, with category 5 describing a more comprehensive and sophisticated approach. Categories 0 and 6, however, outline the lower and upper threshold, respectively, within which students' reflection leads to meaningful learning experiences. Within the growth zone, students increasingly reflect on their learning experience in a systemic way, embedding individual experiences in a societal context, cutting across local and global issues.

We can conclude that the structured reflection programme of XP infused students' project work with critical exemplarity (Negt, 1974; Servant-Miklos & Guerra, 2019). As discussed earlier, in the 1980s, PPL drifted towards a cognitive, skills, and competence-based learning framework. Our findings show that the XP reflection programme went beyond reviving the critical framework of PPL. Being able to grasp the interconnectedness between the classroom and the bigger picture allowed students to step outside of their personal experience, into an intersectional public sphere where other perspectives, values, belief systems, and behaviours can be acknowledged as meaningful, valuable and woven into complex interconnected patterns that affect people's chances and challenges in life. In this sense, our approach to reflection is more alligned with intersectional approaches to critical education (e.g. Carbado et al., 2013; hooks, 1994).

Reflection as Praxis
Servant-Miklos and Noordegraaf-Eelens (2021) argued that, for social-transformative action to take place in the learning process, students need to connect personal reflections on learning with social impact in an action-reflection cycle. They reference Freire's educational praxis:

> We find two dimensions, reflection and action, in such radical interaction that if one is sacrificed – even in part – the other immediately suffers. There is no true word that is not at the same time a praxis. Thus, to speak a true word is to transform the world. (...) When a word is deprived of its dimension of action, reflection automatically suffers as well; and the word is changed into idle chatter, into verbalism, into an alienated and alienating "blah." It becomes an empty word, one which cannot denounce the world, for denunciation is impossible without a commitment to transform, and there is no transformation without action (Freire, 1968, p.87).

Our findings demonstrate both ends of the praxis: Category 0 represents action without reflection, Category 6 represents reflection without action. While the benefits of supplementing content learning with reflection are thoroughly documented in the PBL literature, the impact of an overemphasis on reflection at the expense of action is less so.

Perhaps this is because the two fields in which PBL is used most extensively, namely medicine and engineering, are geared towards action by the nature of the professions they feed into. In the humanities, Servant-Miklos and Noordzij (2021) identified an instance in which students, who learned about the climate crisis in a PBL course with no action outlet, developed despairing thoughts, harming their mental health and failing to effect personal and social change. Feilberg (2016) noted the importance of supervisor guidance and intervention in spurring students' productive introspection on their (unconscious) personal and professional motives in the project learning process. He suggested that supervisors might help students realize when their personal experience leads them to overanalyze project data, a point also made by Jensen (2015). Broadening this argument, we might suggest that by channeling students towards productive reflection (i.e. reflection in praxis) supervisors play a guard-rail role against falling into Category 6.

The context of XP lends itself well to such stewardship: given the small-scale, close-knit learning community created in XP, students built trusting relations with their supervisors and the interview quotes show that they were receptive to guidance and feedback. The context also channeled student energies productively: by giving them space and resources to apply the knowledge acquired throughout the course into project work with real life societal problems. Despite COVID, students' experiences were enhanced by their immersion in community research. The opportunity to engage with society and bring about change, even at a small scale, gave students a sense of agency while teaching them valuable skills about engaging with external stakeholders.

Implications for practice
Our findings suggest that using a structured, multi-dimensional reflection approach in a problem-oriented learning environment can lay the foundations for a more critical, intersectional and engaged relationship with the others and the world. Given the urgent and complex nature of the world's interlocked sustainability and equity crises, keeping PBL in step with the educational challenge posed by these crises will be essential to its future-proofing. In this regard, there are concrete implications for practice to be drawn from this study.

Firstly, we call to attention the role of supervisors in fostering productive, critical reflection. To appraise students' motives, it is essential for educators themselves to invest in a thorough self-reflection process. Educators can scarcely remain indifferent to the fate of humanity when the planet is on fire, to socio-economic injustice at times of extraordinary inequality, or to racial, gendered, sexual and other forms of oppression at a time when powerful interest groups seek to roll back progress. However, it is necessary for educators to be aware of their motives and make them explicit, exemplifying self-reflective practices for students, and creating a basis for dialogue. Students engaged in a reflection process are in a vulnerable situation of self-growth. Educators must be

especially conscious not to impose their dearly held worldviews on students, but to let them grow and evolve their own.

This means, therefore, challenging classroom dynamics. PBL already challenges the traditional student-teacher relation, replacing it with a more collaborative arrangement that varies in teacher-direction depending on the model of PBL (Servant 2016). However, building on the transgressive work of hooks (1996), we suggest that structured reflection practices within project work have the potentiality to engage students and teachers in a more fully human collaboration in which pathos and eros are given space on par with logos.

In the decades since PBL's inception, it has been increasingly instrumentalized by employability discourses, focusing on creating work-ready graduates with marketable competences and skills (e.g. Johnson et al., 2015; Mann et al., 2020; Mitchell et al., 2019). The language of future-proofing in PBL literature has coalesced around skills and competences required for a future that is imagined as a technologically richer continuation of the present, even in the context of sustainability education (e.g. Kolmos et al., 2020). It is becoming increasingly probable that such a future will elude us, and we must instead prepare for a future of resource scarcity, runaway global heating, and ongoing civil and international humanitarian crises (Kemp et al., 2022).

In this context, it is as important as ever to develop what Freire (1968) and hooks (2003) called a pedagogy of hope. Being hopeful doesn't mean placing one's faith in outcomes that cannot materially be realized, such as hoping to avoid climate catastrophe by escaping to Mars – such wishful thinking constitutes a form of denial, as Servant-Miklos & Noordzij (2019) showed, which is fairly common in PBL in engineering education. In the context of Experimental Pedagogics, hope means helping students to accept themselves as incomplete, and therefore open to a search that can be carried out in relationship with others, through the reflective praxis of problem-oriented project work. Such an approach can be conducive to an education in which new relationships between people and the world may be established, which in turn may lead to something unexpected and unpredictable (Biesta, 1998). This would help PBL move away from an instrument for professional development, towards a view that sees problem-based education as a rupture, as a new beginning whereby new possibilities and realities can be imagined.

Conclusion: closing the EAR cycle
Investigating student reflection experiences in XP with a phenomenographic action research design has been a very productive way for us to reflect on our own teaching practices, with the start of the second iteration of XP in mind, as a semester-long Minor from September 2022. Key to improving our practice is the finding that there is such a thing as too much reflection, and that soft scaffolding guardrails and clear pathways

towards action should be put in place to prevent this from happening. We might also think to amend our hard reflection scaffolds, such as the worksheet presented in Appendix 2, to include action prompts. Perhaps, borrowing from Feilberg (2016), we, as teachers, might more explicitly model what reflection praxis looks like for students. This means we may need to take some of our own medicine and practice multi-dimensional, structured reflection on ourselves, before we ask the same of students. To some extent this study participates in that effort, but we may also explore the individual motives and drives that bring us, as teachers, to Experimental Pedagogics, with a view to creating a space, where, to paraphrase Biesta (1998), we can release the possibilities of critical pedagogy.

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APPENDIX 1

Interview protocol

Ask for permission to record the interview –
This interview is voluntary and you can stop your participation at any time.
Do I have your permission to record this interview?

The aim of this interview is to understand how you experienced the programme, how it impacted you and your life as well as what you will take from it moving forward. There are no right or wrong answers to these questions. You can take your time to think about your answer, and ask me to repeat a question if something was unclear.

Questions:
1) Have your expectations/fears/hopes/aspirations materialized throughout the course?
2) Have you reached what you wanted to be able to do/feel/learn by the end of this course?
3) How has the course impacted you as a person?
4) How did you experience the group process in the entire programme?
5) Did the education and project track impact your view on the role of the education in the world?

6) REFLECTION

Experiential questions:
  a. Can you describe your experience with reflection throughout this programme?
  b. Is there any particular moment of the reflection process that you thought was especially important to you?
       i. When in the reflection track did this moments occur?
      ii. What did you do in this moment?
     iii. Why did you do this?
      iv. Was anyone else involved in this reflection moment (other students or teachers)?
       v. How did you feel about this moment
  c. Is there any other moment that was important to you? (repeat sub-questions 1-5). Repeat again until there are no more salient moments.

Summative questions:
  d. Based on what we discussed, what would you say that reflection *is*?
  e. What do you think that reflection is *for?* What is the purpose of reflection?
  f. How do you understand *cognitive* reflection?
  g. How do you understand *phenomenological* reflection?
  h. How do you understand *relational* reflection?
  i. How do you understand *societal* reflection?

Exploring relationship to experiences
      j. Have your views on reflection changed during the course of this programme? If so, how and why did they change?
      k. Did any particular experiences in this programme contribute to your views on reflection?
      l. What are important things that you would recommend we keep in mind when designing reflection exercises in the future?

Concluding questions:
      a. Is there anything that I did not mention that you'd like to tell me about your experience with reflection?
      b. Do you have any questions for me?

Thank you for your participation and thank you for joining the CARE pilot programme!

APPENDIX 2

Reflection Diary prompts

It's time to draft your first learning reflection diary. There is no right or wrong answer for this assignment. It's about helping you to formulate pathways for connecting practice and reflection (dialogical theory of action). There is no word limit. We'd expect between 100 - 500 words for each question, but it's really up to you.

Describe	Describe a major learning event since the start of the CARE programme. This could be a single moment in time, or a blurry sequence of events. This could be a formal learning moment, or an informal, social moment. This could be an individual learning moment, or connected with the group work.
Analyze	Taking into account the learning goals you wanted to accomplish, what thoughts, actions and emotions have been triggered by this learning event?
Reflection	What have you learned from the experience? Why is this learning significant to you at the personal, academic and social level?
Theorizing	How did the experience match with your preconceived ideas, i.e. was the outcome expected or unexpected? Does it relate to any (formal) theories that you know?
Experimenting	Is there anything you would do or say now to change the outcome? What actions will you take in the future based on this learning?

Final reflection question: do you want to make any changes to your learning goals based on this experience?

University Educators' Professional Learning in a PBL Pedagogical Development Programme

Aida Guerra, Bente Nørgaard, Xiangyun Du *

ABSTRACT

This study explored university teachers' professional learning when participating in a pedagogical development (PD) programme. The PD programme, entitled the Aalborg Certificate on Basics of PBL and Curriculum Change, had a workload of 150 hours and ran for four months, involving 23 teachers from Universidad Nacional de Colombia (Bogotá, Colombia). The programme comprised four modules, delivered in a blended mode, and followed a problem- and project-based learning (PBL) approach, as well as being based on PBL principles. This investigation conceptualizes professional learning from the complex learning theory perspective, describing it as a complex dynamic system involving knowledge, motivations, values, attitudes, and beliefs dependent on social and individual contextual factors, and how these can lead to the implementation of alternative teaching practices in classroom (e.g., PBL). Building on that, this work addresses the following research questions: (1) What knowledge and beliefs have the PD programme participants developed about PBL? (2) In which ways do the developed knowledge and beliefs impact participants' change towards PBL? This analysis takes a qualitative approach and uses multiple sources of data, namely participants' portfolios and reflection essays, as well as a qualitative survey. The results show the participants developed a deep understanding of PBL principles and practices by experiencing them through the PD programme, and that reflective

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* Aida Guerra, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of UNESCO, Department of Planning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: ag@plan.aau.dk
Bente Nørgaard, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of UNESCO, Department of Planning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: bente@plan.aau.dk
Xiangyun Du, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of UNESCO, Department of Planning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: xiangyun@plan.aau.dk

practice enables continuous professional learning and development. Additionally, their perceived challenges were related to time, as well as institutional support and infrastructures, in addition to student and teacher training.

Keywords: University educators' professional learning, problem- and project-based learning (PBL), pedagogical development, pedagogical belief, and practice

INTRODUCTION

There is currently an international trend for university educators to participate in various pedagogical development (PD) activities in response to the overall call for the development of graduate competences such as critical thinking and solving complex real-world problems, as well as communication and teamwork, among other aspects (Chalmers & Gardiner, 2015). Despite the variation in delivery forms and duration, ongoing PD elements have focused on supporting university educators who are experts in their own disciplines to develop knowledge and skills for effective teaching practices (Bickerstaff & Cormier, 2015; Chalmers & Gardiner, 2015; Saroyan & Trigwell, 2015). While highlighting the transformation from lecture-based teaching to student-centeredness as a common goal of such PD activities, the current literature remains unclear regarding the ways in which university educators learn from their participation in PD activities (Amundsen & Wilson, 2012; Assen et al., 2016; Chalmers & Gardiner, 2015). Recent works have reported concerns regarding linear approaches to organizing PD activities which assume that university educators may learn from short-term, information transition-focused, and context-dependent activities (Postareff et al., 2007; Steinert et al., 2016; Strom & Viesca, 2020). Instead, university educators' learning should be viewed as a complex matter that encompasses multifactorial aspects that interact with each other, such as individual interests, motivations, attitudes, and beliefs regarding the importance of teaching and learning advancements, which play an essential role in their engagement with learning about how to improve their own teaching and actually implementing new teaching practices (Du & Lundberg, 2021a; Strom & Viesca, 2020).

To address such needs, the literature has suggested that PD activities should consider values such as interactions, peer learning and teamwork (Henderson et al., 2012; Kolmos et al., 2008). Even so, it cannot be ensured that participation in PD activities will necessarily lead to changes in constructivist pedagogical beliefs, or even to adopting teaching practices that underscore student-centeredness (Assen et al., 2016; Du et al., 2020a, 2020b, Du et al., 2021b). Therefore, how educators learn from PD activities is dynamic and complex, involving not only how an individual educator may develop pedagogical beliefs that support their motivation and engagement regarding changes in

practices, but also the actual implementation of new ones, during which they encounter potential challenges related to students' reactions, collegial collaborations, and institutional constraints (Borrego et al., 2013; Du et al., 2020a, 2020b; Du et al., 2021b; Henderson et al., 2012; Lee et al., 2014).

This study attempts to explore the complex and simulative nature of how university teachers learn from their participation in professional development activities. The term "professional learning" is adopted to highlight the focus on how university educators learn through a process of participation in diverse activities to enrich their knowledge, beliefs, skills, and practices regarding pedagogical advancement (Saroyan & Trigwell, 2015). In particular, this evaluation investigates the processes and outcomes of 23 university educators from Colombia during their participation in a PD programme targeting implementing problem- and project-based learning (PBL). In collaboration with the United Nations Educational, Scientific and Cultural Organization (UNESCO) PBL Center, the programme was organized following PBL principles relating to team-based project work on real-world problems, which aimed to provide participants with opportunities to experience PBL as learners through teamwork.

The following research questions were formulated to guide the research process:

1. What knowledge and beliefs have the PD programme participants developed about PBL?
2. In which ways the developed knowledge and beliefs impact participants' change towards PBL?

THEORIES AND LITERATURE

Conceptualizing Professional Learning Through a Complexity Theory Lens

Research on professional learning has been criticized for overstressing disciplinary content knowledge, as well as abstract knowledge about theories of teaching and learning, or instructional strategies (Russ et al., 2016). Therefore, additional important factors that contribute to university teacher pedagogical improvement will be incorporated in the conceptualization of professional learning. Taking a complexity theory lens to the conceptual understanding of professional learning, this study emphasizes the nature of developing, acclimating, growing, and changing. This perspective allows for conceptualizing professional learning with a focus on its involvement of multiple interacting components in a system, instead of only exploring parts of a whole or individual factors. Contrasting with cause and effect as well as linear ways of seeing the world, complexity theory provides a lens through which to conceptualize professional learning as a whole, consisting of relations among numerous factors and their

communications with environments (Morrison, 2008). Rather than an event, university teachers' professional learning is a process of growing and changing diverse connected aspects, including motivations, attitudes, beliefs, knowledge, skills, and actions and interactions. Seeing professional learning systems as dynamic and contextual also makes them emergent and unpredictable (Du et al, 2021a; Garner & Kaplan, 2021; Russ et al., 2016). As such, each individual university educator's professional learning can be understood as a complex dynamic system comprising cofounding and interacting personal, relational, and institutional factors (Garner & Kaplan, 2021; Opfer & Pedder, 2011).

From such a conceptualization of professional learning as a complex dynamic system, university educators' learning demands agency, which should be supported through activities encouraging their roles as experiential, participatory, and proactive individuals. Following this, the professional learning activities in the current study were intended to establish a complex learning environment encouraging educators to make choices in response to diverse situations and contexts and take agentic action to influence their own work, rather than to follow a predetermined sequence of information transmission. In such a complex learning environment, the participants' agency is influenced by their prior experiences and their personal characteristics, which shape how they attain knowledge and skills, and take stances and actions through their professional learning, as well as defining their perceptions on prospective engagement (Garner & Kaplan, 2021; Russ et al., 2016; Opfer & Pedder, 2011).

Highlighting university educator's agency as a core to their professional learning also emphasized the essential role of teacher pedagogical beliefs which to a large extent impact and shape their choices and decision making in practices (Russ et al., 2016; Opfer & Pedder, 2011). Teacher beliefs have been focussing area of educational researcher and widely debated in literature for years, and addressing various issues, namely curriculum, reform strands, and teaching and learning (Savasci-Acikalin, 2009). In overall, beliefs are defined as "one's convictions, philosophy, tenets, or opinions about teaching and learning" (Haney et al. 2003, p. 367), which leads to judgment of truth or falsity of a proposition, inferred "from a collective understanding of what human beings say, intend, and do", and strongly affect human behaviour (Pajares, 1992). Focusing on the connection between educator's beliefs and practices provides an analytics tool to better understand their professional learning (Assen et al., 2016).

Literature Review on Evaluating Professional Learning
University educators' professional learning has been evaluated in various ways. While a large strand of literature has focused on participant satisfaction with PD activities (Stes et al., 2010), several studies have also reported on how university educators, after receiving professional learning, have improved their motivations, attitudes, and

approaches to teaching in relation to student-centeredness (Saroyan & Trigwell, 2015; Stes et al., 2010; Van Schalkwyk et al., 2015). In addition, research has provided evidence connecting the educators' experiences gained through PD activities to their actual implementation of new practices and to the impact on their students' approaches to learning, performance, and outcomes (Du et al., 2020a).

Attention has also been paid to complex factors that have influenced university educators' implementation of student-centred strategies and methods, including personal factors such as motivations, beliefs about teaching and learning, and institutional aspects (Stes et al., 2010). In studying the mechanisms and outcomes of change, the individual and social aspects of teacher development are key to developing their beliefs about their roles as teachers in relation to university teaching excellence (Saroyan & Trigwell, 2015). Teachers' pedagogical beliefs are often understood as being how they think about teaching and learning, which influences how they take stances, make choices, and develop strategies in response to diverse situations (Pajares, 1992; Beck, 2008). Instead of being static, pedagogical beliefs are constantly undergoing change, as well as being shaped by prior experiences, current situations, and future prospects (Beck, 2008; Pajares, 1992). When moving from lecture-based to learner-centred approaches (e.g., PBL), educators are expected to assume constructivist beliefs by adjusting their teaching roles, which motivate and engage them to develop new strategies and ways of organizing class activities (Amundsen & Wilson, 2012; Borrego et al., 2013). While previous works have suggested that beliefs promote and constrain the adoption of new ideas and strategies, the evidence for a connection between university teachers' pedagogical beliefs and teaching practices is lacking (Amundsen & Wilson, 2012; Assen et al., 2016; Du et al., 2020a; Lee et al., 2014).

Various contextual factors have also been explored regarding how they may support or constrain how university teachers may learn from PD activities and connect their development of constructivist pedagogical beliefs to actual practice through implementing student-centred strategies. Student resistance to new teaching strategies has remained a concern raised by university educators (Borrego et al., 2013; Chalmers & Gardiner, 2015; Lee et al., 2014). Another regards the ways in which new teaching initiatives would be accepted and supported by peer colleagues (Du et al., 2021b; Van Schalkwyk et al., 2015). Additionally, institutional conditions have been addressed by several studies (Bickerstaff & Cormier, 2015; Chalmers & Gardiner, 2015; Du & Lundberg, 2021a; Du et al., 2021b; Henderson et al., 2012; Saroyan & Trigwell, 2015), including how new teaching practices would fit current policy constraints, such as for example, whether a newly developed assessment method for students would be approved, whether there would be sufficient facilities and materials provided (e.g., classroom, class

schedule), and whether there would be new external awards for implementing new teaching practices.

In sum, further attention is needed in reference to university teachers' professional learning regarding not only the development of their motivations, values, attitudes, and beliefs, but also how this process can lead to the implementation of alternative teaching practices in the classroom (Assen et al., 2016; Van Schalkwyk et al., 2015). To address the current critiques in relation to examining either the process (via self-reported reflection) or outcome (via a context-dependent measurement) of professional learning, recent literature has emphasized the importance of connecting the processes, inputs, outputs, and outcomes of professional learning with contextually relevant aspects (Bickerstaff & Cormier, 2015; Chalmers & Gardiner, 2015; Saroyan & Trigwell, 2015). Identifying factors that may support or constrain professional learning is equally crucial, including individual challenges and institutional issues, not only during educators' participation in PD activities, but also the subsequent implementation in practice (Du & Lundberg, 2021a; Henderson et al., 2012; Van Schalkwyk et al., 2015).

DESIGNING A PBL-BASED PD PROGRAMME FOR UNIVERSITY EDUCATORS' PROFESSIONAL LEARNING

Following the suggestion by Stes et al. (2010), this study adopted a theoretically driven approach supported by multiple data sources to explore the impact of professional learning on university teachers. The programme design was embedded in our conceptual understanding of university educators' professional learning as a complex dynamic system, as elaborated above. In addition, the programme design embraced the PBL principles of the Aalborg University (AAU) PBL model (Kolmos et al., 2009) (details see Appendix 1 and 2), which meant transferring its principles to practice and using its potential to foster transformative learning through experience and reflection, as well as participants' ownership and centredness. In this sense, the programme involved more than the cognitive dimension of learning (i.e., knowledge and skills), with the incorporation of social, cultural, and intrapersonal dimensions such as their beliefs, motivations, and self-efficacy (Noben et al., 2021).

While integrating problem-based learning ideas into PD activities for tutors has been practised in the health and medical sciences (Salinitri et al., 2015), little has been studied in regard to the resulting practices, particularly on how the educators actually implement them. Relevant works on engineering educators' professional learning as outcomes from PBL-based PD programmes have suggested that it takes longer than expected to change pedagogical beliefs towards PBL, and the gaps between participants' changes in beliefs and their actual practices may be related to multiple factors. These include an individual's

prior experiences and the prioritizing of disciplinary content knowledge over pedagogical thinking (Guerra et al., 2018; Du et al, 2020a), as well as institutional constraints, including a lack of policy or peer support, and student cooperation (Du et al., 2020a, 2020b).

The certificate was piloted in collaboration with the Universidad Nacional de Colombia, Colombia. The certificated started on 12 February 2018 with 23 participants and finished on 1 June 2018 (Guerra et al., 2018). The participants organized themselves into six groups, which constituted their working teams throughout the programme, resulting in six teaching portfolios, which included participants' teaching designs and their reflection essays as an appendix.

RESEARCH DESIGN

Participants

A total of 23 academic staff from three Colombian higher education institutions enrolled, actively participated in all activities, and completed the programme. Of the 23 participants, 17 were affiliated with Universidad Nacional de Colombia (Bogotá), three with La Universidad Icesi (Cali), two with Universidad Pedagógica y Tecnológica de Colombia (UPTC, Sogamoso), and one was the director of the Colombian Association of Faculties of Engineering (ACOFI). The participants were mainly from engineering and science fields, with exception of two, with one from social services and one from economy and management. Of the 23 participants, eight were female and 15 male. The participants also reported that as teachers their time was mostly spent in lecturing and instruction (25%–75%, N = 17), with small lecture groups, project work and supervision the formats in which they spent much of their teaching time.

Regarding participation in PD activities, 13 reported participating sometimes, five very often, two always, and three rarely. In reference to activities that increased their pedagogical knowledge and skills, the participants report that they had engaged in reading professional literature (e.g., journal articles, evident-based papers, etc.) (N = 21), followed by undertaking PD courses (N = 13), individual or collaborative educational research on a topic of professional interest (N = 13), participation in workshops (N = 12), informal dialogues with colleagues on how to improve one's teaching (N = 12), and involvement in educational conferences or seminars (N = 11).

Research Methods and Data Sources

Methodologically, this study employed a qualitative research design with multiple sources of qualitative data, namely i) a portfolio and reflection essays, and ii) a qualitative

survey. The aim is to develop a more comprehensive description as well as convergent views of participants' professional learning (Golafshani, 2003; Patton, 1999). The data collection took place during the period of the certificate implementation, i.e., between February 2018 and June 2018. The participants' demographic information, teaching activities, and formats, as well as previous PD activities, were collected before the PBL certificate programme started, whilst the remaining data were collected during and at the end of the programme, as Table 1 illustrates.

Data sources	Type of data	Data on
Survey (pre-PD activities)	Quantitative (close questions)	1. Demographics 2. Teaching activities and formats 3. Previous staff development (participation and types of activities)
Teaching portfolios	Qualitative	4. Teaching philosophy (in relation to beliefs) 5. Motivations and expectations for certificate 6. Teaching challenges 7. Reflections on the workshops 8. PBL implementation and evaluation 9. Impact of the certificate on one's teaching philosophy, competences, and skills 10. Future plans for staff development
Qualitative survey	Qualitative	11. In which ways the teaching portfolio has supported your learning and reflection throughout the Aalborg UNESCO Centre Certificate 12. What aspects of the Aalborg UNESCO Centre Certificate you consider relevant

Table 1. Data Sources and Type of Information Collected.

Both surveys, i.e., the one regarding pre-PD activities and the qualitative one with open questions, were distributed to participants via SurveyXact, and piloted before that by two PBL researcher experts with experience in PBL training and qualitative and quantitative research methods using surveys. Both the teaching portfolio template and surveys were developed based on literature and previous studies involving teaching portfolios and PD evaluations, namely de Graaff et al. (2011) and Dahl and Krogh (2015).

Data Analysis
The data analysis involved deductive and inductive analysis approaches. The deductive analysis took the point of departure from the literature and research questions to define broad themes for analysis, whilst the inductive approach enabled the defining of codes for content analysis (DeCuir-Gunby et al., 2010; Roberts et al., 2019). The latter involved the following steps: i) reading through raw data (i.e., participants' portfolios and reflection essays, teaching designs, and the qualitative survey), ii) identifying emergent

codes in alignment with the themes, iii) coding the data using the codes defined. The deductive and inductive approaches resulted in the code book presented in Table 2.

Themes	Codes
Pedagogical knowledge and practices	Prior PD activities
	Teaching practices
	PBL knowledge, skills, and competences
Constructivism pedagogical beliefs	Teaching philosophy
	Role of assessment, facilitation, and students.
	Motivation for learning and change
	Expectations from PBL certificate programme
	Challenges
PBL implementation	Prior teaching practices and experiences
	PBL design/intervention
	PBL implementation and evaluation
	Support needed
Future prospects and plans	

Table 2. Themes, Codes for Analysis, and Respective Examples from the Data.

The codes generated were revised by a peer expert in PBL and continuing education. The participants' portfolios, reflection essays, and teaching design were analysed using the software NVivo™, version 21, whilst the qualitative survey answers were downloaded from SurveyXact and evaluated using MS Excel.

RESULTS

The results are presented following the order of the research questions, providing answers, and drawing from the different data sources. Note that responses from groups are identified by their group numbers, while those from the qualitative survey are attributed to the number of the respondent.

What knowledge and beliefs have the PD programme participants developed about PBL?

The answer to the first research question is provided in twofold: (i) knowledge participants acquired during the program which contribute to broader understanding through experience what it means problem-oriented, active, innovative learning practices; and (ii) the beliefs they develop during in relation to constructivism and the struggles inherent in transforming current and traditional practices.

Knowledge for problem-oriented, active, and innovative learning practices

In general, the participants reported three main categories of knowledge acquisition through their learning process in the given PBL programme: (1) active learning for small

innovations in teaching practices, (2) a deep understanding of PBL principles and practices, and (3) reflective practice as an enabler for continuous development.

First, the participants referred to the use of active learning strategies to involve and engage students in courses. For example, Group 3 stated that by learning about active learning strategies, they were able to start innovating teaching practices by "combining lecture, discussion, and other activities learning activities" (Group 3).

Second, the PBL certificate structure and organization enabled participants to experience PBL models, elements, and principles in practice, promoting a deeper understanding of PBL methodology. For example, Group 3 emphasized "that what teachers need to learn is not specific methodologies or ways of doing things in their classes; they need to live the experience where they can see real learning happening" (Group 3). These participants stressed that the PBL certificate programme principles, like experiential learning (see Appendix 1), became central to enabling teachers to develop deep learning when it comes to pedagogical change, meaning it is more important to "experience" the methodology rather than to know about it. This is supported by Respondent 10, who considered the course structure and organization one of its most relevant aspects, which "is coherent with the PBL's principles" (Respondent 10). Group 1 also referred to how self-aware they became of their own behaviour as students in the PBL environment since the certificate used the PBL approaches, stating: "Being a student I was able to see also that I behave just like them" (i.e., like students) (Group 1). Even though we do not have empirical support to suggest in which ways such self-awareness impacts the implementation of PBL and how it supports learning, it is a point worth reflecting on, as well as one to consider exploring in future studies involving PD and PBL implementation in higher education. For example, does the teacher provide additional training and support to students on, for instance, how to organize their learning process when working in teams, such as how to collaborate and how to manage conflicts, etc.?

Additionally, a few participants referred to other PBL elements, like the role of the problem in students' learning. Besides being the driver for learning, Group 2 considered that "PBL is a big opportunity to make the connection in higher-level education with real problems in society" (Group 2).

Third, the participants emphasized the role of reflection as part of the learning process and that it is essential for continuous improvement and the innovation of one's teaching and learning practice. For example, Respondent 20 referred specifically to the teaching portfolio as a relevant instrument, which allowed them to:

> Document our teaching practice, analyse, and reflect on our actions in the classroom, the preparation of this document involves reading theories related to active learning, student-centred learning. It also

allows us to know about the importance of teaching based on context
and experience and the solution to real problems in the environment,
that is, teaching for life, society, and the environment. It has been a
motivating experience, because in addition it implies an in-depth
analysis of my teaching practice and shows a continuous interest in
improving our practice through the adoption of innovative teaching
methodologies. (Respondent 20)

The importance of reflection in practice was also corroborated by, for example,
Respondents 13, 18 and 19, who referred to the help it provided to "manage the progress
of my learning and monitor the development of the course" (Respondent 13), "the
confidence to apply the adequate and appropriated tools and forms to get the knowledge
through the PBL method" (Respondent 18), or "group and individual space to reflect on
my goals and teaching practices" (Respondent 19).

Believing in constructivism whilst 'struggling' in transforming traditional practices
The results show three main categories of beliefs: (1) strong holders of constructivism,
(2) 'struggles' with transition and transformation, and (3) 'followers' of traditional
learning practices.

For example, participants believed that "to inspire and challenge the young minds is as
good as it gets in terms of living a meaningful life", with the role of the teacher and
education being "to guide and show different ways to create new ideas. It is important the
experience and situation used to resolve problems", "to help other people grow and
develop professionally", "to develop in the student his capacity to learn autonomously,
throughout his life", "to contribute to the increase of a student's tools, to generate well-
being. [...] I teach because I enjoy sharing spaces of reflection. I believe that education
can lead us to a better society, and I want to be part of training people for a better society",
with teaching being "the most important means to transform a society. And by education
I do not mean only a transfer of knowledge, but an integral formation that involves moral,
cultural, citizenship and, of course, intellectual aspects", and involving "co-creation,
where the teacher also learns from the students and together contextualizes the situations
to give the greatest possible sense to what is done inside the classroom". The above-
mentioned statements aligned with the perspectives of autonomous learners, the
development of skills, contextual and authentic learning, and the co-creation of learning
environments to meet both student and teacher needs. Additionally, a participant from
Group 3 added the following: "I am a convinced constructivist, which means that I believe
learning is an ever-growing process of understanding by making connections between
what we already have constructed and new knowledge, through doing things with this
knowledge" (Group 3).

Even though the participants held beliefs aligned with constructivism viewpoints, they struggled with the transition and transformation of their teaching practice and with recognizing the traditional learning experiences that influenced their practice. For example, participants from Group 3 claimed "I hope to learn how to adapt my teaching methods, my assessment and feedback to students and course design", or that "My current teaching practices are influenced by the way I received my own education, which was based on traditional teaching practices" (Group 3).

The "roots" of traditional teaching practices and difficulty of change is also extended to students as Group 3 and Group 5 claimed, respectively:

> Another aspect that I analyse is identifying that the change in the students is difficult, they are accustomed to the orientation of the class in a traditional way and don't have the self-discipline to consult bibliographical references and analyse which is the best option to solve a problem. (Group 3)
> At this stage of the engineering students' training, already at mid-career, they prefer traditional teaching. This leads us to think as teachers that we need to start the PBL approach from the first semesters so that we can change the traditional teaching-learning model to a more active and student-centred process and not the teacher. (Group 5)

In which ways the developed knowledge and beliefs impact participants' change towards PBL?

The results provide insights to this question in twofold: (i) the constructive alignment as a tool for a reflective course and curriculum change, and (ii) awareness of their contextual challenges and needs to foster change. The first draws in the knowledge and experience gained during the professional learning, which lead to a realisation of the contextual challenges and needs participants have to foster change towards PBL.

Constructive alignment as pedagogical reflective tool for course and curriculum change
Thematic workshop on course design, the participants were introduced to several curriculum design frameworks, including the constructive alignment framework (Biggs, 2003). Most of the participants used the constructive alignment to redesign their courses and to implement PBL, with particular attention paid to the formulation of the ILOs, the planning of appropriate teaching and learning activities, as well as the student and teacher roles/tasks, and the use of suitable assessment types and instruments. Throughout the programme, the participants were guided by these principles which were used in their progressive project work with the facilitation of their supervisors.

All the groups reflected on their learning benefits from using the constructive alignment principles, which helped them understand and better practise how to structure a course plan. In particular, a member of Group 3 stated that she/he "understood that the first factor of success is the planning of the course, really establishing what the learning objectives are and what are the competencies and skills that the student must acquire at the end of the course" (Group 3). This was also referenced by a member of Group 4, who claimed that "After the course and the intervention developed, I see in a different way the students, assessment and learning objectives of a course" (Group 4). Group 5, for example, referred to the need to prepare new teaching and learning materials, which must be aligned with the necessity for students to develop critical thinking, as the following statement illustrated: "For the intervention it was necessary to prepare a new laboratory guide where each student no longer had the steps that solved the problem, but he had to use his critical thinking and his knowledge to give a solution to the problem" (Group 5). Group 6 noted the need for a continuous reflection and adjustment of PBL practices to ensure students continued to achieve their potential and learn in the best way possible.

Contextual challenges and needs when changing to PBL
The perceived challenges and obstacles to the desired change of beliefs and compatible practices, as well as demands that may support further improvement, as perceived by the participants. Time, institutional support, and infrastructures were among the main challenges referenced by all groups. For example, Group 3 referred to the time needed to support students learning in a PBL environment:

> Then comes the question whether the facilitator or the external supervisor has enough time to dedicate to each of the working groups. It is necessary to be most demanding in the quality of the projects or the problems posed. Implementation will only be possible if there is institutional change and institutional support for it. (Group 3)

Additionally, and in the same quote, Group 3 noted the role of the institution in relation to PBL implementation and change. Support for the implementation is not only related to all the tasks and roles academic staff have within the organization, but to the institution itself. Change should take a systemic approach in terms of institutional movement towards PBL, rather than only at the course level. In connection to this, Group 5 stated that: "It is necessary to train many more teachers in each department or career, so that each iteration of the proposed model can cover a greater number of courses, which in turn covers a greater number of students" (Group 5).

Regarding infrastructures and space, Group 1 noted that "Even though both challenges did go well, the room was not large enough to hold the groups working within during the interventions" (Group 1).

Other challenges related to the perceived roles of teachers and students, as well as their readiness for a PBL environment. From the student side, the participants noted the existence of a preference for traditional teaching methods, as was quoted in the above sub-section. Additionally, there were also issues connected to how students organize their own learning, as well as their motivation and engagement in their own learning processes, as Groups 1, 3 and 4 state. "I would like to know how to motivate students nowadays, I have found this is a challenging issue since new generations do not read much and are hard to engage" (Group 1). "In the traditional groups our students are used to, each one works independently, and only at the end of the semester they meet to unite and deliver" (Group 3). Finally, a suggestion was made that in terms of "Keeping students motivated and being conscious of their own learning process. Assess students and course's progress during the development of the semester" (Group 4). This leads naturally to the need for students' training as well, as the participants expressed, which is particularly important since it relates to the student's role, ownership, and responsibility over their own learning, and it is complementary with the teacher's role, in guiding and facilitating learning. Regarding the teacher's perceived role, the challenges related to a sense of self-efficacy, and the capability to guide students in a PBL environment. For example, Group 5 referred to their own doubts and the effort needed to implement PBL efficiently, as the following shows: "I have some doubts about the method, since I think it will require more effort from the students and the teacher, how efficient is it?" (Group 5). This was corroborated by a member from Group 1, who stated that "[I] conduct a course where the students must resolve real problems. I would like to know how to lead it correctly" (Group 1).

DISCUSSION

This study explores university teachers' professional learning when participating in a PD programme and refers to it as a complex dynamic system involving personal, relational, and institutional factors, leading not only to development of pedagogical knowledge but a change in pedagogical beliefs that argue for the adjustment and transformation of teaching practices towards more student-centeredness. Such a transformation justifies participants' motivations and attitudes towards change (see for example, Savasci-Acikalin, 2009, Assen et al., 2016; Van Schalkwyk et al., 2015). Therefore, and from a complex theory lens, PD activities need to take into consideration such dynamic processes of professional learning and create conditions where participants enact and interact with others and with the environment (see, for example, Assen et al., 2016; Du et al., 2020a, 2020b, Du et al., 2021b). For this reason, the PBL certificate programme is grounded on PBL principles, namely problem orientation, experiential, contextual and collaborative learning, exemplarity and interdisciplinarity, participant- and self-directed learning, and where a group of participants, with the support of a supervisor, change their teaching practices by (re)designing their courses using PBL, and implement and evaluate their

intended developments (Kolmos et al, 2009). Additionally, they reflect and document their learning and processes using teaching portfolios. Taking the point of departure from the analysis of participants' teaching portfolios, combined with their individual answers from a qualitative survey, the results illustrate the changes in their pedagogical beliefs, as well as to what extent they impact the change of their teaching and learning practice through PBL. Furthermore, they highlight the perceived contextual challenges and needs which, from a complex theory perspective, shows the dynamic and complex system participants integrate as well as the cofounding and interacting personal, relational, and institutional factors that affect their agentic behaviour and change process (Garner & Kaplan, 2021; Opfer & Pedder, 2011).

This study provides a few practical implications, chiefly related to participants' level of pedagogical knowledge, as well as their beliefs and expectations, in addition to the understanding of PBL principles and practice, the teacher's role in a process of change and the PBL environment, and the need for a reflective practice for continuous professional learning and development. First, while the participants reported certain levels of learning about pedagogical knowledge and changes in pedagogical beliefs, obstacles remained which hindered the desired level of comparative changes in teaching practices. This indicates that university institutions should not only expect teachers to change automatically by attending certain PD activities, but rather should provide the required conditions to support the actual implementation of changes (Brownell & Tanner, 2017; Du et al., 2021a). Second, the outcome suggested that it takes time for university teachers to change their pedagogical beliefs and practices, which indicates that professional learning is a continuous and long-term process. Third, future PD activities should highlight the phases involving the implementation and evaluation of changes by requesting that university teachers document the outcomes regarding student learning, which should be the ultimate goal of PD activities and educational development in general (Desimone, 2011; Guskey & Yoon, 2008). In terms of the pedagogical and professional development levels, it is important that the training adjusts to participants' knowledge and understanding, and does not take for granted that all higher education teachers will understand the pedagogical language. For example, PD training is outside the teachers' field of expertise and discipline. Therefore, it is of the utmost importance to make sure they have a good foundation, and contribute to a solid basis of pedagogical knowledge. PD programmes should take a "practise what you preach" approach and use the learning principles and methodologies intended for participants to learn about as the core of the programme structure and activities. The learning should be made explicit by having participants experience and constantly reflect on their learning process.

This study has a few limitations and suggestions for future research. First, the outcome remains temporal due to its context and small size. Follow-up studies could meaningfully

further explore how change may happen and what may constrain or support it. Second, this analysis relied on certain types of qualitative data, namely participants' group portfolios and a qualitative survey. Other types of data could have enriched the descriptions provided in this examination, as well as corroborated further some claims. Future works could employ other data sources, such as, for example, narratives to explore how individual teachers grow and enact their professional agency in the process of professional learning. Third, this evaluation took place in one single institute, so additional ones could investigate different social and cultural contexts, and their relationships with professional learning. From an empirical perspective, more data could be collected, using different methods, namely focus group interviews, to explain in depth some of the learning aspects that emerged from the empirical data, such as, for example, the experiential learning that participants underwent and how it impacted their beliefs in relation to PBL and change processes, or the constructive alignment framework. However, the timeline of the PBL certificate programme and access to the participants limited the collection of the data as well. Nevertheless, this evaluation provides some insights and raises a few hypotheses and questions that could be further investigated. For instance, future works could include longitudinal studies, where these participants would be followed over time to explain the ways in which what they learn through PD programmes is implemented in practice and sustained through time, and if not, why. In addition, comparative analyses could be relevant, because there are contextual and cultural aspects to professional development not only at an institutional level but also at disciplinary and country ones. This could provide a better understanding of what different teachers from various disciplinary areas, or countries, value and believe, and consequently assist in adjusting the training to their needs and contexts. Further, it may also be meaningful for future studies to compare outcome of educators' pedagogical beliefs in relation to their practice change through different types of PD activities.

CONCLUSIONS AND RESEARCH PROSPECTS

The results highlight three main outcomes of the PBL certificate programme that impacted participants' professional learning. First, the programme helped them to understand and use the constructive alignment framework to redesign and implement PBL in their courses. This is particularly important given that constructive alignment is a fundamental pedagogical concept with which an educator can restructure their courses and make them more student-centred, as well as enabling deep learning and the performance of higher and more complex cognitive tasks. Additionally, the framework also allowed participants to consider different dimensions when (re)designing their learning and teaching practices, like the ILOs, activities, role of the student and teacher, physical spaces, assessment, etc. It provided a holistic perspective and made their course design more purposeful, and explicit. Second, the learning principles that ground the

certificate programme as well as its structure enabled participants to learn as students do when in a PBL environment, namely in a collaborative, exemplary, experiential, and contextual manner. This not only allowed them to become immersed in their learning process, but also to transform their pedagogical beliefs and values for more student-centred learning. The participants were critical of their own limitations and challenges, at individual and institutional levels, and consequently found strategies to cope with them. Third, the transformative learning nature of the certificate programme facilitated in transforming their views regarding education and their roles as educators, at student, institutional and societal levels. For example, the participants highlighted co-creation and collaboration with students, and the concept of education as a profession, but one which also meant they could contribute to addressing societal problems, as well as questioning traditional models of education and the need to break them and move forward to more student-centred learning environments. From a complex learning theory perspective, the results show the dynamic nature of participant learning processes, where the interplay of multiple components taking place not only at an individual level (e.g., knowledge, a sense of agency, motivation, pedagogical belief, etc.), but also in connection with the surrounding environment (e.g., collegial and institutional support, infrastructures, policy-making, etc.), where the degree of curriculum change and practice is also contextual and culturally dependent (see, for example, Morrison, 2008).

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APPENDIX 1

Overview of the Aalborg UNESCO Certificate course on the Basics of PBL and Curriculum Change (Retrieved from Guerra et al., 2018)

Modules	Format	Description	Duration
I. Introduction and preparation	Online and self-study activities	In the first phase, participants have a two-hour online introduction to the course. The introduction marks the beginning of the course. In the following 10 days, participants should go through the course literature and online resources. The material addresses the topics of: PBL principles and models, other active learning strategies, curriculum design, curriculum change. As part of the preparation, participants also need to start the documentation process through a portfolio.	2 weeks (10 days)
II. Thematic workshop	Face-to-face, thematic workshops	A series of thematic workshops in which participants experience, reflect on and develop further understanding of PBL theory, culminating with the design of a PBL activity. Each workshop provides knowledge, exemplary exercises, group work, plenary discussions and feedback to design the intervention. The workshops themes are, for example: 1) PBL practices and models 2) Course and curriculum design 3) Assessment of and for learning 4) Facilitation and PBL skills 5) Portfolio as a reflective documentation instrument 6) Designing a PBL activity	4 days
III. Experimentation and evaluation	Online supervision sessions, group work and self-study activities	In this module, participants plan and implement the PBL activity designed. The implementation process, as well as its evaluation, must be documented as part of the portfolio. To support this process, the participants have on-line support and supervision from the Aalborg UNESCO Centre. By the end of the five weeks, participants should upload their portfolios for examination.	5 weeks (25 days)
IV. Examination	Online	The examination is done according to the Aalborg University frame of provisions. At least two members compose the examination committee: the supervisor and an external examiner. The grading is pass/ fail. On passing the examination, participants are granted the Aalborg UNESCO Centre certificate.	1 day

APPENDIX 2

Applying PBL Principles to the design of the Aalborg Certificate Course Approach (Adapted from Guerra et al., 2018)

PBL learning principles	Aalborg Certificate on Basics of PBL and Curriculum Change
Cognitive approach: • Problem-oriented • Project • Experiential • Contextual • Reflective	**Problem orientation**: The point of departure for participants' learning is the definition of teaching aims and challenges that they want to address. **Project**: The learning process is not carried out through a project. However, the learning and PBL implementation process is documented through a portfolio. **Experiential**: Several activities are developed and centred on teachers' experiences, namely the definition of teaching challenges, as well as the design of PBL implementation, workshops, hands-on exercises, etc. **Contextual**: By using participants' teaching challenges as the point of departure, learning is placed in the context of their institution, disciplinary field, and teaching practice, with the aim to improve. **Reflective**: Reflection is constant throughout the programme, where different activities and tasks are set up for participants. Typically, they were asked to consider how and why what they have done, experienced and learned can be used to address their teaching challenge. The reflection tasks and activities could be carried out at an individual level, such as in end workshops and in a form of personal notes, and at a group one, such as through status seminars and group portfolios.
Content approach: • Interdisciplinary • Exemplary • Theory and practice	**Interdisciplinary**: Interdisciplinary learning is addressed at two levels: content and collaboration. In module ii, which comprises thematic workshops, groups are formed which might include participants from different engineering fields. Furthermore, the content of the course relates to a discipline that is not engineering, i.e., learning theories and pedagogy. **Exemplary**: The overall goal of the course is to provide a basic understanding of PBL and curriculum change. Consequently, the course, especially the workshops, includes hands-on activities which are illustrative of PBL principles and curriculum elements (e.g., facilitation, teachers' and students' roles, assessment and learning outcomes, evaluation, etc.) and how they can be used to design a PBL activity for practice. The frameworks and exercises are exemplary of how a PBL curriculum should be constructively designed.

PBL learning principles	Aalborg Certificate on Basics of PBL and Curriculum Change
	Theory and practice: The course includes the design of a PBL activity, with the aim of implementing it in practice. The design of the PBL activity encompasses theoretical knowledge of, for example, PBL curriculum design, constructive alignment, problem design, facilitation skills, etc.
Collaborative approach: • Team-based • Self-directed and participant-directed	**Team-based**: While module i (introduction and preparation) is aimed at the individual, in module ii participants take part in a workshop on collaborative learning and group formation in which groups are formed for the rest of the course. By working in groups, it is expected that participants will learn from each other, for example, by communicating and sharing points of view, strategies, and understandings of PBL. **Self-directed and participant-directed learning**: Participants have ownership over their learning. They are the ones who decide what should be changed in their teaching practice and how.

Socialization, Professional Identity Formation and Training for Uncertainty: Comparison of Student- and Clinician-Lead Problem Based Learning Groups in the First Year of Medical Education

Stefan Reinsch, Juliane Walther, Stefanie Oess,
Wiebke Tschorr, Jonathan Nübel, Jannis Schwanemann, Can Gero Leineweber*

ABSTRACT

Clinical knowledge, group facilitation skills, and cognitive congruence are considered important factors for the successful tutoring of Problem Based Learning sessions. In addition, the theory of Community of Practice has become an important tool to approach social learning and knowledge integration in medical education and organizational studies. More research is needed to link these two strands of research. We look at novice medical students' experiences and comparative reflections on student-tutors and clinician-tutors as facilitators of PBL sessions in a participatory, randomized cross-over design. Qualitative methodologies were

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* Stefan Reinsch, Centre for Curriculum Development and Educational Research – ZSAW-BB , Centre for Health Service Research – ZVF-BB, Brandenburg Medical School & Faculty of Health Sciences Brandenburg, Germany
Email: stefan.reinsch@mhb-fontane.de
Juliane Walther, Centre for Curriculum Development and Educational Research – ZSAW-BB, Brandenburg Medical School & Faculty of Health Sciences Brandenburg, Germany
Email: juliane.walther@mhb-fontane.de
Stefanie Oess, Centre for Curriculum Development and Educational Research – ZSAW-BB, Brandenburg Medical School & Faculty of Health Sciences Brandenburg, Germany
Email: stefanie.oess@mhb-fontane.de
Wiebke Tschorr, Centre for Curriculum Development and Educational Research – ZSAW-BB, Brandenburg Medical School, Germany
Email: wiebke.tschorr@mhb-fontane.de
Jonathan Nübel, Centre for Curriculum Development and Educational Research – ZSAW-BB
& Department of Cardiology, Immanuel Klinikum Bernau, Heart Center Brandenburg, Brandenburg Medical School, Germany
Email: jonathan.nuebel@immanuelalbertinen.de
Jannis Schwanemann°, Centre for Curriculum Development and Educational Research – ZSAW-BB, Brandenburg Medical School, Germany
Email: jannis.schwanemann@mhb-fontane.de
Can Gero Leineweber°, Centre for Curriculum Development and Educational Research – ZSAW-BB, Brandenburg Medical School, Germany
Email: can.leineweber@mhb-fontane.de
°JS & CGL share the authorship

used to probe the experiences of participants. In this study, the main factor for successful PBL sessions for first-year students was the creation of a non-hierarchical learning atmosphere, which starkly differentiated itself from the rigidity of a PBL structure organized around clinician-tutors and their hierarchically-imparted knowledge. In contrast, a more flexible strategy of student tutors and their constructive management of "not-knowing" enabled novice students to take steps on their own — of which they were highly appreciative, stressing how it allowed them to develop earlier autonomy with regard to PBL methodology, manage uncertainty, and create a shared identity as a community of learners.

Keywords: Student tutors, qualitative methodology, student insights, community of practice, professional identity formation

INTRODUCTION

Sociologist R.K. Merton has been a pioneer in pointing out the dual nature of medical education, the aims of which are to provide those wishing to become physicians the opportunity to acquire the best available knowledge and skills necessary for the practice of medicine and to support them to develop a professional identity, so that they may come to think, act, and feel like a physician (Merton 1957:7). Medical educators (Parboosingh 2002, Cruess *et al*. 2014; Cruess, Cruess & Steinert 2018) have recently taken up this view of learning, practice, and professional identity formation as inseparable. Professional identity is formed mostly through implicit experiences made at the side of role models as part of a hidden curriculum of rules, regulations and routines, much of which is transmitted by near peers - rather than faculty - in informal teaching situations (Stern & Papadakis 2006). One of these teaching situations is Problem Based Learning (PBL), where the development of team-oriented attitudes like cooperation and responsibility as well as skills in dealing with uncertainty in knowledge is one of the primary goals (Davis & Harden 1999).

Today, Problem Based Learning (PBL) is understood as a valuable tool linking medical knowledge to practice (Barrows 1996). However, the most beneficial qualifications and backgrounds of those facilitating the PBL sessions has not been addressed in a satisfactory fashion. Over the years, research has looked at the characteristics of PBL tutors mainly in terms of two factors: first, the differential influence between content expert and non-content expert tutors, and second, the effectiveness of staff versus student tutors. In medicine, PBL sessions are usually centered around clinical cases. Therefore, content experts are individuals possessing clinical expertise in a given subject or clinical discipline, which can be gained by direct exposure to clinical practice, such as working for years as a physician. In addition, process expertise, the didactic skills and ability to

facilitate group sessions, is considered a separate set of skills important for the successful facilitation of PBL sessions (Dolmans et al 2002).

Regarding academic achievement and student satisfaction, the literature, excepting some studies that are mildly in favor of content expertise over group facilitation skill, is inconclusive (Davis et al 1992; Schmidt et al 1993; Hendry 2002; Gilkison 2003). Research into the relative effectiveness of staff versus student tutors is equally difficult to adjudicate (Moust et al 1989; Moust & Schmidt 1995). Overall, the empirical literature remains unsettled regarding the preferred background for the PBL tutors. Notwithstanding this lack of empirical basis most authors suggest a combination of content and process expertise and cognitive congruence, which is the ability to think like students, and to empathize with their circumstances (Schmidt & Moust 1995; Maudsley 1999; Dolmans et al 2002; Ten Cate et al 2012). However, in most of the studies cited above the students' perspective of what defines a "successful PBL session" is missing (Dolmans et al 2002). Only recently have students been involved in their own curricula as "partners", the focus being less on academic achievement, but to increase the accountability of their curricular decisions, enhance their engagement and responsibility for learning, and strengthen their professional-identity formation (Bilodeau, Liu & Cummings 2019; Zhen & Wang 2022).

At the newly founded Brandenburg Medical School – Theodor Fontane a medical curriculum was established in 2014 in several rural hospitals situated in the state of Brandenburg situated in Eastern Germany. Basic science and clinical elements are taught alongside each other, with basic science making up about 80% of the learning objectives during the first year and clinical learning objectives about 20%. This balance is gradually reversed as students progress through the years. During the first five of a total of six years, PBL is the central curricular element, driving the identification of learning objectives in relation to the clinical case. During a two-hour PBL session, a complex and authentic medical problem is presented at the beginning of each week. PBL small groups define leaning objectives in relation to the case and to the themes of the related disciplinary modules (e.g. The learning objective "Explain, why the RS virus impairs breathing of toddlers more than in adolescents" would relate to pathophysiology of breathing, basic science of gas exchange, and pediatrics). The learning objectives can be approached while studying alone, during seminars, lectures or tutorials. At the end of the week, the group presents its findings to each other and discusses and reflects on the results of learning and occasionally tries to solve the problem during a second two-hour session. Complexity of the clinical cases increases over the course of medical studies and also includes social and ethical aspects. There are no examinations of the PBL learning objectives, which are meant to serve the students' self-directed learning process. However, the PBL cases are related to the overall learning objective of the semester. These objectives are transparent

to the students and form the basis of end-of-semester exams. Good PBL learning objectives would stimulate students' curiosity and be in line with what the faculty expects them to learn over the semester. The PBL process also requires collaboration, critical thinking and practical learning that are part of a hidden curriculum. Participation in 85% of the PBL sessions is the only requirement to be eligible for exams.

In line with the literature on PBL, tutors at our medical school are instructed to act like moderators or facilitators. The aim of the tutor is to help students to arrive at a deeper understanding and develop skills that can be deployed in other domains, rather than merely learning facts. Tutors' roles in PBL differ from other formats like lectures or tutorials. The most relevant skills here are to activate students, supervise the quality of learning, give learning aids, and serve as role models when dealing with problems (Maudsley 1999; Mayo, Donelly & Schwartz 1995; De Grave, Dolmans & van der Vleuten 1999).

When establishing or extending PBL curricular, faculties are often confronted with the task of training many tutors that have no clinical background (Vogt, Pelz & Stoux 2017). PBL tutors in our medical school were mostly clinicians working at one of the medical departments and have been trained in a standardized ten-hour didactic course. Only a minority of clinicians had experienced PBL as students. In 2020, the growing student number required to recruit non-clinical staff such as psychologists, pharmacists or paramedical professionals, as well as some student tutors to fill gaps in the teaching staff. This raised the question of whether the practical experience of senior students could be used to teach PBL to their novice (peer)students: the rationale being that students had accumulated experience in over 100 PBL sessions.

We were unsure, however, if and how this participatory experience could be translated into tutorial expertise. From our perspective, this does not only require content expertise, facilitation skills and cognitive congruence. It also involves the "putting on of a new cloak" as facilitator. Student-tutors, while studying and acting as PBL facilitators, build up a reflective experience (Rolfe 1997) that is subsequently transformed into expertise (Beck 2015). This process is continually reproduced within each generation of teachers and students in the specific community of practice in university medicine.

We approach the question of expertise development and professional identity formation with a focus on social practices (Schatzki, Knorr-Cetina & Sawicki 2001). Practices are understood, broadly, as a set of sayings, doings and organizational ways, abiding by ways of understanding and a set of rules and teleo-affective structures, or aims (Schatzki 2001: 61). The identity of a person (teacher or learner) is conceptualized as a function of relations—and conversely, relations are functions of identity (ibid: 51). This is important, as it allows us to look beyond fixed social roles (student, physician, teacher, patient, …)

and to foreground the relational nature of identity and practices. People perform acts of learning, organizing, deciding, writing-up clinical cases, telling stories, etc. and through these performances they work on identifying as students, tutors or clinicians. Processes of identification are shaped by the practices people perform and the relations with other people that arise within these practices.

Within the field of practice theory and organizational studies of medicine and beyond, the concept of community of practice (CoP) has become an important tool to approach social learning and knowledge integration. A broad definition of a CoP is "a group of people who share a concern for something they do and learn how to do it better as they interact regularly" (Wenger, 1998). The shared learning process creates a bond among the members over time. Originally, it was developed to understand adult learning in apprenticeships e.g., midwifery (Lave, 1991). Today, CoP use has been extended from learning within to learning across disciplinary communities in science, businesses, and medicine (Regeer & Bunders, 2003; Amin & Roberts, 2008; Manidis & Scheeres, 2013; Cundill, Roux & Parker, 2015; Cruess, Cruess & Steinert, 2018). A key concept of CoP theory is, that one becomes a member of a community by acquiring the skills and knowledge of that community; with this, one moves from legitimate peripheral participation to a more central position, transforming oneself, as well as the group (Lave & Wenger, 1991).

The first year of medical education seems crucially important as it is often the first encounter with the set of norms and values central to the CoP of medicine. In our medical school, the longest lasting and most engaged interactions between novice students and experienced members of the CoP of medicine occur during PBL. We hypothesized that these interactions would take different forms depending on whether the group is led by student-tutors or clinical tutors. We wanted to explore if these different interactions would in turn influence the way the small groups of novice students approach the central tasks of PBL: how they interact as a group, and how they deal with not-knowing and the uncertainty of what was known.

MATERIAL AND METHODS

Study Design
The initiative for our study came from a group of students at our medical school who felt PBL could be improved by making use of senior student's experiences. The first author, together with the vice-dean of education of our University (SO) and a group of senior students (CGL, JS, WT & JN) developed a participatory design to conduct and evaluate a randomized, cross-over comparison of physicians and students as PBL-tutors during the first year of medical education. In the academic year 2020/2021, the forty-eight first-year students were randomized into six PBL groups of eight students. Half of the PBL groups

were facilitated by a student-tutor during the first semester; the other half were tutored by a physician. After one semester, student groups were switched (Figure 1). The student-tutors remained involved in all steps of the research, presented findings on conferences and co-authored this publication.
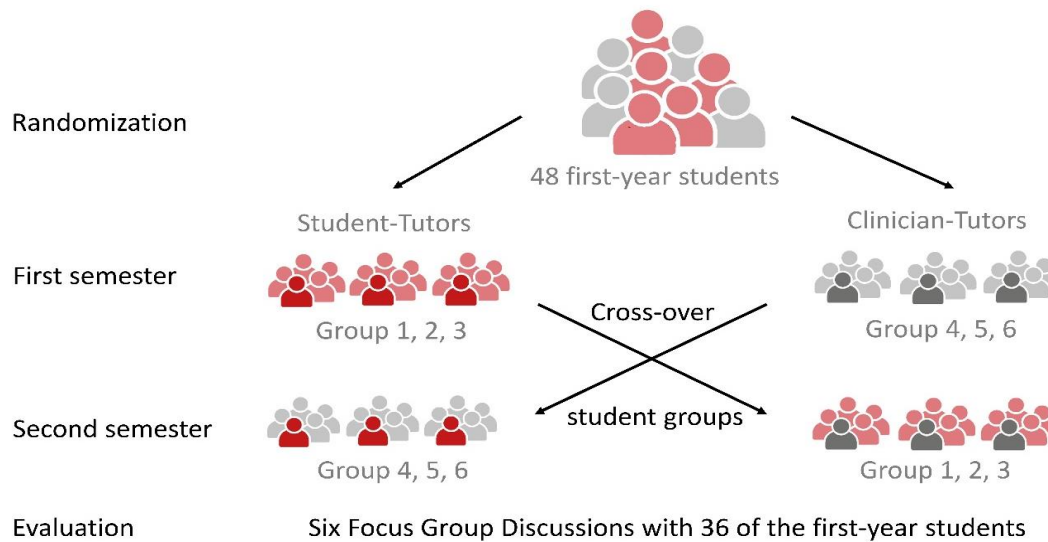

Figure 1: Flowchart of Study Design.

Student population

Post-hoc analysis showed that the student groups were comparable regarding age, gender, A-Level results and previous experience of working or studying (Table 1). Minor differences in age and previous experiences between groups were non-significant. Two students left before the end of first year of medical school and were not included in the analysis.

PBL Group		1-3 (n=24)	4-6 (n=22)	Total (n=46)
Demography	Age	$25,95 \pm 4,69$	$23,5 \pm 2,78$	$24,78 \pm 3,9$
	Male	8 (33,3%)	6 (27,3%)	14 (30,4 %)
	Female	16 (66,7%)	16 (72,7%)	32 (69,6 %)
	A-level results	$2,3 \pm 0,51$	$2,2 \pm 0,5$	$2,23 \pm 0,5$
Previous Experiences	Paramedical	13 (54,2%)	9 (40,9%)	22 (47,8%)
	Nursing	6 (25%)	3 (13,6%)	9 (19,6%)
	EMS	3 (12,5%)	4 (18,2%)	7 (15,2%)
	Midwifery	2 (8,33%)	-	2 (4,35%)
	Various	2 (8,33%)	2 (9,09%)	4 (8,7%)

	Non-medical	2 (8,33%)	2 (9,09%)	4 (8,7%)
	None	9 (37,5%)	11 (50%)	20 (43,5%)

Table 1. Demographics and Previous Experiences of First-Year Students

Tutors

Ten student-tutors volunteered to participate in the study. All of them had previous experience studying or working before their medical studies. Six had didactic experience teaching practical classes at the local skills lab. Four tutors were involved in designing and evaluation of the study. Tutors were studying in the 6th to 10th semester, resulting in 3-5 years of first-hand experience with the PBL format and methodology. However, student-tutors lacked certain content-based and case-related expertise, which the physicians had developed in real-world clinical scenarios. Clinician-tutors had not undergone PBL themselves. They represented a range of experiences: from resident to attending physician to professor and Head of the Clinic. At the start of the study, student-tutors and physicians were trained through the same standardized 10-hour didactic course. During the study, two group-feedback sessions for tutors and two individual supervisions during PBL were offered to all tutors. However, only the student-tutors made use of this offer.

Evaluation

We used qualitative methods, namely participant observation, interviews and focus groups to explore interactions, experiences, and views of participants. Here, we report on the results of the focus groups. Five individual interviews with students-tutors were held before the start of the first semester. They served to explore potential problems and construct the interview-guide for the focus groups.

Six focus group interviews with the first-year students were held after the completion of the second semester. We chose to conduct the focus groups in the same composition of students as the PBL groups. This allowed discussions about shared experiences among the group members. Focus groups were conducted by SR and CGL. Focus groups lasted 60 minutes on average. Thirty-six first-year students, representing 75% of the cohort, participated in the focus groups. Non-participation was due to drop-out from medical school (n=2) or problems in scheduling a time slot (n=10). Focus groups centered on the students' experiences during the first year of PBL. We used open-ended questions and encouraged participants to elaborate and discuss with the group members. We specifically asked for comparative perspectives on working with the different tutors, how this affected group dynamics, the identification of learning objectives, the motivation to study, and if students preferred one or the other tutoring style during the first year. The interview guide for the focus groups is appended.

Interviews and focus groups were audio-taped, transcribed verbatim and pseudonymized following transcription. In addition, we wrote field notes directly after the interviews in order to maintain contextual detail.

SR and JW read all transcripts and analyzed the transcripts both independently and in joint analysis sessions. In these sessions, they developed the themes and selected the quotes which are discussed in this paper. During the process of analysis of the focus groups, identity formation and socialization were identified as useful concepts linking the practice of PBL sessions with their aim. Two analytical concepts *knowledge-* vs. *process-centeredness* and *community of learners* vs. *hierarchy of knowers* were inductively developed from the material. To validate findings, we discussed them first with the student-tutors and subsequently presented our findings to the University's students in a workshops, as well as to the University's working group for curricular development.

Research Ethics
The study was approved by the University's ethics committee. All students and tutors were informed about the research at the start of the study. Non-participation in the study was not possible as PBL is the central curricular element. Participation in the interviews and focus groups were voluntarily, and participants received written information and gave their oral and written consent.

RESULTS

Socialization, Professional Identity Formation and Training for Uncertainty
We shall first look at how the students perceived their tutor's strategies in terms of teleo-affective structure i.e., what was aimed for. Clinical tutors' strategies were perceived as centered on the acquisition of knowledge, while those of the student tutors' were centered on developing the group-process. The clinician-tutor's central position in the CoP of medicine in itself had a powerful inhibitory effect on novice students' ability to speak freely and openly about not-knowing. This was different with the student tutors who were seen as being on an equal footing with the novices. Second, we will contend that position and strategy of the tutors had an additive effect on novice students' identification, as either a *community of learners* or a *hierarchy of knowers*. Third, we argue that the two different group organizations and the values that underlie their respective identifications have repercussions on dealing with uncertainty.

Student-tutors' strategies are group-process centered, clinician-tutors' strategies are knowledge-centered
During all Focus Group (FG) discussions, students reflected on the different ways their tutors adhered to or modified the rules of the PBL classroom. Clinical tutors dominated the PBL process, leaving students little flexibility with the methodology. As a result,

students' attention to the group process moved in the background, and PBL was centered mainly on the acquisition of factual knowledge. The student tutors focused less on knowledge and more on developing the group process. They allowed their students greater degrees of freedom in interpreting the PBL process. Their strategies were described as more flexible and adaptive and as not anticipating or forestalling students' own learning process.

> I had the feeling that during the first semester, PBL [with the student tutors] was a bit more open […] We were somehow freer in our decision-making process. [Focus Group 2, lines 13-17]

> We had found our way in the structure [of PBL] and developed a structure of our own [during the first semester]. This may not have been easy, but then [the clinical tutor during the second semester] said, 'Yes, but I don't want it like that, I want this in a different way, I want that in this or that order. If you did it otherwise, I don't care, but now I say it must be like this. [FG 2, l. 233-40]

> During the first semester [with the student tutors], PBL was not only about acquiring knowledge, but also about working together and getting along as a group—about this, too, being of importance. [FG2, 90-92]

> Especially these anticipating clinical experiences that have been 'inserted' by clinicians have partially taken away the freedom. [FG6, 40-2]

In our FG discussions, students understood the different strategies employed by clinicians and student-tutors as related to their respective differential positions within the community of practice of medicine. Because the clinical tutors were perceived to hold a more central position within the CoP, they had a powerful inhibitory influence on the students who were reluctant to speak freely, fearing to leave a negative impression. The more central the clinician-tutor's position, the stronger the effect. The potential role of their clinician tutors as examiners in upcoming exams added to this inhibitory effect, since students feared their contributions during PBL would influence their grades negatively. The perceived inhibitory effect was not noted with the student-tutors. All the student-tutors were seen as being "on par" (*German "auf Augenhöhe"*):

> We've, of course, also had [the clinic's chief who was the groups PBL tutor] during practical tutorials and a bit of the fear therein is: will he be my examiner later? [FG5, 530-1].

> I believe there was a higher inhibition threshold among us to participate in technical discussions, because one knew that the Head of the Clinic was also listening. [FG1, 165-6]

> Simply because [student tutors] were fellow students from a higher semester, it
> made no big difference in the end [if we impressed them]. I found, we were equals.
> [FG2, 37-40]

In the first section we demonstrated the effect of tutoring style and the tutor's position
within the CoP. In the next section we argue that these have an additive effect. The tutors'
strategies in group facilitation and the respective positions of the tutors within the CoP of
medicine, informed by these strategies, reinforced each other. We argue that this dynamic
leads to the development of two distinct identifications – a *community of learners* of
students and student-tutors and a *hierarchy of knowers* organized around the clinical tutor.

**Two distinct Identifications develop: a "Community of Learners" vs. a "Hierarchy
of Knowers"**

First-year students noted that they reacted to the different strategies by adjusting the group
dynamics depending on the tutor's position in the CoP. All groups reflected how they
aspired to receive the accolade of the clinical tutor. If praise was offered, students felt a
reinforcement of their progress towards the clinician's position. The clinician's strategy
to intervene in the group process by providing clinical knowledge was matched by the
students. They noted that they, too, started to act more knowledge-centered, offering as
much information as possible, irrespective of whether this would help the group. Such a
reinforcement or an active change of behavior was not noted with the student-tutors'
praise. Because of their social, emotional and cognitive congruence, these tutors were
seen as part of the group, despite their formal role as group leaders:

> Receiving praise from the Chief or the attending physicians during the second
> semester for being so structured in our work, this was of course a positive
> reflection of the training that we got during the first semester. [FG1, 227-9]

> With the clinicians we noticed that some [students] felt obliged to provide
> knowledge, of some kind, that may or may not have been relevant in that context.

> Reacting directly to the above statement, a student added: Personally, I perceived
> it like that, too – one noticed when one or the other was courting the clinician's
> favor, which was not the case with the PBL student-tutors. Because, whether I
> impressed them or not was of no importance in the end. [FG2, 57-64]

> Well, they were there – an integral part of the group somehow. It's not like they
> were this extra leader, just simply they were there, in the PBL group. […] Yes,
> officially they were probably PBL group leaders, but it's not like… well, they
> were just integral to the group. [FG2, 227-242].

The three PBL groups that had been initially taught by student-tutors noted a shift in group structure and identification following the transition to having clinical tutors. This switch they described as an erosion or dissolution of the already established *community of learners.* They noticed the development in the process, but were unable to preclude it. In retrospect, the groups reflected that clinical tutors were seen as members of a group, to which the students would want to belong in a 5–6-year long-term perspective. The gap between first-year student and experienced clinician was perceived as leading students to abandon an already established set of shared interests in favor of the interests of the clinician. In one of the strongest-worded statements, a group of students from the second FG reflected on how their group's focus during PBL moved away from them as a group of peers, and sometimes even away from their own learning process, leading to a situation, in the end, where the clinical tutor would become the vanishing point for each member of the group, with everyone adjusting their behavior accordingly:

> I believe that these hierarchies – the gap vis-a-vis the clinician tutor, was simply so huge that, really, our group interests shifted, with everyone then becoming a lone fighter. [FG2, 160-64]

> We were having a discussion and suddenly, contributions would come in whereby one had the feeling that they were not directed at the group at all, or aiming to further the brainstorming, but rather: 'I want to show here, in front of whoever is watching, that I have learned something – throw around some technical terms and create a favorable impression.' And they somehow fed off each other [these people showing off] in a mutual reinforcement such that one felt the person was no longer reachable. [FG2, 168-73]

> Now that there was a certified physician at the helm, it was no longer a communication amongst peers, there reigned this tendency… hierarchy, pure and simple, that was not there before. Somehow one wanted now to please a figure of authority, talk up to them and for their sake, implementing things that were not in our interest just because some superior had dictated them. [FG2, 118-26]

Training for Uncertainty in the "Community of Learners" and the "Hierarchy of Knowers"

In the third section we elaborate on the question of how the two different group organizations and the values that underlie their respective identifications have repercussions on dealing with uncertainty. A central tenet of PBL is to learn to identify knowledge lacunae that could then serve as a motivator to fill-in these gaps, and as a guidance to direct collective learning. Thus ideally, collective learning during PBL requires an open dialogue about what is known and what is unknown to the group and to the community of practice of medicine. The task of differentiating between these two,

sociologist of medical education Renée Fox has termed "Training for Uncertainty" (1957).

Students drew their conclusions about the identification of their tutors mainly from how the latter dealt with knowing and not-knowing. Student-tutors dealt constructively with their own not-knowing, pointing out its important role in learning. Novice students very much appreciated this attitude They learned from the tutors' example that what counts as right or wrong does not depend on a person's position in a hierarchy. Herein manifests the aspect of identification which is seen as central by novice students: their shared identity as continuous learners. In one FG discussion, students referred to a situation where PBL cases unintentionally contained mistakes. These provided an opportunity for students to witness different approaches of student and clinician tutors in dealing with the uncertainty of knowledge and the revelation that knowledge, proffered by authority (the University) may be false:

> I simply discovered during the second semester [student tutored], unlike it was in the first, that the University could be fallible, too; [that PBL cases could contain mistakes and so] that more or less everything, outside the student [realm] be allowed to be fallible. [FG3, 158-60]

> I found it very refreshing that the student tutors either said, 'I believe it to be so-and-so, but do not take it from me – it was really long ago and I can't remember.' Or, 'let's talk about it the next meeting [and make it a learning objective].' [FG2, 253-261]

> We are all students, and we are all still studying. None of us has any official document hanging on the wall that certifies we have already gone through this. [FG1, 457-8]

In contrast, the clinical tutors' self-conception was seen as containing the pretense of knowing everything. Sometimes, knowledge appeared made-up or misleading:

> With the clinician tutors there was always a pretense: 'I am now a certified physician. I cannot say now that I do not know this.' [FG2, 253-4]

> [Clinician tutors gave the impression] 'I have to know this now and I have to say something even though I might not know it all that exactly either.' [FG2, 474-5]

> And then, from the farthest corner of their mind, they would sometimes fetch some scrap of information. Situations would arise fairly often were information was thrown at us that turned out to be false in the end. [FG2, 253-261]

The first-year students connected a clinician's socialization to the pretense of knowing-it-all. However, students underscored that the onus of this expectation toward the physicians did not emanate from the students:

> Of course, if your studies lie some 20 or 30 years back, then you do not know everything razor sharp. But I also think that physicians were brought up to always have an answer, to simply pretend to know exactly. [FG2, 610-20]

> But actually, I don't feel like we have pushed them into this role of having to never make mistakes, of having to be *know-it-all* and *almighty* [English in the original]. Yes. [FG2, 636-7]

In retrospect, all focus groups agreed that they would have preferred student tutors during the first semester, but valued that they had been able to compare between different tutoring styles.

DISCUSSION

We started from the position that learning, practice and professional identity formation in medicine are inseparable. Our basic assumption for the study was that student-tutors would be able to transform the experiences made during their studies and reflexively translate these experiences into expertise in PBL facilitation.

We found that, depending on whether a group was tutored by a *near peer* or a more senior, clinical member of the CoP, the novice students reported differences in the perceived aims underlying the styles of the tutors. In our data, these differences showed repercussions along three main axes. First, they impacted the aspect of group-process vs knowledge-centeredness of the PBL sessions and the students' satisfaction with the PBL sessions. Second, the values and identification of the PBL group were affected, and third, there were repercussions as to how the groups dealt with *not-knowing* and with uncertainty when trying to adjudicate between personal ignorance and unsettled puzzles in the field.

First, we found that student-tutors' strategies were more group-process centered, while clinician-tutors' strategies were more knowledge-centered. Novice students linked these strategies to the tutors' respective positions within the CoP. Within the CoP of medicine, student-tutors occupy an intermediate place in the successive progressions from non-student to medical student to experienced physician. In the words of Merton, students-tutors build an identity as student-physicians while still learning to practice medicine. In line with findings from Schmidt and Moust (1995), we found that this was a position that

allowed them to develop greater cognitive congruence with novice students than experienced clinicians would have. From the novice students' perspective, this group-process centered approach translated into more satisfying PBL group facilitation at the beginning of medical studies.

Second, over the course of the first year of medical school, the students who participated in our study became acquainted with and learned to differentiate between the different PBL tutoring styles. Our results showed that these different styles affected group dynamics and lead to identifications either as belonging to a *hierarchy of knowers* organized around the knowledge of a senior member of the CoP or as belonging to a *community of learners* collectively striving to attain the best available knowledge. The contrasting experiences they made with the student- and clinician tutors allowed students to reflect, i.e. to contrast and compare in the anthropological sense. It is our opinion that in the process of reflecting the values and norms inherent in the different tutoring styles in the PBL environment, novice students undergo a process of professional identity formation.

Third, we were surprised, about the dynamics of learning to manage uncertainty that unfolded in relation to the different tutoring styles. It stands to reason that novice students might feel closer to student-tutors than to clinicians, as the latter are seen as more "establishment", hence further away within the CoP of medicine. Student-tutors are in an intermediate position between novice students and clinicians. They are still studying, but already part of the teaching staff. They embody both the core values of the university and the way forward as student-physicians. In our study, student-tutors were reported to have dealt more constructively with their own not-knowing than clinicians had. Novice students learned from the tutors' example: namely, that what counts as right or wrong does not depend on a person's position within the pecking order. Herein manifests the aspect of identification perceived as central by novice students: their shared identity as continuous learners. Be it as positive or negative role models, clinicians provided a helpful foil for students to contrast and compare styles and values.

One of the strengths of our study, our reporting on the student's experiences and views, also entails a potential confounder. We saw that the people more central in the hierarchy most strongly influenced the group dynamic. We cannot exclude the possibility that participants of the focus groups were also influenced by the interviewer. We attempted to minimize this effect in the following ways: firstly, we were open about the study being jointly led by members of the faculty, clinicians and students. Secondly, the focus groups were jointly held by a clinician and a student-tutor and the two intervened as little as possible in the discussions.

In medical education, student tutors are usually employed in skills labs or as teaching assistants for basic science classes. Such Peer Assisted Learning Programs are chiefly established for practical purposes. According to the literature, the lack of resources to adequately serve a growing student population and the search for cost-efficient ways of teaching are common driving factors. When classes and exams show high rates of failure, such programs may be the ancillary option of choice and it also helps to address blind spots in the curriculum (Herrmann-Werner 2017). Our study tried to test whether student tutors could be of benefit beyond serving as Band-Aids for lacking resources or in the detection of curricular blind spots. Our results show that the purposeful deployment of PBL student-tutors is beneficial for first-year students. The first semesters are potentially most formative in terms of socialization within the CoP. In line with findings from Zheng & Wang (2022), the student-tutors of our study who had personal experience with the PBL format and the local curriculum were able to create situations such that novice student could develop their own, sovereign and autonomous ways of dealing with the affordances of PBL. The student-tutor's constructive example in dealing with personal *not-knowing* and with the uncertainties in differentiating between *personal not-knowing* and the *not-knowing of the CoP* was praised by novices. The underlying values of cooperation and critical thinking helped the novice students to identify as a *community of learners.*

Looking at stakeholders beyond the first-year students, we see clear benefits for the tutors and the institution. Acting as PBL tutors provides the students involved with the opportunity to develop important skills and competencies in professional and scholarly domains in accordance with the CanMEDS model (CanMEDS 2000). We will report our findings from the interviews with our tutors in a subsequent publication.

As a result of our study, the University decided to implement a policy of using PBL student-tutors in the first year. We believe this to be a pathway worthy of further exploration within the bounds of our institution. Our contention is that the student-tutors' embodied memories from similar PBL learning situations create a collectively embodied memory culture. It is this culture promoting a propitious atmosphere that students described as a *community of learners.* It guides the novice students as they navigate medical studies; thus helping in the constitution of new experiences and preparing the ground for lifelong learning.

Looking at the future of PBL beyond medicine, we feel that the idea we tested in our study is well worth embracing by other institutions as well, so that the first and most formative interactions may happen in the company of near peers, such as student tutors, rather than under the auspices of the people most at the center of the CoP. PBL is a highly interactive learning format that has the potential to transform that CoP. The embodied-knowledge of prior generations is re-generated within the contexts of novices'

interactions within the social and material environment of the PBL classroom. If these interactions are more cooperative and less hierarchical, so might become the CoP over time. To borrow a phrase from anthropologist Harris (2005:198), the collective experience of a CoP acts like "a wave which carries forward the history of past actions and embodies their potential".

Acknowledgements

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Education as an Open Question:
A Hermeneutical Approach to Problem-Based Learning

Julien Kloeg *

ABSTRACT

In this paper, this theme of the open question is offered as a hermeneutical approach to problem-based learning. Most of the scientific literature on problem-based learning is in the realm of the behavioral-sciences. To the extent that the latter becomes the exclusive focus of research on problem-based learning, there is a risk of instrumentalization. The hermeneutical approach of this paper is meant to complement this field of research. The subjects of humanities research are not directly available to a humanities scholar, at least not in the way experimental subjects are to a natural scientist. This is Wilhelm Dilthey's epoch-making understanding of the humanities in a nutshell. Philosophical anthropologist Helmuth Plessner, drawing on Dilthey, extends this insight to the historicity of human existence as such, summarizing the latter as an 'open question' that is always impressing itself upon us as human beings, but which at the same time cannot be answered definitively. It is through this process of asking and answering that we leave behind a history in the first place. I use these arguments to show that the theme of the open question yields a series of interconnected educational insights: notably the importance of subjectification, the social and historical context within which education necessarily takes place, and the construction of new knowledge and experience. These educational insights are rendered explicit and put into practice in problem-based learning. I hope in this way to develop a research perspective on problem-based learning as not only a set of behaviors, but as the scene of meaningful action.

*   Julen Kloeg, Erasmus University Rotterdam, Netherlands
     Email: kloeg@esphil.eur.nl

INTRODUCTION

The historical roots of problem-based learning are in the field of medicine. It was first developed in 1969 by "five disgruntled doctors" at McMaster's University, Canada who wanted to develop "a new approach to medical education" based not primarily on adherence to a distinctive philosophy of education or set of ideas, but the desire to offer their future students "a less boring experience" (Miklos-Servant 2018, 4). More than fifty years later, problem-based learning has been adopted by over 500 educational institutions worldwide (Schmidt et al. 2009). While there are many different versions of problem-based learning, the committee started by Bill Spaulding in 1966 with a view to establishing the new medical curriculum established three core principles that continue to distinguish problem-based learning from other approaches today. These are: (1) a self-directed, smallgroup, problem-based approach; (2) a systems-based approach to the curriculum; and (3) a community-oriented attitude to ensure a link to larger society (Servant 2016). The first two principles are accepted as a matter of course, but the status and specific meaning of the third principle, which emphasizes the community-oriented attitude of problem-based learning, is comparatively unclear, also in terms of what it requires. In earlier joint work I argued that the need to offer sustainable education in the present must require an orientation not only with respect to a given, local community, but must educate students for their futures in a world held in common. This implies an extension of the community-oriented attitude as one of the original principles behind problem-based learning (Noordegraaf-Eelens et al, 2019). Connecting community orientation in problem-based learning to sustainable education in this way also makes clear that the way in which problem-based learning relates to the relevant community, be it local or global, cannot take this community for granted or take its existing form as an absolute given. Using the vocabulary of educational philosophy, one might say that problem-based learning is not only about insertion into a given (social or professional) community, but also about how one positions itself in relation to this community as a whole, potentially also 'outside' of it (Biesta 2012, 13).

Community-orientation as a core principle of problem-based learning today thus raises several questions. First, how should the practice of problem-based learning relate to local communities and to the world at large? Second, and cautioning practitioners of problem-based learning about the danger of linking up with society all too readily, how can a certain distance be ensured, so that problem-based learning can not only ensure successful integration into the existing society, but also continue to reflect on it? In this paper, I offer a response in terms of what twentieth-century philosophical anthropologist Helmuth Plessner called the open question of human existence as such. The inquiry into who we are, individually and collectively, requires an answer. However, any such answer is necessarily non-definitive and leads to the re-opening of the question, and thus to further

open-ended answers. Plessner develops this understanding of human existence in connection with Wilhelm Dilthey's influential theoretical understanding of the humanities. I argue that the theme of the open question yields a series of interconnected educational insights: notably into the social and historical context within which education necessarily takes place, the construction of new knowledge and experience, and the importance of subjectification. These educational insights are rendered explicit and put into practice in problem-based learning, while Plessner's philosophical anthropology provides a way for problem-based learning to think through its own situatedness in a way that does justice to its principle of community-orientation. This is the outcome of a hermeneutical approach to problem-based learning, which is distinct from a behavioral-scientific approach in that it applies the method of the human sciences (or humanities) to provide an interpretation of its educational practices. The wider context within which this humanities approach is introduced is that both the behavorial-scientific and humanities approach have an important role to play in understanding problem-based learning.

Such an approach is all the more important because an exclusive focus on the behavioral sciences in the study of education risks an instrumentalization of education, since it focuses on the attainment of skills and educational outcomes independently defined. Part of the value of the hermeneutical approach supported by Plessner that I develop here is that it provides a coherent program of non-reduction (Kloeg 2020), avoiding both naturalist and culturalist monopolizations of education. In order to make this case, I first outline a tentative analysis of the challenge of instrumentalization that faces problem-based learning (section 1). In order to meet this challenge, I introduce Dilthey's understanding of the humanities and the hermeneutic approach of education, as well as Plessner's development of Dilthey in terms of the open question (section 2). I then develop the educational insights that follow from this perspective and indicate what it contributes to the practice of problem-based learning (section 3). Joinly, the sections aim to answer the following question: how should problem-based learning be interpreted from a hermeneutical view following Dilthey and Plessner, and how does this elucidate the theory and practice of problem-based learning?

1: INSTRUMENTALIZATION AS A CHALLENGE FOR PROBLEM-BASED LEARNING

The approach from science and philosophy to education, especially in practice, is one that has to be undertaken with considerable care. Instrumentalization lurks around every corner. This is not the place to offer a full categorization of instrumental approaches to education, but I will offer a tentative analysis below and consider how the approach from philosophical anthropology, as a transdisciplinary approach or *metabasis*, is able to avoid these pitfalls and what it can offer to a renewed understanding of problem-based learning.

The first way in which education can be instrumentalized is tied to a debate on how to interpret problem-based learning. In the information-processing model pioneered by Howard Barrows (Servant-Miklos 2018) education is put in the service of acquiring highly general skills that transcend differences between different disciplines: for instance, general clinical reasoning skills (Barrows & Tamblyn 1980). The supposed generality and independence of these skills is belied by both methodological (Ohlsson 2012) considerations and by the finding that problem-solving skills are in fact context-bound (Servant 2018). This also makes sense of the apparent importance of tutors' subject-matter expertise for the success of problem-based learning (Schmidt et al. 1993; Dolmans et al. 2002; for a complication, see Gilkison 2004). Attempting to inculcate such generalized skills thus risks isolating problem-based learning from the 'shared world' in which we exist as human beings (Noordegraaf-Eelens et al., 2019) and reduces education to a generic procedure designed to facilitate the development of equally generic and decontextualized skills.

A second way in which education can be instrumentalized is through the imposition of certain predetermined values which we then understand simply as needing to be inculcated in those who are to be educated. Paolo Freire refers to this as a form of sectarianism which potentially threatens both conservative and progressive forms of education (Freire 2000, 38). Hannah Arendt expresses a similar worry that "to prepare a new generation for a new world" determined in advance "can only mean that one wishes to strike from the newcomers' hands their own chance at the new" (Arendt 1969, 177; see Noordegraaf-Eelens & Kloeg 2020). This worry attaches itself in particular to forms of problem-based learning that attach problem-based learning to the development of substantial citizenship competencies (e.g. McInerney & Adshead 2013; Moraes et al. 2010) and in general where substantial values are held to be the goal of problem-based learning. This is where we can resist the imposition of pre-established ethical or political normativities and insist on a properly educational normativity, where the norm is generated by the practice of education itself (Biesta 2015b). This idea is bolstered by the hermeneutic approach from philosophy, to which I will return later.

Instrumentalization can also occur in reference to the tasks of education. According to Gert Biesta, the tasks of education are insertion into given social or professional communities, which he respectively calls socialization and qualification (Biesta 2012, 13). While both tasks are valuable, education cannot be limited to them without becoming a form of 'training'. In addition, education is but also about how one positions itself in relation to this community as a whole, potentially also 'outside' of it, which Biesta calls subjectification (Biesta 2012, 13). Training in this sense is clearly a form of instrumental use of education in the sense that the goals of the social and/or professional community are presupposed by and imposed on education, so that the only conceivable function of

education is to instill or express said goals. The goals can be understood in descriptive or in normative terms: in most cases, the goals relied upon explicitly or implicitly are best understood as descriptive/normative hybrids (see Van den Akker & Kloeg 2020, 68). This is true for 'educational outcomes' (Biesta 2017) such as employability, contribution to economic growth, and formal citizenship. Problem-based learning is under threat whenever it is assimilated to such outcomes.

Based on this analysis, instrumentalization of education occurs in the interrelated but analytically distinct guises of the inculcation of generic skills, the imposition of predetermined values, and the reduction of the tasks of education to insertion into given social or professional communities. From a more general perspective this casts education in the role of a means to an independently defined end. For problem-based learning and its place in the scientific study of education, this would mean that both the scope of research and the indication of success in practice are incentivized to focus on technical questions about the efficient attainment of learning outcomes. This is not only a natural phenomenon within the context of an educational culture of measurement (Biesta 2015a) but also means that problem-based learning potentially reinforces and strengthens said culture (Noordegraaf-Eelens et al., 2019). The reverse side of this phenomenon is that questions about the nature and tasks of education, as well as the potential reasons for education to critically relate to its independently defined ends as defined in other domains tend to go missing. The information-processing model of problem-based learning exemplifies these tendencies, with the paradigm of information-processing taken from computer sciences (Newell & Simon 1972; see Servant 2018). This model of education was an important part of the history of problem-based learning in McMasters University. Though it is no longer practiced there (Neville & Norman 2007), it remains an influential approach to problem-based learning globally (Schmidt et al. 2009). While the shortcomings of the information-processing model of problem-based learning do not directly affect the alternative Maastricht or Danish models, the pervasive influence of information-processing in the practice of problem-based learning is itself a reason for investigating how problem-based learning is situated with respect to the nature and tasks of education.

With regard to the scientific approach to problem-based learning, this discussion cannot be engaged exclusively from the perspective of the behavioral sciences, which focus on behavior and observable learning outcomes rather than meaningful action (Biesta 2015b, 665). The link between basic and applied cognitive and behavioral science and the practice of education has been assumed by much educational research, while at the same time this very link is increasingly coming under critical scrutiny (Perry et al. 2021). For these reasons I here favor involving the humanities, in the form of a hermeneutic approach to education in the nineteenth-century tradition of Wilhelm Dilthey and Friedrich

Schleiermacher. The more specific hermeneutic approach I argue for is derived from the philosophical-anthropological work of Helmuth Plessner. Plessner's philosophical anthropology avoids reductionism and instrumentalism (Kloeg 2020, Fischer 2014, De Mul 2014), while his use of Dilthey's theme of the open question offers a promising interpretation of the nature and function of the problem in problem-based learning. In the next section I expand on Dilthey's understanding of the humanities and Plessner's development of Dilthey in terms of the open question. I then develop the educational insights that follow from this philosophical-anthropological view of problem-based learning and begin to consider a number of practical implications.

2: FROM DILTHEY'S HUMAN SCIENCES TO PLESSNER'S OPEN QUESTION

The hermeneutic approach to education

The proposed hermeneutical approach to education (and, granting that, to problem-based learning) builds on an understanding of the human sciences vis-à-vis the natural sciences that was first introduced by Wilhelm Dilthey. Dilthey sought to expand the Kantian paradigm of transcendental philosophy with historical experience in his project *The Critique of Historical Reason*, recalling Kant's *Critique of Pure Reason*. Transcendental philosophy (not to be confused with 'transcendent') here refers to asking for the conditions of the possibility of experience rather than straightforwardly assuming a positive relationship between the human faculty of reason and the external world as it exists in itself. Kant finds these conditions for the possibility of experience in *a priori* (that is, given in but prior to experience) forms of apperception, categories of understanding and ideas of reason (Kant 1974). Dilthey's approves of this approach and seeks to further it. Kant thought that he had arrived at a system of conditions for the possibility of experience that would be logically consistent and universally valid. These were thought-structures that were true of human existence as such, without reference to specific times or places. This is thus also finally the sense in which we can interpret Kant's assertion, in the final years of his life, that the fundamental question underlying his critical-philosophical project was: what is mankind? (Kant 1992, 538). In the generations directly following Kant, a myriad of thinkers attempted to continue or transform his thought. An important step was taken by G.W.F. Hegel, who moved away from Kant's understanding of reason as a static ability of human beings and general and proposed that reason instead develop itself throughout history. The corollary of this view was that the course of history itself was a reasonable process.

Dilthey connects Kant and history in a different way: he notes the contrast between historical sense and the experience of multiplicity on the one hand, and the "appeal of philosophers to universal validity" on the other hand (Marquard 1973, 108). Dilthey's

approach is not to impose a direction or logic onto history, but to start from the approach that "only history shows what mankind is" [*Was der Mensch sei, sagt nur die Geschichte*] (ibid, 117; Dilthey 1914-2005, IV, 529). Thus, the logically consistent and universally valid *a priori* constructions deduced by Kant are themselves the product of historical influences. This is what Dilthey calls the "historical *a priori*" (De Mul 2014, 140). Seen from this perspective, Kant's own philosophy appears as a valuable and decisive innovation, since it broached the realm of transcendental questions; but at the same time, it appears as a limited exercise since only a limited notion of experience is considered. The notion of experience in Kant is mechanistic (Schelling 2004; Benjamin 1961) and suited mostly to the natural sciences, which are amenable to the purely causal mode of explanation Dilthey calls *erklären*. In Dilthey's view, not every domain of human life allowed for this kind of explanation. In order to understand human existence in full, interpretative understanding or what Dilthey calls *verstehen* is required. This is the original formulation of what distinguishes the natural sciences (*Naturwissenschaften*) from the human sciences (*Geisteswissenschaften*). We need to move beyond Kant and his 'lifeless, bloodless' categories of the understanding: accomplishing a synthesis of human existence as knowing, feeling and thinking would be Dilthey's ultimately unfinished life work.

This notion of *verstehen* is what is involved with the hermeneutical approach to education, with hermeneutics being defined as the science of interpretation and reflections on the nature of interpretation and *verstehen* in Dilthey's sense as interpretive understanding. Already in his own work, Dilthey responds to a tendency to approach education with the tools of the natural sciences. Dilthey argued instead for the importance of cultural and historical factors in describing educational phenomena, so that the *Wissenschaft* of education – the study or science, in the broadest sense, of education – had to be a *Geisteswissenschaft* making use of historical and hermeneutical methods (Biesta 2015b, 669). This meant that Dilthey's understanding of a scientific mode of education was not premised on deriving through scientific or normative-philosophical means a predetermined goal for education to aim at or to further, as it were taking extra-educational givens as the ultimate end of education and thus adopting an outside-in approach to education itself. Rather, Dilthey's approach aimed to "clarify (proto)theoretical insights and understandings that (…) are always already at play in educational processes and practices" (ibid, 670). Dilthey's approach was rooted in the thought of the earlier hermeneutic thinker Schleiermacher, who likewise sees educational reality as primary with respect to educational theory and who argues that this practice contains "forces of social power" and "theoretical assumptions" but also a "dignity" that is not instilled by theory, but is already present in the practice of education (Wulf 2015, 20; Wulf 2003, 277; Schleiermacher 1983, 10-11). Thus, the practice of education itself is generative of its principles, so that we might call this an inside-out approach to

education. While Dilthey's is far from the only approach to hermeneutics (see De Mul 2004, 4), this emphasis on the dignity of education as a practice is suitable for the practical nature of problem-based learning and connects directly to Plessner's notion of the open question.

The open question and *metabasis*

The work of Helmuth Plessner, which is my main focus in this contribution, provides a further stage of this development. This could be traced along multiple paths, focusing for instance on discussions in the philosophy of nature or as a further step in transcendental philosophy, both of which are valid and indeed important approaches. An important unifying factor in these possible approaches is the non-reductive nature of Plessner's work. Notably, philosophical anthropology as such is not beholden to any scientific discipline or form of reduction. Plessner understands his work as an engagement of the human question which should be understood as a historical necessity after the onset of the human sciences, in particular the onset of biology, psychology, history, and sociology (Plessner 2019b, 32–35). These sciences offer a picture of reality, and specifically the reality of the human, as a "multiplicity" (ibid, 30) and it is important to take the different aspects of human existence disclosed by these various approaches into consideration. Equally important is the independence of the position philosophical anthropology itself takes on with respect to the sciences. The way philosophical anthropology references the human sciences should thus be understood in terms of a principled ambiguity: the human question is revealed in many news ways by the human sciences, but the latter do not exhaust the former (see also Dietze 2006, 61). As Plessner clarifies in his recently published lecture series on philosophical anthropology (Plessner 2019b; see Kloeg 2019) this means that the specific contribution of philosophical anthropology begins by engaging in "epistemological and methodological questioning" of the scientific mode of proceeding as well as the understanding of human existence that makes this mode of proceeding possible in the first place (Plessner 2019b, 35). We then find that the question into the specifically human aspect of human existence cannot be resolved in terms of the natural or human sciences themselves. In Plessner's example, the evolutionary biologist invokes a specific conception of the specifically human when reflecting on the emergence of the human species in evolution. For instance, when can we say that a specifically human use of language has emerged? (ibid, 37) In this sense the human sciences 'point beyond themselves', in a shift towards a dimension Plessner calls "*metabasis*" (ibid)[1], which I understand as both present within the human sciences in that a specific interpretation of this further dimension is always presupposed, but at the same time outside of the human sciences. It is on the level of the *metabasis* that we have to answer a set of questions that are raised in a specific way by the human sciences precisely because answers to them are built into their respective modes of proceeding.

I want to pick up the trail starting from Plessner's invocation of Dilthey in his important but frequently overlooked 1931 work *Political Anthropology* (Plessner 2018). This work builds on Plessner's *magnum opus* from 1928, *The Levels of the Organic and Mankind* (Plessner 2019a), which sought to map out ideal types for the different forms of life – plant, animal and human life – in order to provide a *metabasis* with respect to our understanding of life. These categories of life are for Plessner the "material *a* priori" (GS IV, 172; De Mul 2018) – his corollary to Dilthey's historical *a priori*, introduced above). Plessner arrives at his notion of excentric positionality as a description of human existence, which is a principled ambiguity that sees the human being both as the center of their lived experience (centric) and as outside of this center and at a reflective distance from it (ex-centric) (Plessner 2019a, 271). One of the implications of the excentric positionality of the human lifeform is that it "continues to push for ever new realizations, and in this way leaves behind a history" (ibid, 314). With this emphasis on the historicity of human beings, Plessner joins Dilthey in arguing that only history can teach what man is. Already for Dilthey, this was one of the reasons why 'human nature' remains inexhaustible [*unerschöpflich*] and "unfathomable [*unergründlich*], yet accessible to the poet, the prophet, the religious man, the historian" (Dilthey 1914-2005, XIX, 329, Dilthey 1989, 489).

In *Political Anthropology*, Plessner proceeds from Dilthey's methodological continuation of Kant's critical project with the inclusion of historical experience (GS V, 173, 175, see De Mul 2004). This then discloses a specific difference between human sciences or humanities [*Geisteswissenschaften*], such as history, and the natural-empirical sciences (Plessner 2018, 180). The human sciences cannot "freely have its objects at their own disposal", and their lack of a specific location in time or space entail the "immeasurability" of their nature (ibid, 181). In other words, the objects of investigation within the human sciences are unfathomable [*unergründlich*] as a matter of principle, and the questions of the human sciences are open questions (ibid). To broach the unfathomable and to commit to it was Dilthey's successful "counterpart to Kant's accomplishment", according to Plessner (ibid, 184). This very commitment to the unfathomable [*Verbindlichkeit des Unergründlichen*] is what continually constitutes the ever-incomplete intellectual world through the thinking and acting of human beings (ibid, 182). Because of this unfathomability, the anthropological 'Quest for the human being' is inevitably an open question, which can never arrive at a fixed answer, neither empirically nor *a priori*:

> It must remain open, for the sake of the universality of its view onto human life in the full scope of all cultures and epochs of which the human is capable. This is why the unfathomability [*Unergründlichkeit*] of the human moves to the center of anthropology, and the possibility of being-human that contains what makes the

human a human in the first place, that human radical, must yield to the standard of unfathomability (GS V, 160-1/Plessner 2018, 26).

Plessner's is a fruitful perspective from which to understand what problem-based learning contributes to the practice of education. Because education is not purely about behavior but at least always also about meaningful human action, a behavioral science of education is possible and in some senses necessary, but when it is cast in the role of the only viable scientific understanding of education risks answering the 'human question' in too definitive a way, which as I offered in the first section takes for granted the nature and ultimate ends of education. In a way such a purely behavioral understanding of education repeats the positivist paradigm to which Dilthey was already responding: the application of methods from the natural sciences to the study of education. With the benefit of hindsight, we can now add that such methods have an important role to play in understanding education (Wulf 2015, 19). At the same time Dilthey's cautions against making it the sole key to understanding still hold true. The more normatively focused alternatives, which for instance see education as an instrument to inculcate a specific set of values, perform the same reduction of education but from a different domain (for instance, normative political philosophy). In this context I also note that Plessner's overall goal in *Macht und menschliche Natur* is to contribute to "civic education and political theory through the indirect, remote route of philosophy" (Plessner 2018, 6) and in general to show the worthiness of politics and properly political drives as part of an intervention in Weimar culture, providing an alternative to its main theoretical modes of idealism and cynicism (Fischer 2018, 108–109). Plessner's work in general has been understood as aiming towards an "education into reality" [*Erziehung zur Wirklichkeit*] (Dietze 2022; Dietze 2011).

With Plessner we find a means to describe the historicity of human existence as such, summarizing the latter as an 'open question' that is always impressing itself upon us as human beings, but which at the same time cannot be answered definitively. I propose to extend this theme of the open question to a hermeneutical understanding of problem-based learning: it is through a process of asking and answering, which introduces collective and situated life horizons of familiarity and strangeness within which we define ourselves, that we leave behind a history in the first place. This emphasizes the fact that education necessarily takes places within a social and historical context, that knowledge is constructed as a response to this context, and that this back-and-forth of the open question takes place at a level that results from reflecting both on questions of natural and human sciences, namely on the level that Plessner calls *metabasis*. In the final section of this paper I develop a number of educational insights as principles for problem-based learning in connection with the hermeneutical understanding that I have introduced thus far.

3: IMPLICATIONS FOR THE THEORY AND PRACTICE OF PROBLEM-BASED LEARNING

If asking and answering is part of human existence, we can only expect it to be a part of education as well. In that sense, the problem as it figures in problem-based learning appears to be a readymade complement. This should not be taken at face value however, as the specific interpretation of this linkage will have significant consequences for the way problem-based learning is implemented. In this section, I want to reflect on several insights that on my view follow from the hermeneutical approach to education and, more specifically, the philosophical-anthropological view on education as connected to Plessner's theme of the open question. I intend these insights as principles that can elucidate and serve to further inform the theory and practice of problem-based learning. In what follows I discuss six such principles: (1) the breakthrough of immanence and the onset of subjectification, next to qualification and socialization; (2) an informed response to problems which are so a certain extent 'wicked' in that they cannot be definitively solved; (3) constructing knowledge and experience that is in some sense new, reflecting the novel contribution of those involved; (4) a sustained reflection on situatedness and historicity, also in terms of the world we share and in which we are irrevocably situated; and (5) allowing the future to remain open, such that it is not predetermined by the past or foreclosed through our very practice of education. I elaborate on each of these briefly below.

The most immediate question that has to be posed in order to achieve these principles is: how should we understand the relationship between the problems of problem-based learning and the theme of the open question? The open question in Plessner has two features: first, the necessity of asking, which means that there is no obvious answer from the initial situation of the student and that some judgment is in order as to what is relevant, what constitutes relevant prior knowledge and what remains unknown and has to be studied further. This highlights the moment at which the students themselves are asked to participate in their own learning process, as is well-known in the literature on problem-based learning. However, at the same time students are asked to assume the position of subject, in the sense that they are themselves asked to position themselves with respect to the problem at hand and also in the sense that they have to reflect. Students decide which of the things they treat as knowledge in everyday life qualify as knowledge relevant to the problem; whether what they in fact desire is really desirable, that is, something that is worth desiring and that they should desire. This reflects what Biesta has called the breakthrough of immanence, which calls the subject into being (Biesta 2008). This is our first principle: subjectification belongs intrinsically to problem-based learning.

A second feature of Plessner's open question is the necessity of providing a response to the problem at hand, which yet remains open-ended, so that further questions can still be

asked and further analysis performed. An implication of this view is that problem-based learning is not or at least not primarily a means to problem-*solving* in the sense of providing definitive solutions to stated problems which then entail that the problems at hand lose their status as problems: they are no longer 'problematic' now that they have been solved. While this may be controversial for some practitioners of problem-based learning who have a technical approach to questions and for whom the desired learning outcomes of a problem are mostly factual or technical in nature, the element of judgment can never be absent from problem-based learning or from education more widely without it ceasing to be education. As soon as that is the case, education becomes more akin to training, which lacks Biesta's element of subjectification entirely, or, worse, indoctrination (Biesta 2015b, 674), which can be understood as an extreme version of instrumentalized education. To provide some examples: charts of human anatomy, while requiring a lot of factual knowledge on the part of the students, connect to discussions about how bodies that deviate from the typically male and Western standard figure in medicine, or the so-called Reference Man. Models in neoclassical micro-economics, while requiring a lot of calculation on the part of students, connect to discussions about the history of economic science, the performativity of economic models (Callon 2010), and how such models are today contested in view of the in-built assumptions about, for instance, ecological stability (Keen 2021).

Taken together, these twin aspects of problems that require an answer on the one hand, with every answer provided needing to be open-ended on the other hand, support and clarify another idea that has often been advanced in the literature on problem-based learning, namely that problem-based learning is suitable to address so-called wicked problems (Thomassen & Stenhoft 2020; Murgratroyd 2010): not in order to solve them, but in order to find a way to address them that does not reduce to finding determinate solutions to 'issues' that can be defined in a straightforward manner. As we have considered, Plessner's notion of the *metabasis* involves all relevant disciplines in their interconnection in the production of knowledge. This reflects our second principle: problem-based learning should not aim to solve but to respond.

This in turn means that what happens in problem-based learning is not just the recirculation of readymade information. What is aimed at is the construction of new knowledge, or knowledge that is newly combined, that allows for a new perspective on the problem at hand or involves new perspectives, if only the particular experiences of the students involved, on how that problem is expressed. That gives us further means to express the theme of the open question in the practice of problem-based learning: what is at stake is the renewal of who we are, what we know and the world we inhabit. Hannah Arendt expressed this by saying that "the essence of education is natality" (Arendt 1961, 174): that is to say: education concerns what each one of those involved can contribute to

the situation at hand that is *novel*. This is our third principle: problem-based learning constructs new knowledge or experience. It comes with a twin requirement: to allow the contribution of the students (as 'newcomers', in Arendt's parlance) to be expressed without preempting it, while also ensuring that what is new remains connected to the existing world. Delving more deeply into this is beyond the scope of this contribution, but Arendt's work on education offers specific if also at points controversial suggestions on how to thread this line (Kloeg 2022).

One requirement that stems from the connection between education and world is that education indeed always takes place in a particular historical episode. If there is, following Plessner, no definitive answer to questions concerning human existence but that different answers follow each other over the course of time, then it matters a lot when and where problem-based learning is taking place. This can be called in a general vein the importance of situatedness. At the same time, this is not a backward-looking concern in which we strive to reconstruct from a supposedly neutral position the historical factors that lead to a specific situation. In another image by Arendt, we should guide students to become pearl-divers diving into the oceans of the past (Arendt 1970; Baluch, 2020; Korsgaard, 2019). The point of the pearl-diving metaphor is that remnants of the past have been 'sea-changed' into 'pearls and corals' that the pearl-diver brings to the surface (Arendt, 1970, 206). Students who are educated as pearl-divers can find the crystallised forms—'those ideas and values that, though they have undergone change, have survived in a different form and can be used to interrupt, critique, and transform the present' (Gordon, 1999, 170). The old thoughts, when brought to the surface, are not directly relevant 'as old thoughts' but now carry 'the "deadly impact" of new thoughts (…)' (Arendt, 1970, 201). Compared to Dilthey's mostly reconstructive hermeneutics, this is a more constructive exercise that seeks to adapt existing knowledge and experience to new purposes (De Mul 2014, 4). This shows how our fourth principle, that problem-based learning should respond from within a certain historical context and incorporate that fact into its practice, is of one kind with the third principle of constructing new knowledge and experience. Both positively require each other.

In a further development of this thought, we can add that situatedness is also important in the sense of what Arendt calls worldliness: that is, rootedness in a situation which is the combination of a wide diversity of perspectives, the multiplicity of which finally makes up what we call the world: namely the world of shared meanings, institutions and concepts (Vlieghe & Swillens 2020). This resonates with the third core principle of problem-based learning as it was originally formulated – a community-oriented attitude to ensure a link to larger society (Servant 2016) – and seeks to not only affirm this principle but to extend its scope to the world as such (Noordegraaf-Eelens et al. 2019). This introduces a new set of questions to the theory and practice of problem-based

learning: for instance how it should relate to both local communities and the world at large (including the material earth), how educational success should be conceptualized, and also concerning, for instance, the importance of involving societal partners (Jiusto et al. 2013; Wieck et al. 2014). Asking and responding to such questions is part of the practice of problem-based learning.

The theme of the open question not only has implications for how we relate to the past, but also for how we relate to the future. If we allow old ideas to enter with the force of the new, we at the same time enable a future that is more than a simple continuation of the past. This is a relatively hopeful message that brings home not only that a lot is at stake for and in education today, but also that it is precisely within education that we can strive to renew the world (without, for that, seeking to predetermine or foreclose the future). This is our fifth and final principle: problem-based learning should be practiced with an eye to the future, which can never be determined in advance and should remain open.

As a hermeneutical approach to problem-based learning, the theme of the open question thus contains a number of important principles that can elucidate and serve to further inform the practice of problem-based learning: the essential role of subjectification, next to qualification and socialization; responding to 'wicked' problems rather than claiming to definitively solve them; constructing knowledge and experience that reflects the novel contribution of those involved; situatedness and historicity as essential components, also in terms of the world we share and in which we are irrevocably situated; and, finally, allowing the future to remain open, such that it is not predetermined by the past or foreclosed through educational practice itself. Education is in this sense an art of plural possibilities (Noordegraaf-Eelens & Kloeg 2020, 556). Philosophical anthropology, which informs Plessner's open question, can only serve these ends if we allow for a "pluralization" of anthropological knowledge, since otherwise we would be imposing a specific and fixed 'image of man' on educational processes – this centrally includes an openness to cultural diversity (Bollnow 1965; Wulf 2015, 11-13). It also important to emphasize once more that while I take this hermeneutical approach to be important to providing an interpretive understanding (in Dilthey's sense of *verstehen*) of education that is able to address the worry of instrumentalization, quantitative and behavioral research remains an important part of educational research; *verstehen* and *erklären* should speak to each other more and should be brought into contact with each other by those in the field of education (Wulf 2015, 19).

CONCLUSION

Problem-based learning is not quite in its young years anymore: as an innovative approach to education, it stands to reason that it should continue to develop in response to our ever-changing world and the challenges that come with it. This goes in particular for the founding principle of community-orientation, which is not clear in terms of what it requires of problem-based learning. The scientific literature mostly approaches problem-based learning from a behavorial-scientific approach, which comes with the specific risk of instrumentalizing education to attain generic skills, impose predetermined values, and to reduce the task of education to insertion into given social or professional communities. In response I have contributed to a hermeneutic approach to education, following Wilhelm Dilthey's example. In particular, I have used the theme of the open question from Helmuth Plessner's continuation of Dilthey, which in Plessner becomes a way to understand human existence as such, as a hermeneutical interpretation and clarification of problem-based learning. This approach brings into view several important principles that are relevant to the practice of problem-based learning. These include the importance of subjectification, the open-endedness of responses to (wicked) problems, the construction of new knowledge and experience, our relationship to local communities and the world at large, and the openness of the future. Plessner's approach also has the advantage of operating at the level of what he calls *metabasis*, which relates to both natural sciences and human sciences or humanities.

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[1] Plessner uses this term affirmatively in his lectures, which is notable as it derives from a phrase by Aristotle (*Metábasis eis állo génos*) which denotes an unjustified jump to another logical domain. Plessner himself had used the phrase in that meaning previously: see e.g. Plessner 2019a, 69.

Integrating the Integration:
The Role and Challenges of Problem-Based Learning in Bringing Together Social Science and Humanities (SSH) and Science, Technology, Engineering and Mathematics (STEM)

Antonia Scholkmann, Nikolaj Stegeager, Richard K. Miller *

ABSTRACT

This paper provides a conceptual elaboration of the role of Problem-based Learning (PBL) in the integration of social sciences and humanities (SSH) with science, technology, engineering, and mathematics (STEM), and an analysis of the challenges this brings about. SSH-STEM integration is an endeavor that is timely, relevant, and urgent given the insufficient answers that higher education provides to the challenges social science and (especially) humanity faces. PBL can be argued as a pedagogical model to naturally cater to this demand. Based on two cases of integrated study programs from Aalborg University, Denmark, we analyze and discuss challenges and potential pitfalls in integrating SSH and STEM. As a result, we pinpoint learnings that can serve as timely guides in future iterations of problem-based, inter- and transdisciplinary endeavors in higher education.

Keywords: Interdisciplinarity, Academic integration, Problem-based learning

INTRODUCTION

It is probably true quite generally that in the history of human thinking, the most fruitful developments frequently take place at those points where two different lines of thought meet.

<div align="right">Werner Heisenberg</div>

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*   Antonia Scholkmann, Department of Culture and Learning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
       Email: ansc@ikl.aau.dk
       Nikolaj Stegeager, Department of Culture and Learning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
       Email: nikolaj@ikl.aau.dk
       Richard K. Miller, Olin College of Engineering, United States
       Email: richard.miller@olin.edu

Over the last decade we have witnessed increased interest in breaking down the barriers between academic disciplines within higher education as part of inter- and transdisciplinary approaches to teaching and learning (Borrego & Newswander, 2010; Grant & Patterson, 2016; Pohl, 2011). Especially integrating social sciences and humanities (SSH) with science, technology, engineering and mathematics (STEM) programs has attracted interest from academic mangers, businesses and professional educators. In this respect, we have seen an increase in (case) studies that seek to investigate the dynamics, effects and value of such an integration, even though research in this area is still quite limited and suffering from methodological limitations (Committee on Integrating Higher Education in the Arts, Humanities, Sciences, Engineering, and Medicine et al., 2018).

Not least in the wake of disruptive change the COVID-19 pandemic triggered and the increased awareness of the massive and extremely complex challenges that our collective society faces, voices have been raised that SHH perspectives should play a vital part in teaching *any* subject or study program in order to prepare students to act upon the burning questions of the 21st century (Morgan Jones et al., 2020; Walker, 2009). However, it must be noted that there is a tendency to argue for SSH integration into STEM with what can be called an "add-on" perspective, i.e., adding "soft" competences to an overall "hard" curriculum. These include critical thinking, communications skills, the ability to work well in teams, content mastery, improved visuospatial skills, and improved motivation and enjoyment of learning (Committee on Integrating Higher Education in the Arts, Humanities, Sciences, Engineering, and Medicine et al., 2018). In contrast, problem-based learning (PBL), especially in its project-based form, has long been argued to be a pedagogical model deeply ingrained with the integration of different disciplinary approaches; PBL is considered to have the potential to re-think especially STEM subjects in totally new perspectives (e.g., Miller, 2021).

Problem-based Learning (PBL), specifically in its project-oriented version (Kolmos et al., 2019), can play a specific role in SSH-STEM integration beyond a competence-oriented add-on perspective. This can be attributed to PBL's historical and conceptual entanglement with a critique of disciplinary thinking. However, also at universities and in programs practicing PBL, iterations of SSH-STEM integration have not been naturally successful in the past. Based on theory of organizational change and the role of disciplines in higher education it can be asked under which conditions PBL's inherent quality of transcending disciplinary boundaries will unfold, and what can be done to allow this approach to unfold its potential in this respect.

To shed light on these questions, this paper analyzes two cases of study programs from Aalborg University, Denmark (AAU), which sought to integrate SSH and STEM a while go, although to various degrees of success. AAU has a long tradition of PBL and has thus

always prided itself as an institution that values interdisciplinarity (Jensen, Stentoft, et al., 2019). When founded in 1974, the original idea was that groups of students should work together on authentic, societal problems across academic fields and disciplines. This Danish interpretation of the PBL idea was broadly based on John Dewey's theory of experiential learning (Dewey, 1938) and Oscar Negt's work on adult education and the development of a new European concept of solidarity (Negt & Kluge, 1990/1973). Over the years, AAU, like most other European entrepreneurial universities founded in the 1960s and 1970s, has gradually transformed its PBL practice to resemble teaching at more traditional (and powerful) universities (Collini, 2012). This has in part led to an abandonment of the idea of radical interdisciplinarity in favor of more discipline-oriented project work. However, coinciding with a general increase of interest in interdisciplinary teaching in the educational sector, Aalborg University has begun experimenting with new approaches toward the integration of academic disciplines in the educational programs. However, the university has had somewhat limited success in terms of sustainability and longevity of the respective programs.

In this paper we will explore the potentialities of empowering SSH-STEM integration in educational programs through a PBL-model. As a foundation for this, we initially discuss SSH-STEM integration in light of the well-elaborated concept of interdisciplinarity, and conceptualize the specific role of PBL for transgressing disciplinary boundaries. We will then illustrate potentialities and challenges regarding interdisciplinary integration by analyzing two recent cases from Aalborg University. This analysis will be based on publicly accessible material and studies and in this sense takes a synthesizing qualitative meta-analytical approach. In our final discussion we will elaborate how learnings from the two cases can be used as foundations for the design of new and more integrated pedagogical SSH-STEM approaches based on PBL principles. With this, we are seeking to answer the following question:

> *What are the potentialities and challenges for PBL-based interdisciplinary integration, based on an analysis of two cases from Aalborg University, and what conclusions can be drawn for future SSH-STEM integration at a PBL university?*

CONCEPTUAL UNDERPINNINGS

Academic disciplines and the call for interdisciplinarity

It is almost a banality to state that the academic world and hence also higher education pedagogies are heavily rooted in academic disciplines as categories of social order (for an elaboration, cf. e.g., Chettiparamb, 2007). Turner (2000, after Chettipramb 2007), tying disciplines to the profession and professional work, defines disciplines as:

(…) collectivities that include a large proportion of persons holding degrees with the same differentiating specialization name, which are organized in part into degree-granting units that in part give degree-granting positions and powers to persons holding these degrees. (p.47).

Others argue that disciplines should be distinguished by the specific area of knowledge that they define, and be understood as "thought domains – quasi-stable, partially integrated, semi-autonomous intellectual conveniences – consisting of problems, theories, and methods of investigation" (Aram, 2004: 380). Both definitions state that academic disciplines are characterized by distinctive traits that render it possible to distinguish them from one another based on their specific practices and paradigms. Furthermore, the academic disciplines hold the capacity to distinguish and attract privileges. In this regard, disciplines are institutions of power and resources, and members of a specific discipline will often go to great length to protect the privileges and opportunities that belong to a certain discipline (Sarangapani, 2011). Such protectionary measures entail the use of a highly coded language that is non-accessible to outsiders, and scientific explanations of world phenomena that almost always rest on answers based on internal logic from within the discipline (cf. Fleck, 1980; Kuhn, 2012).

In opposition to the tendencies of academic disciplines to differentiate and distinguish, the programmatic call for interdisciplinarity has been heard frequently over at least the last 50 years, and in various iterations – often prioritizing the enactment of the concept in teaching over its enactment in research. In 1972, the OECD published the seminal report "Interdisciplinarity: Problems of Teaching and Research in Universities" (OECD, 1972), in which the authors, based on their extensive review of literature and practices in higher education, advocated for a more adventurous approach to interdisciplinary practice at universities. According to the authors, an interdisciplinary approach would increase innovation at the universities, reduce the gap between professional practice and university training and reduce the social costs of overspecialization.

Definitions and dimensions of interdisciplinarity and academic integration
Already in their 1972 report, the OECD distinguished between more loosely coupled and more interwoven forms of interdisciplinarity. Based on the OECD's (1972) original typology, Klein (2017) proposes using the terms *multidisciplinarity, interdisciplinarity* and *transdisciplinarity*. M*ultidisciplinarity* typically means that various disciplines contribute based on their specific paradigms to answer to a common problem, either at the same time or by sequentially applying ideas from multiple disciplines to the focal problem. A more binding way of collaborating is through *interdisciplinary* approaches in which scholars work jointly, albeit from each specific disciplinary stance to work on a common problem. The third mode of operating, *transdisciplinary* approaches, require

> (…) not only the integration of discipline-specific approaches, but also the extension of these approaches to generate fundamentally new conceptual frameworks, hypotheses, theories, models, and methodological applications that transcend their disciplinary origins, with the aim of accelerating innovation and advances in scientific knowledge. (Hall et al., 2012, p. 416)

Though by far not the only attempt to distinguish between different forms of interdisciplinarity, this tripartite taxonomy seems to be the most widely used. Other differentiations make distinctions based, for example, on whether representatives of different disciplines work together *parallelly at the* same time or *sequentially* after one another (Begg & Vaughan, 2011); if the collaboration is *punctual* or *permanent*; and what the *focus* of the collaboration is (Klein, 2017). In terms of the more recent term 'integration', it can be said that integration linguistically has been understood as "the process of combining two or more things into one" (Cambridge Dictionary, n.d.), with a specification that "integration across s.th." can entail also a "reduction of differences" (ibd.). A more scientific point has been provided by The Subcommittee on Interdisciplinary Teaching at Emory University, in which *pedagogical integration* is defined as:

> (1) the enrichment of one discipline by use of the language, methods, or canons of one or more other disciplines; or (2) the common inquiry into universal themes, such as health, justice, or violence, using the language, methods, and canons of two or more disciplines. (after Chettiparamb, 2007, pp. 31)

As inferred from these elaborations, (academic) integration can be understood as synonymous with interdisciplinarity, which we will therefore use from here on as the dominant wording.

Integration of various disciplinary approaches into teaching has been suggested to take place under various contingencies, such as the *level of implementation* (course or program), whether students come from *one or different academic programs*, how *far apart their specializations* are, how *long the pedagogical activity is scheduled to last* and if this activity is *part of the general curriculum or scheduled as an extra-curricular activity* (Ashby & Exter, 2019). Additionally, Jensen et al. (2019) have pointed out that the enactment of interdisciplinary approaches in higher education can be operationalized either so that various disciplinary approaches are *represented through different participants*, such as students from different academic programs; or so that the various disciplinary approaches are *represented through the provision of learning content,* which is selected under an interdisciplinary focus.

Problem-based Learning (PBL) as a "natural blueprint" for academic integration across the disciplines

As Klein (2017) points out, already in the initial OECD (1972) report, interdisciplinarity and academic integration were thought of as arising when knowledge creation is conceptualized in relation to working on real-world problems. It is precisely in this focus that the Aalborg PBL model in particular provides an almost "natural" blueprint to bringing this intention to life.

The Aalborg PBL model is just one of several variations of the problem-based learning approach (Scholkmann, 2020) and, together with Roskilde University, the AAU-model represents a Danish interpretation which, in its original form, was very much about modelling a democratic process (Milner & Scholkmann, forthcoming). Concretely, in the Aalborg PBL model students work in groups on a self-defined problem, often over the course of an entire semester. They "own" both the problem and the process and work with an academic facilitator. Their learning process is supported by more traditional forms of learning, such as attending lectures, workshops and seminars and self-study. The dominant form of assessment is a written project report that is defended orally in front of internal and external assessors (cf. e.g., Kolmos et al., 2004).

Considering the roots of PBL in the Deweyan notion of learning through engagement with authentic problems, the circularity of the process and the societal relevance attributed to learning outcomes, it becomes quite obvious that the problems addressed here lean towards interdisciplinarity (Thomassen & Stentoft, 2020). Also, gaining experience in collaborating in groups for the sake of learning can be considered a nucleus for exchange of thoughts about and across boundaries (personal, conceptual, disciplinary) that can be instrumental also in interdisciplinary project work (Jensen, Ravn, et al., 2019). Related to this, Ravn (2019) has pointed out that interdisciplinary project work is not about establishing the one right answer to a problem (in the positivistic sense). Instead, it must be considered as an ongoing establishment of a joint language:

> (…) Thus, interdisciplinary project work can be interpreted as a production of knowledge that is unique to a very specific and contextualized problem formulation [*i.e., a research question – annotation by the authors*], which means that it could be the only scientific approach with exactly this particular setup. (Ravn, 2019, p. 67).

In this sense, each PBL group process can be understood as the formation of a new community in which knowledge is constructed and reconstructed to fit the very specific and contingent project. Creatively expressed, each PBL group forms their own academic discipline, thus providing, in a nutshell, a call to understand disciplinarity as a human invention whose current form emerged contingent on somewhat arbitrary circumstances

(Collini, 2012). In this regard, PBL values the often-mentioned belief that breakthroughs in research more frequently occur at the boundaries of disciplines (e.g., Chettiparamb, 2007; Gibbons et al., 2015; Nowotny et al., 2003). Hence, parsing problems into a particular academic disciplinary framework, we simultaneously take them out of context and create limitations in the ability to see connections and approaches for solutions (cf. also Klein, 2021).

Interdisciplinarity: potentialities and challenges
Arguments for interdisciplinarity both in research and teaching have been predominantly based on normative and pragmatic demands (cf. Chettipramb 2007 for further elaborations). Empirical evidence on the learning outcomes of concrete integration of specifically SSH topics and methodology with STEM subjects is scarce and mostly inconclusive, as it often suffers the problem of independent variables (Graff, 2016). Despite these shortfalls, evidence from evaluative studies suggests that the integration of SSH with STEM can foster a range of beneficial learning outcomes such as critical thinking abilities, higher-order thinking and deeper learning, content mastery, problem solving, teamwork and communication skills, together with high motivation and preparedness for suitable jobs in respective industries (e.g., Committee on Integrating Higher Education in the Arts, Humanities, Sciences, Engineering, and Medicine et al., 2018; Ernest & Nemirovsky, 2016; Gurnon et al., 2013; Ghanbari, 2015; Scholl et al., 2014; Stolk & Martello, 205 C.E.) A strict focus on (measurable) gains in learning, motivation and competences can, however, cloud the fact that what lies at the heart of an interdisciplinary program should not (merely) be relatively short-term individual learning gains, but the ability to work collaboratively towards answering not yet well-elaborated, complex challenges.

As Weingart (2000, p. 26) states, it is quite paradoxical that so many reports, textbooks and public funding calls proclaim, demand and hail interdisciplinarity, supported by empirical evidence, while at the same time discipline-based education largely prevails. When the OECD, in the paper "Interdisciplinarity Revisited" (Levin and Lind, 1985), revisited the concept of interdisciplinarity a decade after the initial 1972 report, the conclusion was that university practice had remained mostly unchanged and the authors concluded that interdisciplinarity had lost its momentum.

Elaborations on challenges when integrating disciplines have been part of the literature on interdisciplinarity from the beginning. Already in 1972, OECD listed several challenges for universities striving for interdisciplinarity in research and teaching. These included: "the rigidity of institutional structures; the rigidity of people involved including resistance offered by disciplinary frameworks, and the lack of facilities" (Chettiparamb, p. 36; cf. also Telléus, 2019 for a more in-depth elaboration of the problems with disciplinary logics for PBL, specifically). Recent publications have taken this up and

developed it further. For example, Braßler (2020) identifies challenges to the implementation of interdisciplinarity at the organizational level, team level and individual level. They mention, amongst other things, differences in discipline-based learning conceptions among teachers; incommensurable study regulations; and lack of institutional support as challenges to implement an interdisciplinary program involving both teachers and students from different academic fields. In the same line, Ashby & Exter (2019) have pointed out that "(…) designing an interdisciplinary learning experience requires close collaboration, team planning, and co-teaching of subjects by faculty from different disciplines." (p. 204), with precisely the creation of interdisciplinary exchange amongst co-teaching faculty being a major challenge to the enactment of interdisciplinarity (Richards, 1996, after Ashby & Exter, 2019).

In sum, interdisciplinarity in higher education is a contested field. While intentions are clearly in favor of an increased focus on interdisciplinarity, university practice has not really responded to the many voices calling for interdisciplinary research and teaching. The literature suggests that this dissonance between intentions and practice can at least partly be attributed to the regulating influence of the academic disciplines, which permeate the organization of higher education. However, when it comes to future iterations of academic integration, and the merging of SSH and STEM specifically, other factors can be seen as potentialities and challenges in designing interdisciplinary study programs, especially in consideration of the close entanglement between interdisciplinarity and PBL. Thus, in the following, two cases from Aalborg University is presented to examine potentialities and challenges of academic integration in a PBL-based educational system.

METHOD

Analytical approach
The cases analyzed in this paper are the AAU Megaprojects and the Techno-Anthropology (TAN) program. Both programs ambitiously and successfully integrated disciplines across SSH and STEM with different angles and approaches. However, both have recently experienced problems in terms of longevity and a sustainable interdisciplinary integration: the AAU Megaprojects are currently on hold; the TAN program faces a significant cut in student numbers, with education at AAU's Copenhagen campus being closed down altogether, and only the much smaller program in Aalborg continuing in upcoming years. The fact that neither program, although ambitious and forward-thinking in their PBL-based approach to interdisciplinary integration, could totally secure its existence invites a glance at the specific potentialities they were working with and the challenges they were facing in enacting interdisciplinarity.

Materials

The following analysis is based on publicly accessible information about the cases studied. Hence, an in-depth scrutiny of complex dynamics and micropolitics is not in the focus. We will instead rely on materials such as study program descriptions and self-presentation of the programs on their homepages as well as on academic writings in published books and journals elaborating the pedagogical design as well as on evaluation reports. The analysis of the AAU Megaprojects was based on the following material: The website and subsites of the Megaprojects (*Megaprojects*, n.d.; *What Is a Megaproject?*, n.d.; *For External Parties*, n.d.; *Simplyfing Sustainable Living. Fall 2019 - Spring 2021*, n.d.) and the academic evaluative papers by (Bertel et al., 2022) and Routhe et al. (2021). The analysis of the TAN program was based on the presentation of the program on AAU's website (*Bachelor Technoantropoligi*, n.d.); the presentation of the program's pedagogy and learning goals by Bruun (2019) as well as the program's competence profile in Karadechev et al. (2021); and the elaborations on the program in Børsen & Botin (2013). This will be supplemented with evaluation reports on the programs (Institut for Planlægning, n.d.-c), minutes from study board meetings (Institut for Planlægning, n.d.-a) and an evaluation report by the interest organization Danks Industri (Aziz, 2020). Moreover, we rely on press coverage regarding the partial closure of the program announced in 2022 by Baggersgaard (2022) and by Ravnsted-Larsen (2022).

Framework for the analysis

To shed light on potentialities and challenges within the program we will apply the framework by Braßler (2020) as a starting point. As elaborated above, Braßler (2020) distinguishes challenges to the enactment of interdisciplinarity in PBL-programs on the organizational, the team/group and the individual level. These also mirror some of the classical layers of organizational learning (Berson et al., 2006); however, we will supplement the taxonomy with an inter-organizational perspective (Ingram, 2017). For each of the two cases, we will also focus on potentialities as well as challenges for a more nuanced picture.

ANALYSIS

Presentation of the two cases

AAU Megaprojects

AAU Megaprojects were launched in 2019 as a new interdisciplinary initiative across the university. Megaprojects strive to bring together students from different faculties, disciplines and specializations. Each Megaproject centeres around a *central theme* which must be routed in one or several of the UN Sustainable Development Goals (SDGs; United Nations, 2015). To ensure that the Megaprojects were in fact interdisciplinary and to guarantee the authenticity of themes, an interdisciplinary group of faculty members assessed and developed each theme in collaboration with private and public stakeholders

(Bertel et al., 2022). The central theme is broken down in *sub themes* (focus areas) and further specified in *challenges*. Thus, in the first AAU Megaproject Simplifying Sustainable Living one focus area was "to reduce use of plastic" with one of the underlying challenges being "to avoid plastic in daily shopping" (*Simplyfing Sustainable Living. Fall 2019 - Spring 2021*, n.d.). Each challenge can contain several *cluster*s, each involving up to five student groups of four to seven students, coming from a specific academic field. As a result, a cluster could contain groups from sociology, engineering, business, computer science and philosophy, among others, all addressing the same challenge but from their specific academic perspective, while at the same time sharing knowledge and insights with the other groups within the cluster (cf. figure 1).

At the end of each semester, the university hosted a Megaproject conference for project participants, invited researchers and stakeholder representatives as well as potential future project participants and facilitators. At the conference participants presented the current state-of-the-art knowledge and proposed solutions from all project clusters in each Megaproject. Even though the ideas behind the Megaprojects were highly acclaimed by managers and academics, they were also subject for criticism (see below) and development of new Megaprojects was subsequently put on hold in 2021 while the team behind the projects evaluated the experiences and addressed some of the problems in the setup (Routhe et al., 2021). At present no announcement has been made as to the future of the Megaprojects.

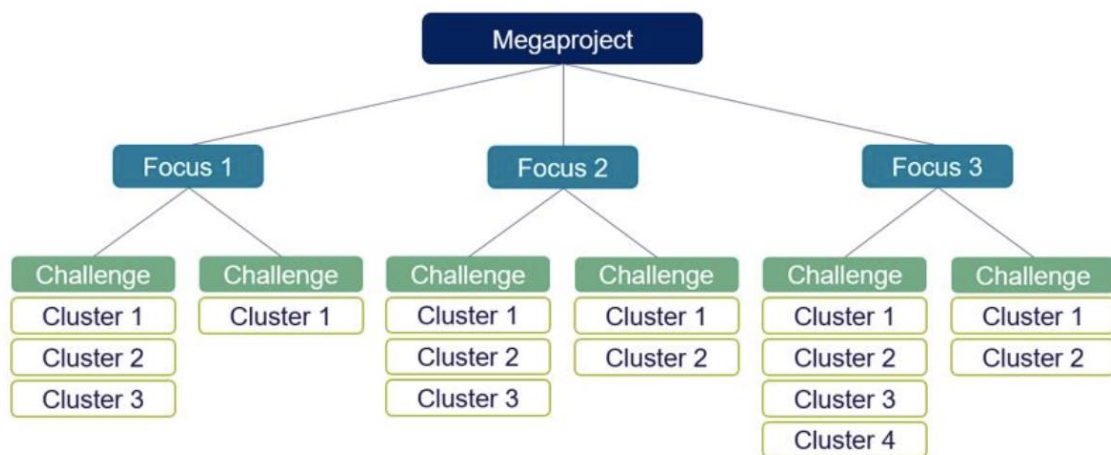*Figure 1. Structure of AAU Megaprojects (What is a Megaproject?, n.d.).*

The Techno-Anthropology program (TAN)
Offering a bachelor and master's degree, the TAN program runs at AAU's campuses in Aalborg and Copenhagen, respectively. The program was established in 2011 (bachelor) and 2012 (master), and has, from its beginnings, prided itself on being a truly

interdisciplinary program. The trademark metaphor of the education is "the bridge", since its aim is to bridge technical understanding with anthropological- and ethical analysis (Bruun, 2019). The program has always been very aware of the different forms of academic integration and its ambition is thus to achieve "transgressive interdisciplinarity" (Bruun, 2019: 38). With an explicit PBL approach, participation requires that students work on problems that address social challenges related to the human-technology interface, combining knowledge and methodology from the fields of technology, anthropology and ethics (Karadechev et al., 2021). Courses in the program are co-taught by teachers from different departments, and project groups are co-supervised by two supervisors from engineering and humanities, respectively (Bruun, 2019).

The program's far-reaching transdisciplinary approach is intended to provide the students with competences to act as mediators between human actors and technology (*Bachelor Technoantropoligi*, n.d.). Notably, these competences have also been underpinned by a theoretical model (Børsen, 2013a) that defines three central competencies within the techno-anthropological field, which can only be acquired through an interdisciplinary education. The first is interactional expertise which is described as "the mastery of the language of a domain" (Collins & Evans, 2007, p. 30, after Børsen, 2013a). The second is social responsibility, i.e., individuals' ability to orient themselves based on their own ethical orientation system (Børsen, 2013b). The final competence is anthropology-driven design, which is the ability to combine the Scandinavian model of participatory design with classic anthropological field research (Børsen, 2013a) (cf. figure 2).

Despite meeting high interest with students, AAU's board and central leadership decided in the spring of 2021 to close the Copenhagen campus program and thus only continue with the much smaller program in Aalborg (Baggersgaard, 2022).
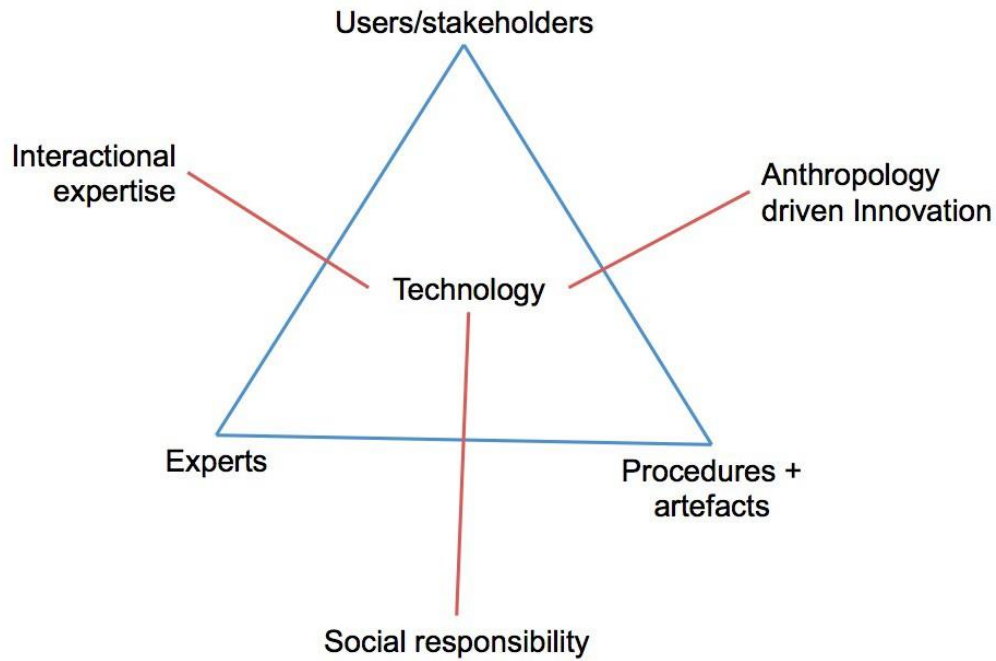
Figure 2. The techno-anthropological field (Botin, 2013).

Potentialities and challenges within the two cases

As evident in the two cases, integrating interdisciplinarity into academic education is no guarantee of success. Different potentialities and challenges seemed to foster and hinder the success of the two programs, sometimes detrimentally. Table 1 provides an overview of the outcome of our analysis.

	AAU Megaprojects		**The Techno-Anthropology program**	
Analytical level (after Braßler 2020; Ingman, 2017)	*Potentialities*	Challenges	*Potentialities*	*Challenges*
Individual/ student	Excitement about working with Sustainable Development Goals and interest in the interdisciplinary setup of the project	Declining appreciation for the interdisciplinary experience over the course of the program	High student interest, intake and good evaluations	Lack in feeling of cohesion within the program
Team/group	Increased understanding of other disciplinary perspectives through in-cluster communication by the students	Quality and intensity of collaborations depended on the engagement of individual teachers or student groups	Closely collaborating team of teachers	Power struggles amongst groups of teachers; additional time needed for coordinating and developing a joint practice

Organizational	Alignment of university teaching on a common goal; joint practice across disciplines	Differences in "project-logics" across the participating faculties and departments Tensions with the pre-set structure of the disciplinary programs	[no information retrievable from the documents]	Disputes on economy and authority between departments
Inter-organizational	Excitement about a new approach to PBL and interest in Sustainable Development Goals as a lever for university-industry collaboration	Difficulties in finding suitable partners due to the specific prerequistes of the program (collaboration with large private or public organizations)	Graduates as bridgebuilders between in-company departments and different professional perspectives	Low employment rate amongst graduates

Table 1. Potentialities and challenges for interdisciplinary integration in the two cases.

Potentialities and challenges within AAU Megaprojects

For the AAU Megaprojects, the material provided a rich source on the individual/student level, as especially the evaluations on the program dove deep into the student perspective. As a potentiality here, the students' excitement about engaging with SDGs in a project can be highlighted, hence an *interest in the interdisciplinary setup of the project* was evident across student evaluations (Bertel et al., 2022: 1182). However, as a challenge, students expressed *declining appreciation for the concrete interdisciplinary experience*, raising uncertainty on how to live up to the interdisciplinary demands stated in the program setup, and how to align engagement in the (extracurricular) Megaprojects with the disciplinary logics of their regular studies (Bertel et al., 2022: 1182f). As an effect, students, contrary to the intentions behind the program, chose to work in discipline-oriented groups and clusters, as coordinating with peers from other disciplines was experienced as difficult, time-consuming and with little relevance for their final grade (Routhe et al., 2021: 175f.).

The challenges experienced at the individual/student level seemed to be closely intertwined with challenges at the organizational level, as the resources integrated in the analysis showed. With this university-spanning interdisciplinary initiative the *differences in the "project logics" of the different faculties* required what (Routhe et al., 2021) have called "coordination in a decoupled system" (p. 179), being that students performatively

worked in an interdisciplinary manner, whilst in fact reverting to working in disciplinary silos. This coincided with a feeling amongst teachers and local program coordinators that in order to hold the projects together an all too rigid structure was applied in terms of deciding on project topics and focuses, which were pre-set by faculty and stakeholders rather than defined by students themselves (Routhe et al., 2021). Bertel et al. (2022) here state that "the interdisciplinary collaboration was often driven by the structure of the megaproject rather than the nature of the problem." (p. 1183).

At the team level, students expressed appreciation for the opportunity to *learn about other disciplinary perspectives through in-cluster communication*. Talking to fellow students from other disciplinary fields allowed them to not just understand how other disciplines approached the problem that they themselves were trying to solve, but also brought them new perspectives on their own theoretical field. However, it seems that the spreading of the AAU Megaprojects across all faculties and departments also came with challenges in establishing interdisciplinary collaboration, and that the *quality and intensity of collaborations depended on the engagement of individual teachers involved* (Bertel et al., 2022). The same was true in a way for students, who felt that it was put as a requirement upon them to *self-organize towards interdisciplinary collaborations* (Bertel et al., 2022: 1182f).

At the organizational level the Megaprojects have helped to increase an organizational focus on sustainable education across disciplines and educational programs. Thus in 2022 The Times Higher Education Impact Rankings placed AAU as number one amongst all universities in the world on SDG 4 "Ensuring and disseminating quality education that supports global sustainable development". When the rankings were announced, AAU's Vice-Rector stated:

> Our unique pedagogical model of problem- and project-based learning, where student learning is based on real-life issues, directly addresses the UN's global goals. AAU focused on global sustainable development long before it was on everyone's lips. Most recently, our megaprojects involve students across semesters and programs working together to find sustainable solutions (Aalborg University, n.d.)

Although Megaprojects hold the potential for organizational alignment, it was also evident that *differences in 'project-logics' across the participating faculties* was a continuous obstacle. Vast differences in e.g., teaching practices, module setup, academic expectations, student credits amongst participating faculties made it hard to coordinate and create opportunities for actual interdisciplinary collaboration.

At the interorganizational level the AAU Megaprojects show more as a potentiality than as a challenge: based on the self-presenting material, they mainly present as surrounded

by *goodwill, excitement about a new approach to PBL and massive interest in the SDGs as a lever for university-industry collaboration* (*Megaprojects*, n.d.; *For External Parties*, n.d.). A potential challenge that did not materialize due to the short life and relatively few realized Megaprojects, is that the scale at which Megaprojects operate requires interorganizational collaboration with quite large organizations (the first two were initiated with one of the biggest municipalities in Denmark). In this respect, one could speculate that it would become increasingly *difficult to find suitable partners* interested in participating in a project of such magnitude. In fact, the third and final megaproject Better Together which premiered in 2021 was without an external partner (*Megaproject: Better Together*, n.d.).

Potentialities and challenges within the TAN program
At the individual/student level, the TAN program was well received more or less from the opening in 2011. The responsible teachers succeeded in explaining the program rationale and intended learning outcomes as well as the interdisciplinary competence profile, resulting in *high interest, student intake and relatively good evaluations* (Børsen & Botin, 2013). However, some challenges at the individual/student level could be found in the student evaluations, in which we see that *students rate the cohesiveness of the education rather poorly*. Students (especially in the first semesters) seemed to find it hard to understand how the different academic fields can be integrated and quite a number feel that they do not get enough help with the integrative task they face (Institut for Planlægning, n.d.-c).

At the team/group level the program was run by a *closely collaborating team of teachers*, resulting in highly transdisciplinary teaching content and processes (Bruun, 2019, p. 36). However, these positive working relationships required massive effort to develop and maintain. Thus, teachers had to *spend more time than they normally would* on teacher meetings and seminars. Furthermore, as is evident in the minutes from the study board, the first years was also characterized by academic power struggles in which different academic groups argued for their academic specialty to play a more prominent role in the education (Institut for Planlægning, n.d.-a).

At the organizational level, the material does not give any information about possible potentialities. The challenges at the group level, however, seemed to carry over to the organizational level, resulting in *disputes on economy and authority between departments.* When initially establishing the program two departments (the Technical Department and the Anthropological Department) were to share academic and economic responsibility for the program. Due to the bureaucratic and economic structures of the university, it proved impossible to uphold this joint ownership and the Technical Department was made sole program owner. In 2019 seats on the study board were re-

allocated following these lines, resulting in only lecturers from the Technical Department holding seats with deciding votes (Institut for Planlægning, n.d.-b).

At the interorganizational level a report from 2021 describes graduates from TAN as *bridgebuilders between in-company departments and different professional perspectives* (Karadechev et al., 2021). Through their education, the graduates acquired competences that enabled them to "engage in dialogue on professional, disciplinary and interdisciplinary topics with stakeholders, and representatives of different professions and disciplines within selected technological domains" (Karadechev et al., 2021: 8). Furthermore, the report documents that graduates work in a variety of different fields both in the public and private sector, often involved in project management, user involvement and user experience or technology assessment, technology planning and technology design (ibid.: 16).

Even though the report emphasized their competences and the job opportunities, in a recent report from the interest organization Dansk Industri (DI, English: *Danish Industry*), TAN was rated amongst the ten technical education programs in Denmark scoring lowest in terms of employment rate among graduates (Aziz, 2020). This was subsequently the primary reason behind the managerial decision to close the program located in Copenhagen. Even though is seems fair to call TAN a success from a pedagogical point of view, the economic world and specifically employers have not shown the same kind of appreciation for the education as the students (Ravnsted-Larsen, 2022). Just as students and teachers can struggle to see the benefits of academic integration, so too can a labor market, where notions of traditional professional competences and professions are prevailing. In this sense it can be said that the biggest challenges that TAN has faced have been at the interorganizational level.

DISCUSSION: INTEGRATION AND DISCIPLINARITY – WHICH WAY FORWARD?

Even though the two cases in some ways draw a rather bleak picture of the potentialities of SSH-STEM integration, we believe that the challenges the programs encountered can serve as a starting point for an elaboration of new and sustainable practices of integration. In this final section we will jointly discuss lessons from the analysis of the AAU Megaprojects and from the TAN program. Although discussing these under three distinct aspects, we of course consider them as being highly intertwined and to be taken into consideration holistically in future endeavors of academic integration.

Balancing structure and freedom through internal alignment
As a first aspect, academic integration (whether SSH-STEM or otherwise) needs to find a balance between a clear structure and the freedom for students and teachers to explore

relevant questions. As could be seen with the AAU Megaprojects as an extreme case, the need for providing a clear organizational structure (in this case: across faculties and departments) can sometimes compromise the problem-oriented nature of the interdisciplinary endeavors. The TAN program showed that this was better achieved on a smaller scale. However, a large or "mega" project interdisciplinary program should not per se be dismissed as unfeasible in this sense. By aligning project start dates, departmental expectations and assessment criteria across faculties, some gains could certainly be made here (cf. the recommendations by Bertel et al., 2022). Moreover, full academic interdisciplinarity as a regular part of the study program instead of an extracurricular activity would be beneficial, as suggested in a student project-expertise on the future of the AAU Megaprojects lately (Imre et al., 2021).

In this sense SSH-STEM integration must clearly be a topic at the top level of the university, where (vice) presidents and deans need to discuss how to provide spaces and study conditions under which students from various disciplines can be encouraged to work together in an interdisciplinary manner. However, as can be inferred from the TAN case, the potentially difficult task of practicing interdisciplinarity cannot be placed on students alone, while university teachers comfortably remain in their discipline's distinct department without much inclination for collaboration. Academic integration cannot come to life if only practiced in few places of relatively low prestige (as sadly still the case for teaching). An institution embracing interdisciplinarity in teaching must also walk the talk in other areas, by establishing a culture of integration also in research and knowledge dissemination (Klein, 2021). Also, for academic interdisciplinarity to flourish, research and teaching cannot be perceived as activities existing in separate spheres. Instead, activities in both areas must be co-designed to necessitate reciprocal dialog and foster long-term cooperation among academics and students.

External alignment as a long-term investment
As illustrated in the TAN-case, internal alignment is not necessarily enough in itself to ensure the longevity of an interdisciplinary program. If employers (and thereby society) do not understand the reasons for or see the value of such programs, chances are such initiatives will be short-lived. Of course, aligning teaching and learning with the surrounding world touches upon very fundamental questions about the nature of higher education, and the role that universities should play in it (Hearn, 2003) (Hearn, 2003). With the advent of mass university after World War II, the increased influx of students has changed the university from an elitist and isolated institution for the few, and the university of today must necessarily integrate and involve itself in society in completely different ways than ever before (Rasmussen, 2006).

Generally speaking, it seems fruitless to insist on the academic privilege of the pursuit of pure knowledge for the sake of knowledge itself. However, taking up on the idea of this

paper again we want to argue that integration runs both ways, and universities can and should make use of the fact that today much tighter bonds between universities and society exists. We as teachers and scholars must engage in societally relevant discussions about the value of interdisciplinarity. We must argue for our choices and in this way initiate discourses that stress the necessity of interdisciplinarity in the years to come. As so overwhelmingly illustrated by the systemic nature of the SDGs, the most important problems that we face today are systemic and thus by nature interdisciplinary (Capra & Luisi, 2014). Even though businesses might still operate on the basis of a traditional linear logic, it is an academic obligation to argue for the competencies that will be needed in the future not to give in for the demands of today.

Reconfiguration of understandings of STEM and SSH
A third lesson to be inferred from the two cases is that the disciplinary expectancies especially toward STEM-educated professions could benefit from an overhaul when integrating them with SSH-perspectives. As Miller (2021) pointed out in his keynote to the PBL2021 International Conference, positioning excelling in mathematics as the primary signifier for becoming an outstanding engineer is no longer valid in the 21st century. Engineers of the future, so Miller states (2021), should be equally good, if not better, at analyzing the societal challenges they are addressing through their work, and understand the content of engineering subjects as processual rather than factual knowledge.

Integrating SSH aspects into the engineering curricula holds the potential for educating professionals that can envision futures that do not yet exist, thus shaping rather than reacting to the world. This calls for new forms of disciplinarily integrated courses, in which STEM, SSH and business education play a role on equal terms, to educate for a forward-thinking mindset. It also entails understanding emotional well-being and support as part of the educational process, ultimately leading to transformational education experiences. The global challenges humanity will face in just the next decade demand a broader "systems framing" that spans many current disciplines in order to even define the problems, e.g., accelerating global climate change; the re-emergence of global fascism, the Ukraine war, the continuing global pandemic, the expiration of dozens of antibiotics, the epidemic of youth suicide, growing widespread concern over mental health, the unintended consequences of AI, the emergence of a "surveillance economy", and the rapidly growing global economic recession. For all of these massive challenges it stands true that "no amount of emphasis on narrow specialized knowledge (or academic courses) will produce the innovators we need!" Miller (2021). This notion also calls for a reconfiguration of the roles of universities, who must think beyond their current position as providers of specialized knowledge for the next generation, and beyond academic parochialism. To continue to be relevant in an ever more complex world, the university

of tomorrow must embrace the urgent need to shape the attitudes, behaviors and beliefs of the next generation. This is key to enabling them to understand the diverse and multi-faceted knowledge that universities produce, and to act upon this understanding.

CONCLUSION

To conclude on our discussion, we can state that, despite the somewhat sobering picture that can be drawn upon reflection of the two case studies elaborated earlier, it is pivotal not to lose faith in the fact that academic interdisciplinarity is a viable goal for the future of academic education. As mentioned above, there are no alternatives to a continued effort to integrate the knowledge and expertise of the academic disciplines if we are to respond to the challenges of today and tomorrow. Extrapolating from major academic change initiatives that one of the authors of this paper was involved in, we will end this paper with five key points that might increase the success of such endeavors:

- First, *keep experimenting.* Looking at innovations in the domain of engineering education, it becomes clear that none of these were perfect solutions in their first version. Iterations and refinement are pivotal to progress, so failing at one attempt should not discourage educational developers from continuing to experiment with what they believe in.
- Second, *start small.* The most successful examples of systemic change in learning models almost always begin as an experiment. This strategy has proven successful because it set low expectations and thus tend to avoid severe criticism at the beginning. While the stakes for a project rolled out at large scale are enormous, a smaller experiment can be enlarged subsequently in later iterations .
- Third, *provide a very clear picture of the problem or concern that you are addressing by integrating different disciplines.* The limitations of each discipline alone make it impossible for any single department to succeed in developing a comprehensive solution. Instead, the need to talk to each other to even frame the problem will lead to changes in behavior across the institution. While this does not always lead to breakthroughs in thinking, it seems to work more often than other approaches.
- Fourth, *engage external stakeholders from the beginning*. When employers are ambivalent about the capabilities of graduates from new non-traditional and highly integrative programs, this can be a sign that they were not engaged in the process of designing the content and pedagogies in the new program. Integrating external stakeholders is crucial, as they potentially will become invested and thus motivatied to contribute to the success of the program.

- Fifth and finally, *don't forget the important role of the students.* If students are invited to be partners in the design and iteration of new pedagogical models, they can become powerful advocates too. In a highly engaging educational environment, students are often willing to exceed requirements and continue their education beyond the end point for the degree to obtain a more comprehensive learning outcome. Experience shows that it is often hard for even the most traditional and conservative faculty member to deny their best students the opportunity to learn in new ways that they are passionate about.

On this note, we would like to close this paper with another quote – both as encouragement and inspiration for the continued efforts of academic developers to keep striving for urgently needed new ways of designing and conducting higher education:

> It ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them.
>
> Niccolò Machiavelli (1513)

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Sustainability Matters:
The Evolution of Sustainability Awareness, Interest and Engagement in PBL Engineering Students

Virginie Servant-Miklos, Jette E. Holgaard, Anette Kolmos *

ABSTRACT

The purpose of this study was to identify patterns of change in students' awareness of, interest in and engagement with sustainability issues during the process of acclimatisation to their PBL engineering studies, and to look for differences between engineering disciplines with respect to these aspects. This study used a longitudinal qualitative approach with a theory-led thematic analysis. There were 16 participants in total, interviewed at 3 intervals during a period of 18 months at a faculty of engineering in Denmark. The authors found a pattern of increase in sustainability awareness, interest, and engagement throughout the three semesters of the study. Some differences between engineering disciplines were visible, especially between sustainability-oriented engineering and the others. Most students who increased their sustainability awareness and interest were also likely to engage further with the topic. That engagement built up from individual engagement, to professional engagement and for some, into institutional and public sphere engagement. The findings are timely given the pressure faced by engineering education to incorporate sustainability issues. It provides avenues for educating engineering graduates who will display interest, awareness, and engagement with sustainability issues. It suggests institutional engagement as a potential avenue to explore for engineering educators.

*   Virginie Servant-Miklos, Erasmus School of Social and Behavioural Sciences, Erasmus University Rotterdam, Netherlands
Email: servant@essb.eur.nl
Jette E. Holgaard, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of UNESCO, Department of Planning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: jeh@plan.aau.dk
Anette Kolmos, Aalborg Centre for PBL in Engineering Science and Sustainability under the auspices of UNESCO, Department of Planning, and Institute for Advanced Study in PBL, Aalborg University, Denmark
Email: ak@plan.aau.dk

Keywords: Sustainability, engineering education, problem-based learning, qualitative research

INTRODUCTION

Sustainability issues are increasingly at the heart of engineering education design and implementation. Guidance from international bodies such as the United Nations (UNSDGs) has prompted engineering curriculum designers to review how to integrate sustainability into the learning process. There has also been increasing pressure for change from students (Ralph & Stubbs, 2014) at a time of high media interest in sustainability and the publication of alarming reports on climate change (IPCC, 2021) and biodiversity loss (IPBES, 2019).

For over two decades, the Education for Sustainable Development (ESD) literature has advocated for change from education *about* sustainability to education *for* sustainability (Blake et al., 2013; Filho et al., 2018). As a result, there has been increasing interest in the potential of pedagogy, particularly forms of project-based, problem-based and active learning, to foster interdisciplinary sustainability awareness, interest and engagement (e.g. Holgaard et al., 2016; Mintz & Tal, 2018; Noordegraaf-Eelens et al., 2019). Interest in the student perspective on sustainability education is relatively recent, including in engineering education (Watson et al., 2013; Berdanier et al., 2018), and remains relatively understudied, with an over-representation of quantitative studies (Cebrián et al., 2019).

Recent publications have advocated the use of problem-oriented project-based learning (PBL) to develop sustainability competences in engineering education (Holgaard et al., 2016; Guerra, 2017), including "contextual knowledge, cultural awareness and sustainability agency as well as professional identity and scientific-technical competence" (Holgaard et al, 2016, p. 3480). In engineering education, PBL is a learning approach in which students work in group projects based on real-life problems in every semester (Kolmos et al., 2004). Systemic PBL refers to the implementation of PBL across an entire institution, with 50% of study credits allocated to project work. This is currently only being implemented fully at Aalborg University in Denmark (Kolmos, 2017). But the impact of PBL on engineering students' awareness, interest and engagement with sustainability remains understudied. Beginning in 2010, Kolmos and Holgaard (2017) performed a longitudinal quantitative study across all the engineering schools of Denmark with the goal of identifying the progression of students' generic sustainability competences over the course of their studies. They assessed variables related to sustainability competences, including self-reported "readiness" with regards to environmental impact and social responsibility. By their final semester, a higher percentage of students at a systemic PBL university in Denmark assessed themselves as "very well prepared" for tackling sustainability issues, and had increased confidence in

their sustainability competences (Kolmos et al., 2020). However, the connection between PBL and the increase in sustainability awareness, interest and engagement was not explored, and differences between engineering disciplines were not analysed. A longitudinal qualitative research might usefully provide insights into the entanglements between student learning trajectories, PBL and sustainability issues. Our study therefore looks at the period in which undergraduate students *acclimatise* to PBL throughout the first three semesters, a period during which they develop core PBL competences, including sustainability competences (see Methodology section; Servant-Miklos & Kolmos, 2022). We will address the following research questions:

- What are the patterns of change in students' awareness, interest, and engagement with sustainability issues during the process of acclimatisation to their PBL engineering studies? What does this tell us about the awareness, interest and engagement with sustainability?
- Do we see differences across different engineering disciplines, and what can we learn from this about engineering students' professional identity development?

The following literature review will, besides presenting an overview of findings from previous studies on students' awareness, interest, and engagement with sustainability, point to different perspectives of awareness, interest and engagement to evaluated in the light of the analysis of our empirical data.

EMPIRICAL UNDERPINNINGS

The purpose of a theory-led thematic analysis being to relate categories developed in the established literature in the field to new data, we parsed through the Education for Sustainable Development (ESD) literature to identify key frameworks for describing how students relate to sustainability. From our analysis of the literature, three categories of relations emerged: awareness, interest and engagement. Engagement was further divided into four categories: private, institutional, professional and political. These categories form the theoretical underpinnings of our theory-led thematic data analysis (Braun & Clarke, 2012) by providing the ground-work for coding the data.

Student awareness of sustainability
Based on Sammalisto et al (2016) and Oberrauch et al (2021), we define sustainability awareness as student knowledgeability about sustainability issues, including awareness of the urgency of moving towards more sustainable development.

Theory and Practice. This relates to whether students' sustainability knowledge is mainly theoretical, or complemented by practice, and is important with regards to the the topic of our study because it connects awareness with engagement. Meyers (2006) challenged the idea that theory and practice in environmental education are opposable approaches, suggesting a pragmatic continuum between the two. Aguilar and Krasny (2010) proposed that the classroom itself could be a community of practice in-the-making, where joint enterprise and mutual engagement on learning goals create a shared repertoire of theoretical-practical understandings. More recently, the literature has offered broader definitions of the terms, with "theory" comprising various forms of theory-in-the-making including action research (Paredes-Chi & Viga-de Alva, 2020), and research-meets-professional-practice (Pizmony-Levy et al., 2021). "Practice" has come to include normative commitments to social justice (Ceaser, 2012; McGregor & Christie, 2021), decolonial praxis (Rodriguez, 2020) and ecofeminism (Gough & Whitehouse, 2020).

In a meta-analysis of sustainability education pedagogies, Lozano et al. (2017) identified the best pedagogical approaches to bridge theory and practice, including problem-and-project based learning, jigsawing, and service-learning. Affolderbach (2020) showcased this in practice, in a problem-and-project based approach to geography education in the UK that gives students the power to design, pitch and potentially implement green-economy projects. Recently, interest has emerged in more experimental pedagogies to bridge theory and practice, such as garden-based learning (Zuiker & Riske, 2021), community volunteering (Eiseman et al., 2020), and place-based learning (Cincera, et. al., 2019).

Systemic *vs.* Domain-specific awareness. This relates to the question of whether sustainability is understood by students as transdisciplinary and systemic, or narrowly embedded within one or several disciplines. Bajracharya and Maskey (2016) conducted a survey of 373 American students' awareness, knowledge, values, and perceptions of environmental sustainability, suggesting that students were reasonably aware of sustainability issues. However, approximately 20% of the participants perceived sustainability as outside their disciplinary remit, while 30% of the participants agreed that sustainability should be integrated into core courses, pointing to the concerning conclusion that students perceived sustainability as neither core to their studies, nor interdisciplinary.

Recent studies suggest that interdisciplinary approaches to education fare better than disciplinary ones in promoting a systemic understanding of sustainability issues (Servant-Miklos & Noordzij, 2021; Walsh et al., 2021). In particular, interdisciplinarity is better able to convey concerns on systemic sustainability and intersectionality (Maina-Okori et al., 2018).

Student interest in sustainability

Interest relates to students' motivation to learn more about sustainability and take responsibility for their own learning around sustainability issues.

In a survey of American students' perceptions of sustainability education, Watson, Noyes and Rodgers (2013) found that 70,6% of students indicated a strong interest in sustainability, however, they lacked confidence in their ability to speak knowledgeably about sustainability. Another survey from Texas (Msengi, et al., 2019) indicated an even larger detachment between interest and awareness: while 95,8% of participants believed that sustainability was important, only 30% encountered sustainability in their study programmes. In other words, even when students show interest in sustainability, the lack of options for studying sustainability leads to awareness trailing behind interest. Where integrating sustainability within the curriculum is not possible, there are options to offer extra-curricular or elective sustainability courses (Spalding et al., 2014). Teachers could also give room for sustainability concerns in student-directed pedagogies. For instance, project work gives students a chance to integrates sustainable thinking in their problem analysis (Guerra & Holgaard, 2019).

Students' engagement in sustainability

Engagement relates to acting towards sustainable development. By engaging, students take responsibility for sustainable practices in different spheres of their lives. As we have shown, the lines between sustainability education and normative engagement are increasingly blurred. The modes of engagement emerging from this normative commitment are still being defined, with a paradigmatic divide forming between a pragmatic view and a relational view. The pragmatic view compartmentalizes engagement into distinct categories, such as individual, professional, or public and tackles each one in turn, with oppositions between private and professional spheres, and institutional and political spheres, and some convergences possible between institutional and professional (e.g. sustainability officers), private and institutional (e.g. installing recycling stations in the university for private use), private and political (e.g. donating to an activist group), and political and professional (e.g. becoming a green party politician). The relational view, on the other hand, understands all forms of engagement in sustainability education as related and inherently political (Ferreira, 2019; Walsh et al., 2021). In this view, the boundaries within which professional, institutional and private choices are made are politically determined, complicating attempts to distinguish between spheres of action. The relational view dominates in the humanities, whereas the pragmatic view tends to characterize engineering education.
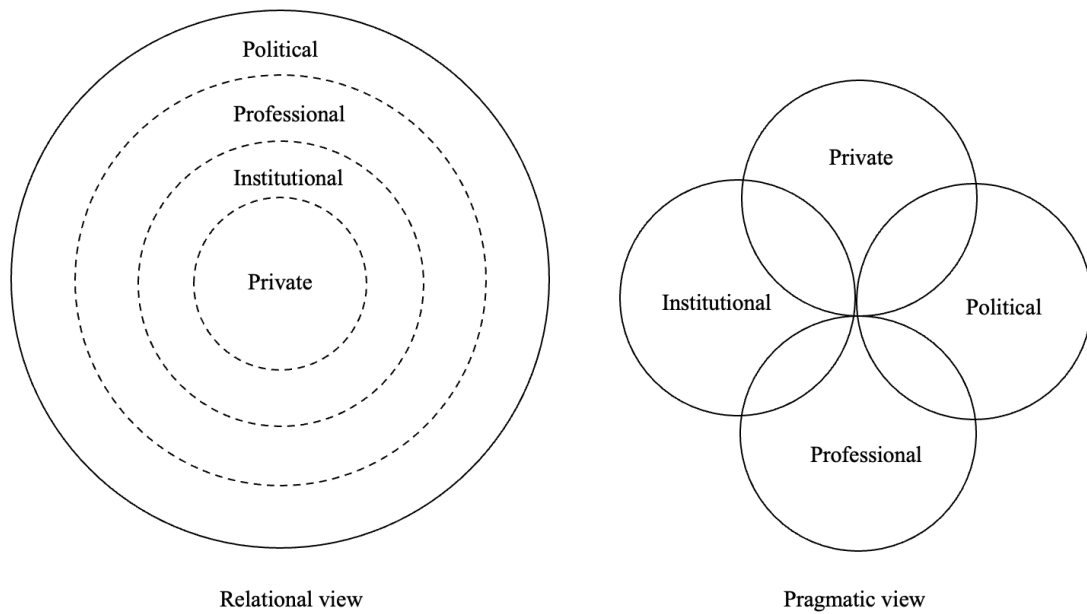
Figure 1. Visual representation of the relational and pragmatic views on the relationships between sustainability engagement categories.

Private engagement. Whilst exclusive focus on action in the private sphere has been justifiably decried as insufficient to enact systemic change (Ferreira, 2019), it is nonetheless understood that individual change is necessary for system-level change (Lafuite et al., 2017). Sustainability education has been identified as a key factor in developing individual engagement (Varela-Candamio et al., 2018). However, the understanding of what changes support "sustainable lifestyles" tends to be narrow. A study of British students showed that they strongly, if not exclusively, associated sustainability with recycling, despite the low impact of recycling on sustainability outcomes (Chaplin & Wyton, 2014). In the United Arab Emirates, students associated sustainability with minor lifestyle adjustments like purchasing reusable containers and less frequent use of the washing-machine (Al-Naqbi & Alshannaq, 2018). A study from the Netherlands showed that while some students were willing to consider vegetarian diets, larger behavioural changes such as giving up international air travel were off the table (Servant-Miklos & Noordzij, 2021).

Institutional engagement. Some studies report on student engagement within the institutional sphere, namely trying to change higher education from the inside, by engaging within schools and universities through official channels such as board, councils, committees, campus magazines, student associations and other official organs, to push for more sustainable policies and practices. At Portland State University, 20 student representatives were selected to form a "Student Sustainability Leadership Council" that developed a student sustainability vision and provided feedback to faculty

(Spalding, Williams & Wise, 2014). The same paradigmatic tensions operate at the level of institutional engagement, with some scholar investigating institutional engagement as a discrete sphere of action, while other understand institutional engagement as a localized form of political action (Hoover & Harder, 2015). Van Poeck and Östman (2018) investigated the circumstance under which the politicisation or de-politicisation of institutional questions emerge in sustainability education. They concluded that de-politicisation happens when educators control the narrative on which normative concerns to address and how to address them, while politicisation emerges when education is conceived as an open space where conflicts can be analysed and debated.

Professional engagement. Professional engagement is one example of gearing normative concerns towards a given solution. In engaging through the professional sphere, students are encouraged to plan their careers around sustainability issues, generally understood within a market-based framework with companies as primary actors. The discourse on sustainability education as professional learning is not new (Stevenson, 2007), however, the seismic shifts in business interests in sustainability over the last decade have increased the uptake of this view.

Central to the professional engagement premise is the early input of private stakeholders and "real-life problems" in the education process, usually through project learning (e.g. Kricsfalusy et al., 2018). Here, a distinction is made between interdisciplinary learning projects that integrate various parts of the curriculum, and transdisciplinary projects, where students learn to work with external stakeholders (Segalás, et al., 2010), a participatory form of transdisciplinarity also known as *mode 2* research (Andersen & Kjeldsen, 2015). In Denmark, PBL students do both, working with companies, municipalities and other third parties on projects to address current sustainability problems in industry (Kolmos & Holgaard, 2019).

Political Engagement. A critical body of literature rejects the de-politicisation of sustainability education, gearing the narrative towards political solutions instead. These scholars understand environmental issues as inherently conflictual arenas where individual, private interests clash with collective, public goods (Ferreira, 2019; Van Poeck & Östman; 2018). Within this view, personal and social responsibility are intertwined with institutional decision-making (Boyd & Brackmann, 2012). Håkansson, Kronlid and Östman (2019) identified three forms of political engagement in sustainability education: socially-critical, social learning, and radical democracy. The first is linked with a structural, social justice reading of systemic sustainability. The second offers a more participatory, bottom-up reading with a strong emphasis on emotional processing and reflexivity. The last tries to eschew the perceived normative biases of the first two with open, deliberative practices that do not take positionings on sustainability for granted. Student sustainability campus activism tends to fall into the

first category, occasionally the second, and rarely the third. As a discrete sphere of operation, political engagement could be understood as public sphere engagement, differentiated from institutional engagement by the fact that students do not work through official university organs, but rather act as an oppositional force to university institutions by leaning on political organisations (e.g. political parties, activist groups) that work in the local, national and international public sphere. For instance, student activism resulted in Cornell University declaring sustainability as a core value in research, education, outreach and campus management (Too & Bajracharya, 2015). Recently, in the Netherlands, several major universities were occupied during student-led political protests. The protests led to police interventions on campuses, prompting debates about the ties between universities and the fossil fuel industry within the university communities (Erasmus Magazine, 2023).

Disengagement. The examples highlighted above might give the impression that student engagement is the norm, but there are numerous studies showing student disengagement. For example, Eagle et. al. (2015) reported that undergraduate business students regard societal issues as beyond their personal control, and consequently outside their responsibility. These findings are consistent with the "attitude-behavioral gap" identified by Owens and Driffill (2008) and the "identity dissonance" identified by Servant-Miklos and Noordzij (2021). The latter showed that although most sustainability students expressed a moral identity geared towards environmental care, this did not translate into shifting unsustainable pre-existing beliefs and behaviors. As such, awareness is a precondition for informed concern and action – Sammalisto et al (2016) showed a significant correlation between increasing awareness and taking action. But increasing student awareness about sustainability is not sufficient to ensure sustainability engagement. For instance, both Sammalisto et al (2016) and Oberrauch et al (2021) showed that gender strongly influences the likelihood of action: at the same level of awareness, students identifying as women are more likely to take action than students identifying as men.

In the following, we will use these concepts from the literature review as lenses to analyse students' awareness, interest, and engagement in sustainability in a PBL engineering programme.

	Categories of student relations to sustainability issues		
	Awareness	Interest	Engagement (pragmatic view)
Sub-categories of relations	Theory v. practice		Private
	Domain-specific v. systemic		Institutional
			Professional
			Political / Public

Table 1. Overview of categories of student relations to sustainability found in the ESD literature and used for the data analysis of this study.

METHODOLOGY

Our study used a qualitative thematic analysis approach (Braun & Clarke, 2012), characterised by relatively small sample sizes, rich data analysis, and a focus on transferability rather than generalizability. This thematic analysis was "theory-led" (Braun & Clarke, 2012) in that the thematic categories were guided by the literature presented in our review. Thematic analysis is an epistemologically flexible methodology, though epistemological assumptions should be clarified up-front. We operated within a social-constructivist epistemology, meaning that we were not looking for "objective" descriptions of social phenomena with essential qualities, but for the ways in which participants constructed meanings and understood their place within social phenomena whose interpretation is subjective to participants and researchers alike (Bailey & Douglas, 2014).

Participants

We used purposive sampling (Etikan, 2016) to gather participants from different types of engineering studies within the same engineering faculty of a systemic PBL university in Denmark: electronic engineering, mechanical engineering, tech-oriented engineering (a media-tech design programme called "medialogy"), and sustainability-oriented engineering, for which we chose a planning programme in environmental management (BEM). We recruited male and female participants at the start of their programmes, in proportions which reflect roughly the student population in each programme. Six participants signed up for each programme, and two dropped out in between the first and second interview, bringing the total number of participants to 16 over the entire study, listed in Table 2.

	Grouped per engineering degree programme		
Student (Pseudonyms)	Age (at the start)	Gender	Degree Programme
Elena	19	Female	Electronic Engineering
Jan	33	Male	Electronic Engineering
Claus	23	Male	Electronic Engineering
Vincent	32	Male	Mechanical Engineering
Jens	29	Male	Mechanical Engineering
Peter	19	Male	Medialogy
Helga	22	Female	Medialogy
Tomas	20	Male	Medialogy
Erik	22	Male	Medialogy
Kasper	19	Male	Medialogy
Johan	19	Male	Medialogy
Maria	21	Female	BEM
Poul	18	Male	BEM
Lykke	21	Female	BEM
Ana	20	Female	BEM
Cecilia	22	Female	BEM

Table 2. Participants in the study, grouped per engineering programme.

Interviews

All participants were interviewed in their first, second and third semesters. All participants were provided with a slide deck explaining the purpose of the study, the number of interviews, and how the data would be handled. They provided consent to record the interview and use the data before each interview. There were three rounds of interviews, shown in Table 4: one round at the beginning of the undergraduate programme during the introductory project period known as P0 (semester 1), one round after students completed their first full project, at the beginning of the project period known as P2 (Semester 2), and a final round at the end of P3 (semester 3), by which point students have completed their first full independent team project, are considered acclimatized to PBL as a learning method.

P0	P1	P2	P3+
• 1 month long • Focus on structural and problem-oriented competences. • Learning to write a report • Learning group-based assessment	• 2 months long • Focus on metacognitive and interpersonal competences. • Disciplinary scientific contents begins to be integrated	• 1 semester long • Project is oriented towards disciplinary scientific contents • Written evaluation of PBL competences	• 1 project per semester • Focus is exclusively on disciplinary scientific contents

Table 3. Structure and contents of student projects from P0 to P3 (adapted from Servant-Miklos & Kolmos, 2022).

Interview Round	Interview Structure	Question themes (based on categories from the literature)
R1 (Start P0)	Semi-structured, 45 minutes, same structure for all students. Questions not sent in advance.	Personal history; Reasons for choosing engineering; Sustainability awareness and interest; Sustainability actions related to 4 spheres of engagement
R2 (Start P2)	Unstructured, 45 minutes – 1 hour, following on from answers from R1. Questions not sent in advance.	Students asked to reflect on previous responses, and anonymous responses of others.
R3 (End P3)	Semi-structured, 45 minutes – 1 hour, but structure is personalised for each student based on previous answers. Questions sent in advance.	Sustainability awareness and interest Sustainability actions related to 4 spheres of engagement Reflections on relationship between students' specific field of engineering and sustainability Future perspectives on sustainability

Table 4. Structure of the longitudinal interview rounds.

All interviews were run by the first author, in English, to accommodate the language preferences of all participants and authors. The interviewer used a semi-structured approach: a list of key themes was kept in view during the interviews but no structured phrasing or order of questions was enforced (Waller et al., 2016). This was done to invite participants to lead the interview process, providing space for marginalized perspectives and participant agency (Lee, 2011; Sochacka et al, 2018).

Analysis

Thematic analysis does not require verbatim transcripts (Braun & Clarke, 2012), so the researchers used the audio recordings to not be weighed down by the large amount of data, with note-taking as a primary means of identifying important information.
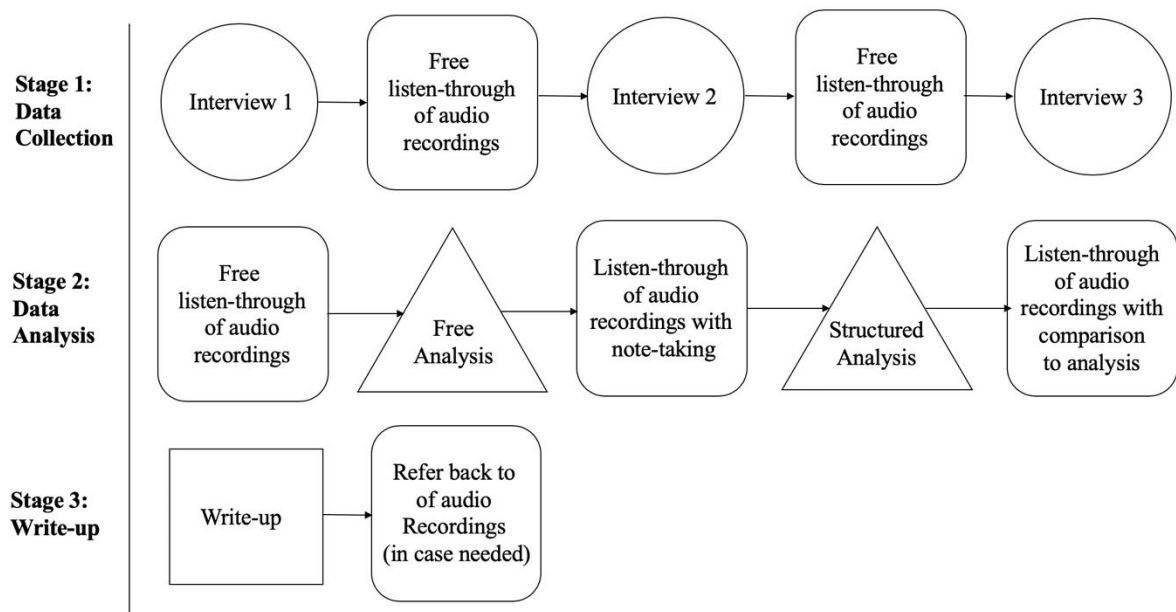

Figure 2: Longitudinal qualitative thematic analysis research method process map.

The interviewer (first author) listened through to the recordings between each round and drafted questions for the next round, as shown in Figure 2. Once all interviews were conducted, the first author listened to the audio files to perform a free analysis, meaning that initial ideas and thoughts were memo'ed without attempting to organize the analysis into codes. Then, the first author performed a structured listening round (looking for the theory-led categories mentioned above) and took systematic notes, summarizing key points made by participants, transcribing interesting quotes verbatim and operationalizing them into the established categories. The interview notes were shared with the other authors, then organised thematically in a collaborative process designed to increase the reliability of the findings. The themes from the literature and the data extracts were matched. The recordings were listened through a final time to ensure that the categories convincingly corresponded to the data, discrepancies were corrected by aligning the interpretation more closely with the data. During the write-up phase, if some quotes were missing or some interpretation was unclear, we referred to the audio files. The second and third authors acted as devils' advocated in the data analysis process to reduce researcher bias in the analysis process. The authors are from different institutions, different countries, and different disciplines which allowed for a diversity of perspectives to be reflected in the analysis. The first author is a psychologist from the Netherlands, while the second and third authors are engineering educators from Denmark, Having a

researcher external to the institution where the research was conducted as interviewer and first author reduced the risk of bias in the interview process (less likely to ask leading questions), and in the analysis (less likely to expect certain outcomes). Having internal researchers as second and third authors provided the analysis with an insider perspective and insider tacit knowledge to clarify difficulties in interpretation.

FINDINGS

Whereas the literature examined the categories of student relation to sustainability as discrete sphere, our findings present them as an evolutionary process of student sustainability awareness and interest on the one hand, and engagement on the other. The link between the two will be considered in the discussion section.

Increased sustainability interest and awareness

Our participants fell into four graduated categories of awareness and interest, based on the gradient criteria shown in Table 5. There was a propensity for them to shift from one category to the next as they progressed through their studies.

Category	Description	Illustrative quotes
Category 1: No interest, limited awareness	Students express no interest and little knowledge of sustainability issues.	**Johan (M; R2):** "I know it's a thing, but I don't know what to do about it… well, it's partly my own fault because I haven't looked up what I could do about it, but … this global warming, I don't know what I could do to help… *ignorance is bliss.*"
Category 2: Limited interest, basic awareness	Students show interest in sustainability issues, and express curiosity about the topic. They understand some of the drivers of those issues, and that these issues are getting worse, but are not interested enough to challenge their basic belief systems.	**Tomas (M; R2):** "I know about the effects that the meat industry has on a global scale, but I would never really consider becoming a vegetarian because I like the taste of meat... I think it's part of a healthy diet and all the like, and perhaps it's also a bit… we have climbed our way to the top of the food chain, we have opposable thumbs, we deserve to eat meat."

Category 3: basic interest, basic systemic awareness, high domain-specific (disciplinary) awareness	Students are sufficiently motivated to actively seek out news on sustainability, to pick up on the issue when it is raised in their studies, and to involve it in their PBL projects. While they have a good basic awareness of sustainability issues, they tend to focus on disciplinary aspects of sustainability, often at the expense of more systemic understanding.	**Helga (M; R2):** "In the 2nd semester we had the options of working with exercise or food waste, and I was very excited about working with food waste and I actually got to do that and that sparked an interest in how I could continue to work with these things."
Category 4: High interest, high systemic awareness	Students are actively interested in sustainability issues, and try to integrate these issues in their studies and as part of their lives. They show a good understanding of the scale and scope of sustainability issues, and understand the complex systems in play in tackling sustainability issues.	**Lykke (BEM; R2):** "there's a lot of individual people, or small groups, especially with plastic or with how you need to stop using plastic straws or something, there's a lot of small, individual groups of people saying – "this is bad" (…) but it's not only the plastic straws that need to be dealt with, it's the whole plastic industry."

Table 5. Categories of sustainability interest and awareness in students.

Figure 3 below depicts the evolution of sustainability interest and awareness throughout the study:
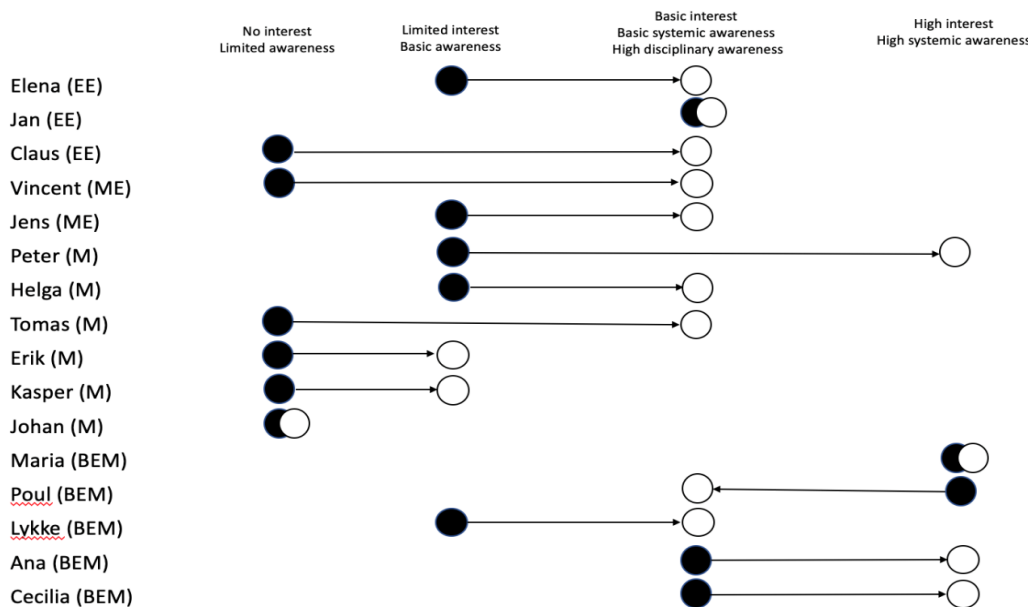

Figure 3. Evolution of sustainability interest and awareness between R1 and R3. Black circles mark the starting point, white circles mark the end point.

Interpretation of the findings

Category 1: no interest, limited awareness. Six of the students interviewed could be classified in Category 1 at the start of P0, and only one could be classified as such by the end of P3. There were three rationales offered for this initial lack of interest and awareness. The first was that the students were devoting so much cognitive bandwidth to their studies that they didn't have time or energy to get informed about sustainability issues.

The second was that personal issues meant that the students were more focused on their immediate worries than about global problems. They consider sustainability to be a luxury problem compared with immediate issues like financial worries:

> **Claus (EE; R1):** I don't really know what I would do if my house was submerged in water. I mean it's not really things that I worry about daily. I have other things to worry about, like how I survive the end of the month.

The third was that in the absence of obvious strategies to solve sustainability problems, students prefer not to worry about it, as a kind of learned helplessness.

> **Vincent (ME; R1):** Pfff, I haven't really given [sustainability] much thought, and I don't… I try not to interfere with stuff that's out of my reach.

Students in Category 1 tried to keep sustainability concerns at bay, out of their studies and out of their lives. We saw a large shift away from this category as students acclimatized to PBL.

Category 2: **limited interest, basic awareness**. Five participants could be classified in Category 2 at the start of P0, and two could be classified as such at the end of P3, demonstrating another shift towards increased yet limited sustainability interest and awareness. For these students, we noted expressions of cognitive dissonance associated with this knowledge. Cognitive dissonance can be defined as an attempt to reconcile incompatible beliefs and actions and is a common reaction to increased sustainability awareness (Stoll-Kleeman et al., 2001), as noted in the above-quote from Tomas (M). One strategy to resolve cognitive dissonance was providing moral mitigation to make the belief-system fit with actions: "we deserve to eat meat". Another reaction to this basic level of awareness was conflicted emotions, and technological escapism:

> **Elena (EE, R2):** I've been in this denial thing, "oh this will affect my children, my grandchildren", but then I've learned that it is happening now, so it is affecting me, so I've gone to "I sort my plastic, I sort the waste and I don't use plastic straws and all that stuff". It's not enough to make it OK. So, I'm also a bit in despair, well, we're kinda screwed, let's go to Mars!

In contrast to the first category, students in Category 2 expressed sustainability concerns, but resorted to psychological deflection to avoid delving too deep into the subject. Whilst this was the endpoint of the sustainability journey for two of the medialogy students, the rest also shifted towards further increased awareness and interest.

Category 3: **basic interest, basic systemic awareness, disciplinary awareness.** Three participants could be classified in Category 3 at the start of P0, and nine could be classified as such by the end of P3. This was the most common status of sustainability awareness and interest for students by the end of P3. One of the drivers for this was the prominence of sustainability issues and eco-celebrities in mainstream media:

> **Jan (EE; R3):** I think it's great to have someone with a network like Greta Thunberg has got now. The network she has built, the organisation around her, it moves something.
> **Jens (ME; R2):** Maybe I'm listening too much to Elon Musk. He thinks we can solve all the world's problems by shooting rockets to Mars.

The result was a foundational knowledge base on sustainability issues, and an interest in finding out more. In this category, there was also specific knowledge and interest in one or several disciplinary domains. This specific interest appeared to be triggered by a PBL project on a sustainability theme, or a class on sustainability within the curriculum.

> **Vincent (ME; R3)**: We had a lot on the mechanical properties of plastics, we had a lot on microplastics - the lecture definitely was an eye opener for me. I'm definitely thinking about it more than I used to.

However, the more students focused on their domain of interest, the more they tended to lose sight of the systemic picture.

Category 4: High interest, high systemic awareness. Only two participants could be classified in Category 4 at the start of P0, and four could be classified as such by the end of P3. All the students who achieved this level of interest and awareness were already interested and aware before their studies, but pushed it further during their degree programme.

> **Peter (M; R3):** I've realised how much of a huge deal it is, it's bigger than all of us…. When I saw how close we are, that we have a deadline, by 2040, we need to change. And that kind of woke me up, like, yeah, this is really messed up.

This level of awareness correlated strongly, but not exactly, with public sphere engagement, as we shall see in the next section. Systemic awareness was most prominent in the BEM group, and Cecilia (BEM) credited the study programme for this:

> **Cecilia (BEM; R2):** I think there's a lot in my personal life, but also, I think also the studies because you read about all these things that are being done and the possibilities on what more can be done, and that motivates you.

There was likely a selection-bias at the start of the programme, as students who are already aware and interested in sustainability are more likely to opt for environmentally-oriented studies (Prevot, Clayton & Mathevet, 2016).

Interpretation of Exceptions. Overall, there was an increase by one or two categories among the participants. There were three exceptions, which could be explained individually. Johan (M) was truly afraid to delve into the subject and lived by his motto than "ignorance is bliss". He would rather not know at all, than know, and then need time to build up sustainability competences to address his anxiety. Jan (EE) was already aware of sustainability issues, but he found the subject too depressing to go further, given his other personal issues. Therefore, these students did not progress in their sustainability interest and awareness for personal reasons. Poul is an interesting case: he became less systemically aware of his own volition to focus on energy, from the disciplinary standpoint of theoretical physics. He explained this change as a result of conflicts with his BEM project team, prompting him to leave the BEM programme altogether – this is further explored in the next section.

Broadening engagement

Viewed from a pragmatic lens, we identified a progression from disengagement to private sphere engagement, to professional engagement and in some cases, public and institutional engagement, shown in Table 6. The relevance of these findings for a relational lens will be addressed in the discussion.

Type of Engagement	Description	Illustrative quote
Disengagement	Students are unwilling to get involved in action for sustainability.	**Johan (M; R3):** "I don't want to focus on this, I don't want this to be who I am, even though it might be necessary for our survival. It's just difficult, yeah?"
Private Sphere	Students take private actions towards "sustainable lifestyles", primarily by making responsible consumer choices, minor adjustments to their lifestyles, voting "green" and donating to environmental charities.	**Elena (EE; R3):** "I don't think it's something I'm going to spend a lot of money on, or a lot of time on, like actively going to protests… But I will do what I can from where I am now, when I vote for political parties or just generally talk to other people about this".

Professional sphere	Students incorporate sustainability into their professional plans, defining themselves as working towards sustainability as technical experts.	**Jens (ME, R3):** "When I'm done with my education I would like to work with some company who takes their responsibilities."
Institutional sphere	Students form groups to pressure the university into adopting sustainability policies.	**Peter (M, R3):** "I'm starting my organisation because I don't think the study is focusing on [sustainability] enough. I don't think any study is"
Public sphere	Students join environmental movements in and out of the university, seeking to push for change on sustainability through changes in politics and civil society.	**Maria (BEM; R3):** "I have been taking part in critical mass rides, where you are blocking the roads as a cyclist."

Table 6. Categories of sustainability engagement among students.

We saw a tendency towards a build-up through the categories, with students going from disengagement to private engagement, then in nine cases adding professional engagement, then in three cases adding institutional and public engagement on top of the previous two. However, this does not imply a progressive process in which public engagement is the outcome, as shown in Figure 3.
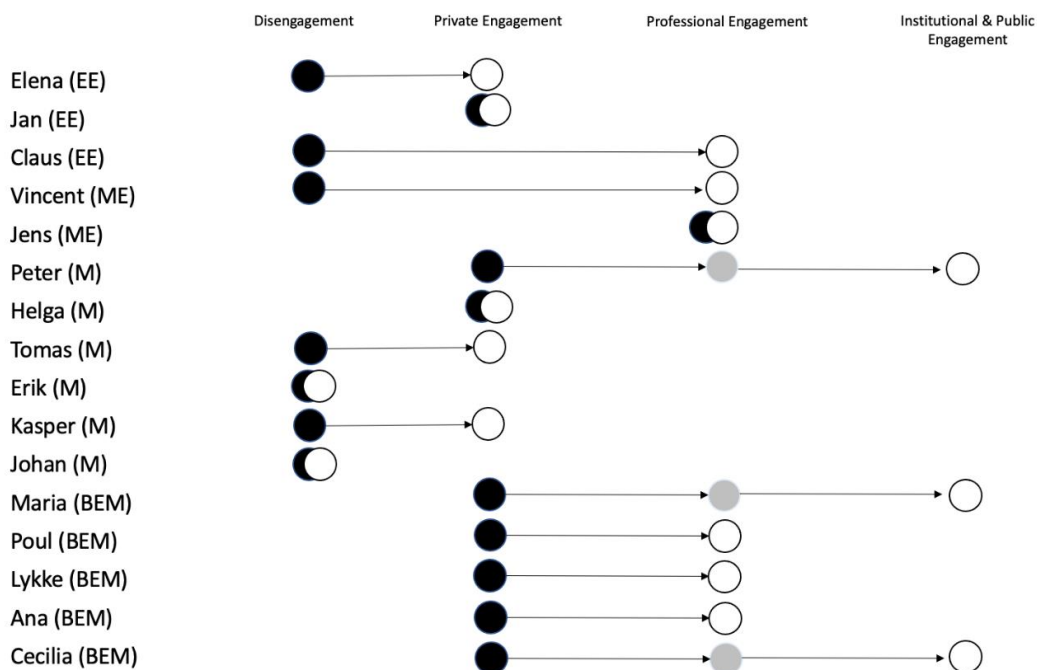

Figure 4. Evolution of sustainability engagement between R1 and R3. Black circles mark the starting point, white circles mark the end point, grey circles mark an intermediary position.

Interpretations of the findings

Disengagement. Seven of the participants were "disengaged" at the start of P0. This correlated strongly but not exactly with participants who also had no interest and limited awareness of sustainability issues. Disengagement was explained mainly as a lack of (knowledge about) possibilities – students felt that there was nothing they *could* do:

> **Vincent (ME;R1)**: During the past year we have read a lot of texts and received a lot of information about global warming and stuff like that and of course that's a worry of mine but there is nothing I can do about it right now.

By the end of P3, only two students were still disengaged, the shift towards engagement coinciding with the shift towards greater awareness and interest. The two remaining disengaged students *knew* what could be done, but feared that if they engaged, they would confront themselves with the colossal scale of the problem, and that would disturb their core professional identity, e.g. as a video game developer:

> **Johan (M; R3):** I guess I'm worried that I'm going to focus too much [on sustainability]… I'm worried I'll feel compelled to do something about it and that compulsion will divert me from doing games, and I don't want to do that.

All other participants engaged with sustainability to some extent by the end of their acclimatization period. But the scope of engagement differed among them.

Private engagement. Eight participants were engaged in this manner at the start of P0, including all the BEM students. By the end of P3, three participants who were previously disengaged had also begun to engage in the private sphere – primarily through voting for green parties, donating money to environmental charities, recycling and eating less meat.

> **Tomas (M; R3):** You can donate one dollar to that charity, and they'll plant a tree for it. […] I've donated to it because, again, obviously, as a student I can't do that much but I've done something, I've done my part.

All participants who engaged privately at the start of their studies continued to do so as they expanded the scope of their engagement. Broader forms of engagement therefore built on top of, rather than replacing private engagement. There were two exceptions to this – Vincent (ME) and Claus (EE) went straight from disengagement to professional engagement. In some sense, because they discovered the severity of sustainability problems during their studies, they immediately channelled these concerns into their professional potential as engineers.

Professional engagement. Only one participant was professionally engaged with sustainability issues at the start of P0. This was an older student, who joined engineering education later in life precisely because of his admiration for the power of engineers to transform the world through technology:

Jens (ME, R1): I'm just going to be a small pawn in the big game but I still want to play my role in trying to solve problems like that. I want to leave a legacy with my engineering job, if possible.

The other participants did not have clear ideas about how they could contribute sustainability through their engineering careers at P0. However, nine of them developed concrete aspirations to work within professional sustainability pathways by P3. Six out of these nine participants did not develop other forms of engagement, and did not want to do so. They expressed a strong preference for solutions that optimize existing processes, with a focus on rapid technological change:

Lykke (BEM; R3): I would like to make environmental solutions to existing problems. […] I personally feel like that's the way that is easier to transition into. In my opinion the problem is that you have to get everybody involved in it, and not just a few doing something radical. The easiest way to do that is to get the technology transition... It's the everyday technology.

Three participants who engaged professionally also engaged institutionally or publicly. Their professional-sphere engagement was less focused on technology, and more focused on societal change.

Cecilia (BEM, R2): I still think there needs to be some kind of political intervention about how we are doing or how we are living, we can't just rely on the technology to improve that much in the time we have.

Institutional sphere. One student, Peter (M), founded an organization within the university to pressure the study boards into including sustainability contents into the curriculum.

Peter (M, R3): The reason I'm starting my organisation is because I don't think the study is focusing on [sustainability] enough. I don't think any study is.

Institutional engagement did not seem to be a prominent feature of this engineering Faculty's "culture". None of the other students mentioned it.

Public sphere engagement. There were no participants who engaged in the public sphere at P0. Some of the BEM participants expressed a desire to do so, but were not sure how to go about it. By the end of P3, two BEM participants were engaged with environmental movements. Their engagement correlated with systemic sustainability interest and awareness. Cecilia (BEM) joined the *Grønne Studenterbevægelse* (Green Student Movement), a political group focused on creating societal pressure for change through education and information. Maria (BEM) joined Extinction Rebellion, a civil disobedience environmental group. They both also expressed commitment to a career in sustainability management. Their public sphere engagement added to their professional

engagement, rather than replacing it. They justified public sphere action as a frustration with the slow pace of change compared with the urgency of the crises, and the perceived inadequacy of their studies in rising to the challenge.

> **Maria (BEM; R3):** I feel less alone, I feel like I have a place, and people who want to do just as much as me…. On another level than the studies.
>
> **Cecilia (BEM; R3):** I've been looking for this community of other people who think this is important because I didn't find it here in my studies.

They both expressed frustration about not finding like-minded people in their studies. In fact, public sphere engagement was generally viewed negatively by other participants:

> **Lykke (BEM; R3):** I was in a meeting for the Student Green Group, I heard what they said, it was OK, but I also felt that what they said was more… just to bring attention to the problem and not doing anything about it.
>
> **Ana (BEM; R3):** I don't like Extinction Rebellion. I don't like Greta Thunberg. She had some beautiful views in the start but she was corrupted. She has done some good things but now she should stop. Instead, we should educate people. Education is the best thing we can do. I think some of the extremes we have are very extreme and that's going to backfire.

In summary, two of BEM participants engaged in the public sphere by their third semester. However, they were out of step with other participants who trusted in individual action and professional engagement only. Institutional engagement was almost non-existent.

DISCUSSION

The outcome of a theory-led thematic analysis being to relate categories developed in the established literature in the field to the interpretations that emerge from new data, we will evaluate the contribution of our data to concept development in the field.

A dynamic interpretation of interest, awareness, and engagement

While the categories of interest, awareness and engagement in the ESD literature reviewed in our empirical underpinnings section have been treated as discrete, we uncovered a progression in interest, awareness, and engagement for most participants. There was an alignment between the development of interest and awareness, and engagement – although engagement was concentrated in the individual and professional spheres. We can suggest two causes for these shifts.

The first might be traced to what mainstream media termed a "Greta-effect" (Nevett, 2019), according to which the media presence of prominent climate campaigners spurred a world-wide increase in awareness and interest in sustainability among young people.

As extreme weather intensifies with climate change, it may also be harder to stay insulated from awareness of the problem.

Secondly, the literature suggests that PBL may have an advantage in raising sustainability awareness and interest among students (Affolderbach, 2020; Lozano et al., 2017). While our findings seem to support this, it was not clear whether PBL had an advantage over regular lectures in introducing students to sustainability issues, since both were mentioned by students as factors triggering interest. Based on Lozano et al.'s 2017 analysis of the impact of pedagogy on sustainability awareness, however, we could infer that the "real-world" nature of the PBL project problems encouraged awareness and interest, as shown for instance by the quote from Helga (M, R2) but this is hypothetical.

We identified several differences between the engineering disciplines we examined: there were higher levels of systemic awareness among BEM students, whose sustainability-focused programme includes inputs from social sciences. Perhaps broader interdisciplinarity that includes social sciences and humanities inputs might further encourage systemic sustainability awareness (Servant-Miklos & Noordzij, 2021; Maina-Okori, Koushik & Wilson, 2018; Walsh, Böhme & Wamsler, 2021). While there is a selection bias towards environmentally aware students within the BEM programme (Prévot, Clayton, & Mathevet, 2017), other engineering disciplines could still offer appealing sustainability problems and contents within their field. The institution has taken some steps towards this: for instance, through "Mega Projects" that engage teams from different engineering disciplines to address wicked sustainability problems, but this remains engineering-focused (Kolmos, Bertel, Holgaard, & Routhe, 2020).

Engineering identity and dimensions of sustainability engagement
A core debate in the literature on student sustainability engagement also played out in our data: what counts as engagement? What the extant literature that we examined left out but which came out of our analysis, is the role of professional identity in defining engagement (e.g. Maria, Lykke, Ana).

The pragmatic view generally held in engineering education compartmentalises engagement within discrete spheres, as shown in our literature review. In this view, engineering faculties have a responsibility to foster professional engagement by training engineers who understand the stakes, are conversant in the latest technological breakthroughs, and can operate within a sustainability-driven global market. In line with this view, sustainability competences have been added to the package of generic engineering competences expected of graduates (Holgaard & Kolmos, 2019).

Our findings indicate that this professional emphasis impacts students' engineering identity formation, as shown in the conflicting viewpoints brough forward by Maria,

Lykke and Ana in the section on public engagement. Tonso's (2006) seminal study on engineering identity showed that university campuses were cradles for identity formation, and "campus culture" (p. 35) was critical to determining the engineering identities that emerged. In that regard, the history of the institution we studied is illuminating. Historically, the Faculty of Engineering has distanced itself from political discourse, emphasizing its ability to create work-ready engineers as a unique selling point among Danish engineering programmes (Servant-Miklos & Spliid, 2017). The faculty's focus on professional competences has yielded positive results, with students rating their sustainability competences higher than other Danish engineering graduates (Kolmos et al., 2020). However, our findings suggest that students may narrowly focus on professional engagement: some of the students we interviewed expressed indifference, suspicion, or outright hostility towards other forms of engagement. The most vociferous arguments about professional and public sphere engagement occurred *between* members of the BEM programme, suggesting that identity questions flare up around sustainability engagement when interdisciplinarity increases. Such arguments may negatively affect students' study experience - as shown by Poul's decision to leave BEM entirely. Alongside increasing interdisciplinarity, it might therefore also be good practice to explicitly address engineering identity formation through appropriate reflection practices.

The relational view argues that pragmatic distinctions between spheres of engagement obscure the political relatedness of all forms of engagement, thereby impeding collective action for change (Ferreira, 2019; Walsh et al., 2021). A critical analysis might suggest that views ostensibly described as "pragmatic" support a status quo which thrives on the separation of spheres of action and depoliticization. However, while relational discourses may resonate with humanities and social sciences students who are used to thinking the personal in political terms, there may be too wide a cultural gap within engineering education for this to land. Yet, a growing consensus around engaging education to push social tipping-points for the sustainability transition leaves no doubt as to the necessity and urgency of widening the scope of engagement, including in engineering education (Otto et al., 2020).

One avenue to explore to bridge pragmatic and relational viewpoints in engineering education could be institutional engagement. Van Poeck and Östman (2018) and Håkansson et al. (2019) suggested that the democratization of norm-setting within the institution could create space to discuss contentious issues without a pre-established normative agenda. Offering possibilities and encouraging students to engage within the Faculty, through democratic student bodies, academic affairs councils and other dedicated groups could create space for students to experiment with their own agency, modulating between different spheres of engagement. This could challenge the exclusionary dominance of professional engagement within the campus culture shown in

the "public engagement" section of the results. Peter offers an example of how this might work: he built a group within the Medialogy programme to advocate for more sustainability contents in the courses – with none of the backlash that students engaged with political movements experienced. There are experiences from the literature one could borrow from (e.g. Spalding, Williams & Wise, 2014). Thus, practical competences for engineering students could be broadened to include norm-building within academic institutions, aligning engineering education with recent theory-practice developments on norm-building in sustainability education (McGregor & Christie, 2021).

CONCLUSION

We found a pattern of increased sustainability awareness, interest, and engagement throughout the three semesters of this study. The data offered a more dynamic inderstanding of the relationship between the three categories of awareness, interest and engagement. Differences between engineering disciplines were visible, especially between sustainability-oriented engineering and the others, but there were also differences within the BEM group. Most students who increased their sustainability awareness and interest were also likely to take some form of action. Engagement built up from private engagement to professional engagement, and for some, into institutional and public sphere engagement. However, a large group of students resisted public engagement, likely related to engineering identity and "campus culture". We suggested developing institutional engagement as a potential bridge between these conflicting norms and identities.

Practical Implications
There a several implications for PBL engineering education from these findings. First, since increased awareness and interest tends to increase engagement, it might be productive to increase emphasis on sustainability issues at the start of students' studies, particularly in more traditional engineering programmes that don't focus on sustainability. Second, professional identity development might usefully figure more explicitly and prominently in the PBL process. Servant-Miklos & Kolmos (2022) have suggested that this could be integrated in broader reflection practices around the projects. Third, institutional engagement might be made more accessible to students, for instance, by publicizing the work of committees, councils and other university organs working on sustainability, while offering concrete avenues for students to participate in institutional work on sustainability, including through their PBL projects.

Limitations and Future Perspectives
This study was limited by the qualitative design, which renders the results transferrable, but not generalizable, due to the small sample size and purposive sampling method. But

such a qualitative study sets the scene for future research to delve deeper into the specific issues raised herein, such as a study focused on the impact of PBL projects in fostering sustainability awareness and interest at the various stages of the project, and the impact of engineering identity and "campus cultures" in affecting modes of sustainability engagement, including institutional engagement. It would also be beneficial to design quantitative studies to investigate the generalizability of the of the findings presented in this paper. The study is also limited by the pre-covid data collection: sustainability is a fast moving field and covid may have impacted perceptions of sustainability issues. A follow-up post-covid study would therefore be of scientific interest.

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