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Exploring the Near Future or Next Practice of Problem-Based Learning

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INTRODUCTION

Dear Reader,

Problem-based learning (PBL) has become a widely accepted pedagogy in many higher education institutions. However, emerging trends increasingly invite us to challenge, develop, criticise or expand our conceptualisations and practices of PBL.

One such trend is the digitalisation of higher education, where digital technologies are reshaping not only disciplines, but also how lecturers teach and supervise, how students collaborate, and how lecturers and students can practice PBL. New blends between online and on-site teaching and learning are emerging and enabling the development of new hybrid PBL models that seek to harness the opportunities afforded by digital technologies while remaining firmly grounded in a commitment to students' mutual learning, sense-making and collaborative engagement.

Another trend is the institutionalisation of PBL in higher education. Rather than PBL being pursued mainly in single courses by individuals or small teams of lecturers, we are seeing a move towards institutions increasingly challenging traditional teaching models in higher education and rethinking programmes, the curriculum, or even the entire institution according to principles of PBL.

Finally, a trend of conscientisation is emerging, where PBL is seen as a means to raise critical consciousness around issues such as environmental and social sustainability.

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Rather than simply being an effective teaching strategy, PBL is increasingly seen as a pedagogy for students to engage as critical change agents with complex real-world grand challenges such as sustainable development, social justice and equity.

These trends together can potentially trigger the design and development of entirely new types of PBL models and environments that explore hybridity across different dimensions such as online/offline, disciplinary/interdisciplinary, local/global, and group/complex network and encourage higher education to move beyond a narrow focus on disciplinary competences and employability towards engaging students as critical learners and change agents who actively participate in an increasingly complex, global and network-based society.

This special issue presents ten research papers that challenge, develop, criticise and expand our current conceptualisation of PBL from different theoretical, conceptual and methodological perspectives and contribute to further explore and unfold visions for the near future and next practice of PBL. In this way, this special issue is aimed at an audience that is actively involved in developing near future and next practices of PBL as well as the theoretical and methodological frameworks for understanding, analysing and envisioning such PBL practices.

The papers address these emerging trends, changes and practices on different levels, at a student/individual, student/group, course/curriculum, and institutional level.

The first paper (Scholkmann and Lolle) analyses the engagement of students from different study programmes in a series of reflective activities aimed at making them more aware of their professional competence development. Their reactions were analysed and the insights gained are summarised into a model that can help teachers to design pedagogical opportunities for meaningful reflection in higher education.

The second paper (Clausen) investigates the development of attitudes and behaviours conducive to self-directed learning in Bachelors students enrolled at a PBL university, applying a statistical instrument. The study reveals that the students become more self-directed throughout their studies, and that the progression happens in two distinct steps. Students develop their ability to be self-regulating during their first year and gain more confidence in their ability to administer and direct the processes during their second. The paper provides possible theoretical explanations for this development, as well as implications for near future and next practice of PBL.

The third paper (Velmurugan, Stentoft and Davidsen) presents findings from an analysis of the interactions in a group of PBL engineering students. The study focuses on the negotiation of disagreements between group members and suggests that conversation structure has a profound impact on whether any given student suggestion is accepted and implemented in the group project. The paper contributes to the area of student-centred problem identification, which is an under-researched and hard to access area of PBL, and suggests further studies to elaborate on the findings.

In line with this, the fourth paper (Gyldendahl Jensen, Gade, Madsen, Andersen and Olsen) applies Dewey's concept of sequential inquiry processes to create and test new ways of scaffolding PBL learning sequences to help students grasp some of the abstract learning concepts that characterise PBL, such as "problem and theory identification" and "designing the prototype". The results suggest that the students achieved an increased understanding of the concepts and understanding of the processes of problem-based work. The discussion suggests that the increased scaffolding might hamper students' development of self-directed learning, but that the trade-off might be worth it, particularly during the first few semesters.

The fifth paper (Svarre Kristensen, Bruun-Pedersen, Kofoed and Andreasen) addresses these themes at a curriculum and semester level and looks at IT initiatives to help better integrate courses and project work into a PBL semester. The findings suggest that a shared language to support interdisciplinary communication and coordination across all activities of a semester can mitigate some of the problems of integration, but that it requires a large investment of time and effort. A common semester theme is suggested as something that might help support cooperation and integration in current and near future PBL practices.

In line with these reflections on digitally supported PBL, the sixth paper (Simboeck, Marksteiner, Machacek, Wiessner, Gepp, Jessenberger, Weihs and Leitner) presents findings from a survey study conducted in the immediate aftermath of the Covid-19 pandemic lockdown, which included a switch from hybrid on-/off-site sessions to a completely online teaching format. The findings suggest that the on-site activities were particularly difficult, if not impossible, to replace with online sessions in a satisfactory way. The hindrance to communication and the lack of access to laboratories during the lockdown especially were very difficult problems to mitigate, which highlights important questions and challenges related to online and on-site teaching and learning in future potential hybrid PBL models.

The seventh paper (Boelt, Kolmos and Bertel) investigates the prevalence of formulations of generic competences in formal curricula at a PBL university. The findings suggest that the curricula have very few explicit mentions beyond the first semester, thus risking that such knowledge, skills and competences become tacit to the point where expressing and relating these to the development of a professional identity might be hindered. The authors argue that this problem might be mitigated by the revision of curricula with integrated generic competences throughout, suggesting that an elaboration of generic competence frameworks is needed for these to be properly integrated in future PBL curricula.

The eighth paper (Nariman) investigates how PBL can be applied to increase low-income native Hawaiian students' interest in and motivation to enter the STEM-related workforce through a coherent set of experiences. The findings suggest that technology-enhanced PBL with a focus on STEM and industry collaboration allowed the students to develop interest, motivation and capacity, and that the students' exploration of the impact of problems in their local area especially helped them understand the severity of the problems and thus motivated them further.

The ninth paper (Montoya, Peterson, Kinslow II, Fruchter, Fischer and Bustamante) is an investigation of project-based Applied STEM Career and Technical Education (AS-CTE) workforce pathways in Silicon Valley, and the barriers historically marginalised groups face when trying matriculate into the highly skilled workforce. Through ethnography, the authors observed that when social mobility was added as a metric of high quality PBL in a predictive ontology framework for education success, an improved level of attendance was observed, thus arguing for social mobility to be added as a metric of near future and next practice PBL AS-CTE program outcomes.

Finally, the tenth paper (Bertel, Kolmos and Boelt) explores normative scenario thinking as an approach to educational development, presenting the first steps and initial findings from a process of normative scenario development within a PBL university. The aim of this process was to identify and extrapolate key trends and core values informing the development of future scenarios for the conceptualisation and implementation of PBL at the university in a digital age. The methodology is exemplified through the analysis of a specific scenario related to project variation and reflection, and the initial results show how value-based and problem-oriented approaches to scenario development can support collaborative exploration of emerging futures, facilitating innovation and transformation in PBL models at a systemic level.

We hope that you will enjoy reading.

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Opportunities, Challenges, Tools and Helpful Relations. Development of a Model of How to Foster Reflections in Higher Education

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ABSTRACT

This paper presents a model which can be used to help teachers to design pedagogical opportunities for meaningful reflections in higher education. Within the PBL Future initiative of Aalborg University, we worked with a group of students from different study programmes and levels. In a three-semester long process these students engaged in a series of reflective activities aimed at helping them become more aware of their professional competence developments. In an iterative process we analysed their reactions to and interactions with a set of given reflective tasks (both face-to-face and online), and with the research team. We summarise our insights into the complex dynamics of reflective processes in a model which conceptualises reflections as taking place as interplay between opportunities, challenges, tools and helpful relations, and with inspiration from the outside world.

Keywords: Reflections, reflection model, problem-based learning, higher education, competence

INTRODUCTION

> "[Researcher:] When it comes to speaking with people outside the university, it's not about saying 'How am I going to make myself be the number one?' or 'How do I compete?', but of course, when you are in an interview situation, you want to…
>
> [Student:] So, you mean, it will be more about, what you call that, more about 'How *I* will be able to do the job?', rather than 'How *good* I will be in it?'"
>
> (Transcript talk with student Amar, February 2019)

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The above citation was part of a longer conversation between a student and two members of our research team in which they elaborated on how this student could communicate the competences that they acquired while studying to an outside audience of employer representatives. It is a good example of the reflective and transformative processes that can occur, facilitated in this case by communication, when students engage in understanding what they are capable of as individuals in a world beyond university. However, the citation also illustrates the challenging nature of the act of reflecting, and the difficulties students encounter on the journey to owning their learning experiences.

That students struggle to perceive themselves as competent and capable individuals can also be observed throughout the study programmes at Aalborg University (AAU): Although the development of transferable competences lies at the heart of AAU's Problem-based Learning (PBL) model (e.g., Holgaard et al., 2020), it seems that many students experience difficulties in translating the learning outcomes from courses and projects into reflective, personal and communicable professional competences in new situations. This is the case even though many of AAU's students are provided with space for reflection on their learning and development as part of the respective curricula. These problems point to more general challenges around students' struggles to produce reflections on their personal and professional competences at the end of their studies (e.g. Johnson & Ulseth, 2016; Roters, 2015; Scholkmann & Huckfeldt, under review), despite studying in problem-based and/or research-based curricula.

As part of a larger initiative throughout AAU we have researched the processes that students undergo when engaging in reflections around their professional and communicable competence development. In a qualitative approach, inspired by action research and design-based research methodology, students from different faculties and study programmes were invited to find their own "language of transcendence" (Ryan & Ryan, 2013, p. 246) regarding the communication of their professional competences to each other, as well as to an outside audience, being representatives of the respective target industries of their studies. Their individual reflective activities (both analogue and digital) were supplemented with face-to-face meetings with peers and facilitators, which were continuously analysed by the research team.

Besides gaining insights into students' individual competence trajectories, our engagement with the students in this project has also led us to explore and analyse the pedagogical architecture and the elements that we used to engage students in reflections. We have collected these elements, whether tacit (such as concrete tools or assignments) or ephemeral (such as conversations or concrete activities and practices), in a model for reflective practices that can inform teachers and facilitators when designing pedagogical architectures that comprise reflective elements

In the following we will present this model and its theoretical and empirical underpinnings. The model is the result of a three-semester research activity in which we worked with, and researched the reflections of, eleven students participating in our project on a voluntary basis. We see our model as a supplement to existing proposals on how to foster reflections in students (in problem-based education, and beyond); our model adds to these by focusing on the concrete practices of engaging students in reflections. Hence, the research question addressed throughout this article will be: Which elements constitute the concrete practices of facilitated student reflections, and how these can be described in order to inform the design of pedagogical architectures to engage students in reflections about their professional competence development?

THEORETICAL UNDERPINNINGS

The role of reflections in the learning process

Following relevant theorists, reflections can be seen as nothing less than what lies in the heart of any meaningful learning process (for an overview cf. Rogers, 2001). Specifically, following Mezirow (1991), reflections can be considered the cognitive, social and emotional enterprise which transfers concrete experience into abstract learning (cf. also Ryan & Ryan, 2013). However, reflections within the context of formal education must be distinguished from private or everyday reflections (e.g., Moon, 2013), with the former being "academic" or "professional" (Ryan & Ryan, 2013, p. 245), i.e., serving the purpose of facilitating students towards critically scrutinising theory and developing a professional identity (cf. also Boud & Walker, 1998).

A fair amount of the theory and research around reflections is concerned with describing potential dimensions of the content and complexity of reflection. Some theorists have put an emphasis on the *processual nature of reflections*, and classified them in terms of occurring before, during or after an experience. Examples here are Schön's reflection-in-action vs. reflection-on-action (Schön, 1983), Loughran's anticipatory, contemporaneous and retrospective reflection (Loughran, 1996) or Mezirow's thoughtful action vs. retroactive reflection (Mezirow, 1991; cf. also Rogers, 2001). Another group of theorists focuses on the *content of reflections*. For example, Mezirow (1991) identified content, process and premise as potential focus points of reflections; other authors have distinguished between reflections on learning content, learning strategies and personal beliefs/values (Jenert, 2008) or added reflections on (learning) contexts to this list (Du et al., 2020).

Additionally, there have been calls to distinguish between different levels in the depth of reflections. Qualitative distinctions are made between reflections directed towards reporting/describing, responding, relating/justifying, reasoning/critiquing and reconstructing/discussing (e.g., Bain et al., 2002; Leijen et al., 2012) or between various levels of elaboration in the sphere of deep and transformative reflections (e.g., Grossman, 2009). Although similar to the content-process-personality continuum mentioned before, we think these types of distinctions constitute a class in itself, which can be labelled as *complexity and transformativity of reflections*. The idea of (certain types of) reflections being transformative in nature has permeated the literature on this concept for many years. A transformative reflection is seen as leading to change in individual or collective assumptions (Mezirow, 1997) – something that we were also aiming for in our project with respect to students' understanding of competences as being personal and transferable. Transformative or critical reflection requires scrutiny not only of learning content and strategies, but of one's own assumptions, values and ability to re-visit previous reflections to interpret them in new lights (Grossman, 2009; Kemmis, 1985). Therefore, circular and spiral models are advocated as leading towards this type of reflection (for an overview cf. e.g., Mills, 2014, p. 18).

Reflections within problem-based educations

In the sphere of problem-based and project-based education, reflections have held their core place within the learning process, although with a slightly different angle than in more traditional pedagogical approaches: In PBL and its relatives such as inquiry-based, research-based or challenge-based learning, reflections are conceived as occurring as an integral part of the learning process (Scholkmann, 2016).

It seems almost intuitive that, when working with complex problems, students must necessarily reflect on their existing knowledge, their use of strategies and the personal and contextual meanings and conditions they are working in. Consequently, both traditions of PBL practices (i.e., the more cognitively oriented Maastricht tradition and the more pragmatically oriented Aalborg tradition) aim not only for reflections on learning content and strategies, but for scrutiny of fundamental conceptions and underlying beliefs – hence for some form of transformative learning. In addition, reflecting upon learning experiences has recently been argued as being at the heart of students' competence development, since only through critical reflection can concrete experiences be brought into a state that makes them transferable to new situations (for an overview cf. Scholkmann et al., forthcoming).

All study programmes at AAU explicitly state reflective competences as part of the intended learning outcomes. For example, in the Bachelor of Health Technology students in the first semester are expected to reflect on and develop their own learning, and in the second semester reflect on their own learning process, the organisation of group cooperation and solutions for possible problems or conflicts in the group, an their professional role within the healthcare system.[1] In the Bachelor of Nanotechnology, students in the first semester should reflect on the study format of PBL and their experiences with this. They should also reflect on and develop their own learning process and reflect on their professional work in connection with the surrounding society.[2] However, these reflections are mostly limited to the scrutiny of a) the application of theory to the problem at hand, b) the group process and c) the competences as a professional (cf. Lolle et al., forthcoming). What they mostly lack is a clear pedagogical vision about how a transformative and/or transferable competence reflection can be achieved (for a first exception, cf. Holgaard et al., 2021).

However, as we discovered in our work, the starting point for any reflective process in (formalised) higher education is a pedagogical architecture that offers certain degrees of structure and scaffolding (cf. also Tucker et al., 2003; Zarezadeh et al., 2009). Hence, although ultimately aiming for ambitious goals, a problem-based education can also benefit from inspiration on pedagogical elements that, very tangibly, can be implemented in order to increase the potential for transformative reflections and the acquisition of transferable competences.

Models and frameworks on how to foster reflections

The literature and research on reflection does not fall short on suggestions of how to foster reflections. Numerous pedagogical templates and models have been suggested (e.g., Coulson & Harvey, 2013; Deslandes et al., 2018; Etscheidt et al., 2012; Grossman, 2009; Güngör & Güngör, 2019; Lai & Land, 2009; O'Shea & Kearney, 2016; Plack et al., 2008; Porntaweekul et al., 2015; Runnel et al., 2013; Sen & Ford, 2011; Tucker et al., 2003; Zarezadeh et al., 2009, to mention only a few). Most of these models have been developed in direct interaction with students and are therefore highly context-bound, as are reflections themselves of course. However, the provision of a pedagogical template always calls for a certain degree of de-contextualisation (Scholkmann, 2020), and not many of the existing suggestions for models on how to foster reflections provide that.

One model that strives to provide a general framework for reflections has been proposed by Ryan & Ryan (2013), who criticised many reflection practices as lacking "necessary scaffolding or clear expectations for students" (ibd., p. 244). Ryan & Ryan (2013) further pointed out that "professional or academic reflection is not intuitive and requires specific pedagogical interventions to do well" (ibd.). This resonates with, for example, Larkin & Beatson (2014), who found that reflections in work-based learning contexts are suffering from a lack of knowledge or skills for reflection, limitations of physical reflection tools (in this case: journals), a lack of facilitation of different forms of reflection and missing suitable models for teaching and assessing reflections. As a solution to this, in their model Ryan & Ryan (2013) acknowledge the complexity of reflections and combine them with the perspective of developing from known and familiar content to unknown, new and unfamiliar/challenging content to reflect on. They also stress that is is not only a specific context upon which students should be expected to reflect, but a modelling of the context in which they gather experiences to reflect upon (such as a more formalised learning context in their first year of study vs. a work-integrated context later on, cf. Ryan & Ryan, 2013, p. 251).

The authors position their model as a transferable template to be used across various learning contexts, and disciplines to design learning situations that allow for the integration of reflective activities. It provides a well-structured yet flexible approach to a systematic implementation of reflections into a curriculum. However, it at least in part falls short in recognising the more dynamic, tacit and interpersonal attributes of reflective processes, some of which have been elaborated on only after the model was published. For example, Foong et al. (2018) pointed out the importance and role of others in collective reflection and knowledge creation. Also, there lacks a more active integration of specifically digital tools to foster reflections. Last but not least, the model does not take a stance on the question of when/at which points in time or in time-space relations reflections can or should be positioned. The literature on reflections only discusses this aspect only indirectly (e.g., McLeod et al., 2015, p. 450), but does not elaborate on the necessity of time-spatial configurations in order for reflections to take place.

METHOD

Research context and general research design

The findings presented in this article were gathered in the context of a larger research initiative, in which future directions for the Aalborg PBL model were explored. Our research project within this initiative engaged a diverse group of students (i.e., from various study programmes and various semesters) over three semesters in a series of reflective activities. These activities were designed as to be individual, i.e., they engaged participants in reflections on their individual study experiences as well as on their personal competence trajectories (for a distinction between individual and collective reflections, cf. also Lolle et al., forthcoming). The intended outcome and closing point of these activities was a workshop in which students would be given the opportunity to present themselves and the competences acquired while studying to a group of external stakeholders (especially representatives of industries relevant to their study programmes, as well as representatives from the study boards). All participants took part in the project on a voluntary basis.

The reflective activities in which the students engaged were as follows:

- During the *first semester of the project* (spring 2018) we held three face-to-face workshops with sub-samples of the participants in which they were invited to reflect upon their competences at this point in time; specifically, participants were asked to draw a mind map on how they perceived themselves as professionals.

They then had to communicate the content of this mind map to their peers and to the research team. Participants were physically present for the workshops and could communicate and get inspired by each other's activities. They could also communicate with the research team when in doubt about the task.

- During the *second semester of the project* (autumn 2018) three reflective tasks were provided online in a collaborative platform, each approximately four weeks apart. All three tasks were designed to give students prompts to produce reflective artefacts, either digitally or physically (in the latter case, also to provide digital documentation thereof) and post them on the platform. In the first tasks students were asked to tell a short story about why they chose to study at AAU. In the second task they were invited to visualise a skill acquired from their studies by making use of one of different digital tools (e.g., a website, a sensory postcard[3], a pecha-kucha[4] presentation, a pencast[5] video or a cartoon) and in the third task they were invited to reflect on how PBL had contributed to the acquisition of this skill. Students were also encouraged first to explore the different options before choosing how to respond to the task. There were no physical meetings during this second semester.
- During the *third semester of the project* (spring 2019) one individual face-to-face reflective activity and two group face-to-face reflective activities took place. The individual activity was a talk with members of the research team on progression and competence development during their studies, together with reflections on how to communicate these towards external stakeholders. Amongst the group activities, the first was the afore-mentioned workshop with external stakeholders and the second an (not originally scheduled) internal workshop with participants and the research team. Seven external guests were invited to the official workshops (both labour market representatives and members of study boards), and the students' assigned reflective task was a five-minute pitch of themselves and their competences. Students received feedback from the guests afterwards and engaged with them in a general discussion on competences. For the internal workshop three students met with the research team in a group meeting. As a final task, participants were asked to revisit their initial mind maps and comment on their own progression and previous reflections on competences.

Methodological approach

Acknoledging the processual nature of reflection, it makes sense to collect data on reflections over a longer period. Therefore, our research approach followed a combination of different methodologies and underlying philosophies of science that integrate the idea of processuality and (iterative) developments. As a first source of inspiration we followed the paradigm of action research and its underpinnings in pragmatic theories, which are focused on action as a foundation for the conception and awareness of individual and collective understanding (for an overview, cf. Mills, 2014). Specifically, inspired by design-based research methodologies (The Design-Based Research Collective, 2003), we followed a co-constructive approach, in which we treated each encounter between the students, the reflective task, any other persons and the research team as an instance of intervention and data-gathering that would lead to reflections on the part of students and on researchers and hence constitute an iterative process.

The second perspective was a sociocultural understanding of learning as a "result of complex interactions between people in particular social, physical and cultural contexts" (Cowie et al., 2010, p. 83), and the resulting approach to engage student through different modalities, such as face-to-face, virtual, in spoken, written and non-verbal forms of engaging students). As a third perspective the concept of peer-learning in the sense of Boud et al. (1999) was integrated (cf. Fladkjær & Otrel-Cass, 2017). An additional layer of mutual learning can be seen in the engagement between participants and the research team, and the openness on both sides to be challenged and inspired by what was coming from the other side (for a more detailed overview over our methodological approach, cf. Lolle et al., under preparation).

Participants and ethical considerations

Eleven students from five different study programmes across the five faculties of AAU participated in the study. The selection of students was targeted specifically towards creating variety in how far advanced they were in their studies, with a focus on the second semester at both bachelor and master level. Students were included from the second semester bachelor level because it was assumed that these students would already have some experience of working with PBL and with reflections as part of their studies. Students at second semester master level were chosen because at this point students at Aalborg University are expected to be highly reflective and able to articulate their competences, according to their study programmes. Additionally, most students at this point would have participated in practice semesters, where the focus demands a high degree of reflection on the individual student's contribution in practice.

All participants were informed about the objective of the study as well as about the planned activities and their expected involvement. They consented to participation under the terms defined by the Danish version of the European General Data Protection Regulation (GDPR), that is, in the knowledge of their ownership of their data and the permission granted to the research team to present them when cleared of personal and sensitive information. All students will be referred to under pseudonyms in this article.

Data basis and analysis strategy

Following our research approach, we analysed what the students did during the three semesters and in interaction with their assigned tasks, the research team and external stakeholders (in semester three) in iterative reflective cycles in our team. Again, we followed here the elaborations of Cowie et al. (2010) who recommend a holistic, rather than strict triangulatory, approach to students' voices in such research projects, and call on researchers to analyse them with a focus on emergent topics and patterns. In this sense, we treated students' conversations and artefacts not as realities but interpretations thereof and validated them through multiple feedback rounds both with the research team and with the students which involved the sharing of our interpretations, and subsequent checking of whether we had understood them correctly. Extensive material gathered over the course of the project served as the basis for this. This material comprised: transcripts of the video recordings of all workshops held during the projects; documentation of all visual or verbal or blended artefacts (such as websites, sensory postcards, comics etc.); and field notes on several levels of reflection (such as direct field notes from the workshops, reflective field notes on talks with students and transcripts of audiotaped reflections during the analysis of the different materials).

FINDINGS: OTCR ELEMENTS OF THE REFLECTION PROCESS

In the following we will present the outcomes of the above analysis with respect to a set of recurring elements that emerged as central to students' reflective practice and the fostering of reflections. These should be understood as recommendations to inform the design of pedagogical architectures to engage students in reflections about their professional competence development. These elements and their interplay are systematised in the Opportunities, Challenges, Tools, Helpful Relations, and Inspirations (OCTR) model.

The OCTR model as a whole

The OCTR model consists of an inner dimension, in which there is an interplay between *opportunities*, *challenges* and *tools* to and with which to reflect. These need to be seen as constituting an inseparable triangle which fuels reflective dynamics. These reflective dynamics are evolving on the grounds of *helpful relations*, which provide both a basis and a driver. Moreover, these dynamics are conceptualised to be open to an influx of *inspirations and impulses from the outside world* – from students' everyday experiences and encounters, including in connection with their project work. These elements are not to be conceived of as fostering reflections independently but must be understood as interacting entities. Therefore, we have decided to formalise them in a model in which we assume that in order to foster students' reflections, all elements need to a) be present in an adequate pedagogical form and b) be actively set into relation with one another (cf. figure 1).

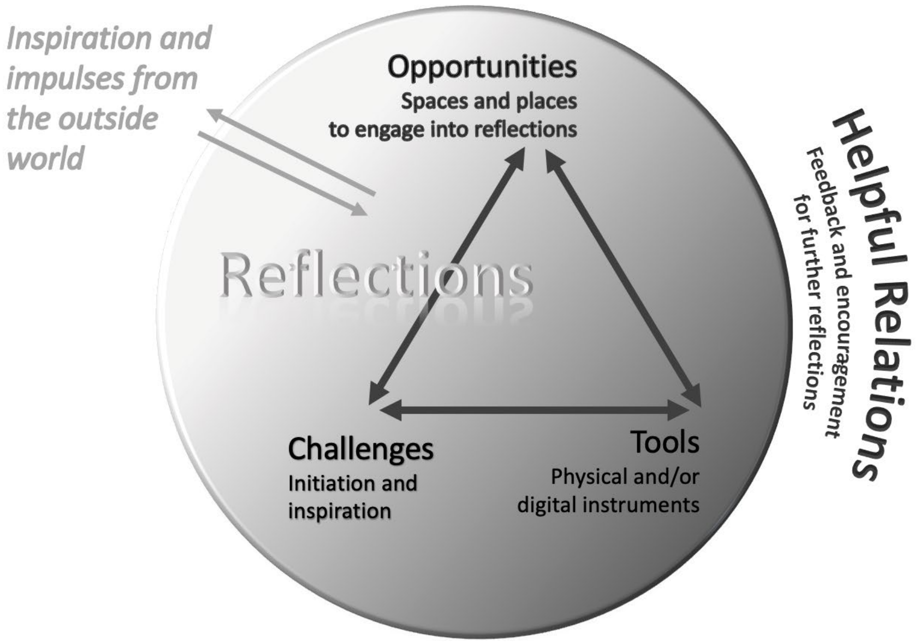

Figure 1. The OTCR model.

Description of the five elements

Opportunities

The first element we propose is distinct time-spatial configurations or opportunities, in which reflecting is expected and possible for students in formalised higher education settings. This can be the timing of a 15-minute activity within a lesson, a formal or informal reflection-talk or any other form of provision of an opportunity to engage in reflections. The notion of materiality and the provision of distinct time-spatial configurations as part of reflective learning processes can be found in literature on portfolio work (e.g., Chen et al., 2005). However, coming from the angle of models to foster reflection, none of the frameworks that we studied has pinpointed this aspect, explicitly. Partly this seems to be due to the fact that the provision of opportunities to reflect is often conceived as being inherent within other aspects, namely the provision of challenges and tools (e.g., Kandiko et al., 2013; Plack et al., 2008). In at least one recommendation, where reflections are conceived as taking place in group settings, the provision of opportunities can be interpreted as being implicitly present through these defined group meetings (Zarezadeh et al., 2009). However, it can be argued that a merely implicit provision of opportunities to reflect is probably not enough for students to understand the assignment, and that this can lead to the afore-mentioned lack of clear scaffolding that reflections need in formalised higher education settings, cf. (Ryan & Ryan, 2013).

Throughout our project it became clear the provision and clear communication of distinct time-spatial configurations in which reflection was expected and possible constituted an important, yet also contested element, in students' processes. The production of reflective artefacts during the project was, on the one hand, happening clearly as a response to the provision of time and space (during a specifically scheduled workshop, in a different channel on the digital platform etc.). On the other hand, participants were also prone to forget about these times and spaces (demonstrated in late deliveries, no-shows to workshops), which we interpreted as an effect of students economic behaviour, which led them to allocate more attention to assignments that promised tangible gains in the form of grades (Biggs & Tang, 2011).

However, although the provision of opportunities was met with mixed enthusiasm, students evaluated the experience as meaningful in the long run. Through several oral communications we learned that participants perceived a difference in how we engaged them in our project compared to what was required of them in their regular learning processes, and that they had been deprived of this kind of work in their study programmes. As one member of the research team noted in their field notes:

> *"Very interesting (and long) talk about the competences she is getting from [her study programme]. (...). She knows that she has gotten a lot of competences out of her studies, but it is difficult to put it into words, and she thinks that study programmes should also teach the students to be reflective of the knowledge they get." (*Field notes researcher 3 on talk with student Johanne, February 2019)

During the final workshop one student added to this that the project had made them more reflective of the impact of their study programme on their competence development. They stated:

> *"The project has been useful in helping me to present, to become more reflective, to find out what the study has given me personally. I would also like to have made a website [that I could use to present myself]."* (Transcript final workshop, April 2019, student Malene)

Challenges

The second element we propose is the provision of challenges that engage students in reflections. Challenges are a classical approach to engage students in (structured) reflections by providing them with an inspiration, question, puzzle or other cue to reflect upon. Many models and approaches to reflections operationalise challenges in the form of questions (e.g., Zarezadeh et al., 2009) or reflective prompts (e.g., O'Shea & Kearney, 2016). Other reflective challenges have also been described, for example the use of concept mapping to foster reflection on learning content (Kandiko et al., 2013), the elicitation of metaphors (Sykes, 2011) or the implementation of virtual action learning for medical students (Plack et al., 2008). Also, challenges are often presented with progressive complexity, for example following Ryan & Ryan's (2013) model (cf. Larkin & Beatson, 2014) or Leijen et al.'s (2021) levels of reflection (cf. Runnel et al., 2013).

In our project challenges were conceptualised as a series of reflective tasks, which provided a variety of descriptive, reflective and critical questions. An important aspect of our challenges was that the students should be able to see a benefit of engaging with them for themselves, and that this would create momentum for them to continue working with the challenges independently. We saw this approach come to life in the first and third semester of the project: The very first challenge, the mind map drawing activity, resulted in conversations such as the one transcribed at the beginning of this article. Moreover, when students were invited to re-visit their mind map after more than one year, this triggered some powerful modifications. One student added seven *post-its* to their previous competence descriptions. The interesting phenomenon here was that, while in the first mind map this student described competences mostly rooted in concrete activities and contexts (such as "family", "study" or "voluntary work"), in the amendments this student both physically and conceptually added a new layer focusing on values, identity and projections of their professional future. In this sense, this student, through engaging with a reflective challenge, came to reflections on their competence that were much more elaborate and personal (mind maps 1 and 2, student Malene). Another student decided to remove certain aspects from their original mind map (on personal aspects) and explained that they experienced a shift in relevance during their reflections (transcript final workshop, April 2019, student Amar).

Challenges can be difficult, though, as demonstrated when our participants were confronted with the task of presenting themselves to the external stakeholders. While some struggled with what to present at all, others were concerned with how to make a good impression on an important external group. This led us to offer a preparatory talk for this assignment with someone from the research team, which several participants made use of (and which led to integration of the element *Helpful Relations* into our model, cf. 4.1.4). What we also saw, though, was that – with or without our help – students experienced agency in meeting this challenge – or, as our participant Malene put it: *"I talked with the study board member about Logbook as a recurring thing on my education. Cool to be heard."* (Transcript final workshop, April 2019, student Malene). Additionally, one member of the research team after the event wrote down the following reflection, which mirrors both the challenging nature and the helpful relations within the experience:

> *" (...) I found it very interesting how*
> *- the students wanted to present themselves, their competencies, their products and what they'd learned*
> *- The external people tried to support the students' experiences. (...)"*
> (Excerpt of field notes by researcher 4, reflecting on the stakeholder workshop, February 2019)

As a first conclusion of our challenging students during this project we can state that in fostering reflections challenges should be considered as being much broader a concept than is the case in existing reflection models. Currently, challenges are often implemented as questions or prompts for mainly cognitive reflections. By also integrating personal topics, non-linear approaches and iterations as well as multi-modal and non-verbal forms of expression, it became possible to use challenges more creatively and to enrich reflections with aspects of values, emotions and personal growth. A second conclusion, emerging from the observation how the students engaged with challenges over the course of the project, is that what is perceived as a challenge can vary in different situations and contects. Since students in a formal educational setting are working under pressure and high constraints, teachers should explore carefully which challenges fit with students' everyday realities, their motivations and goals, and search for ways to integrate these aspects when designing meaningful reflections.

Tools

The element "tools" relates to the use and construction of reflections through any kind of artefact. In the literature on reflections, by far the most common tool is the use of personal journals (e.g., Bain, Mills, et al., 2002; Pavlovich, 2007), which has gained much traction especially in its digital form (e.g., Schwendimann et al., 2018). Other tools have been for example voice-over photos (Mulder & Dull, 2014) or concept mapping (Kandiko et al., 2013). Often, reflection by means of tools is documented and analysed by looking at the resulting artefacts. The most common way to collect these is the portfolio (Scully et al., 2018), often in digital form and through the use of respective software (e.g., Barrett, 2004; Jenson, 2011; Simatele, 2015; Yancey, 2009). However, it needs to be stated that the portfolio is not necessarily a tool in itself but should be treated as a meta-tool to collect artefacts created through more concrete tools such as the ones mentioned above.

In our study we made use of both physical and digital tools which covered a broad variety of potential forms of expression. Some of them were more intuitive, others were more structured. The value and relevance of these tools to foster reflections can be seen in some of the students' products. For example, during the second semester of the project, in which students were provided with challenges on an interactive platform, they engaged with these both in digital as well as in analogue/blended forms, by posting written answers in the chat, creating a homepage, a sensory postcard and a Pencast video. For the presentation, two other students also tried out Flipsnack[6]. We could see variation in students' use of and preference for specific tools and noted that they mixed the tools according to their needs or specific circumstances. For example, one student whose participation overlapped with a periodabroad had a bad internet connection and would draw a cartoon and upload this to the platform.

In conclusion, we can say that at the core of this element lies not the prioritisation of specific tools, but the importance of the availability of a variety of tools, which should be in accordance with the specifics of the respective learning context, and pedagogical considerations to facilitate students in their exploration and choice of the tool that best suits their reflective practices. Hence the importance of trying out different kind of tools.

Helpful relations

Throughout our work with the students and the application of our research methodology it became clear that reflections can only develop their full potential when they are embedded in a network of helpful relations coming into play at any time in the process. By relations we mean any kind of social interaction and contact that provides resonance and feedback to the individual student and helps to mirror their reflective thoughts.

The reflection literature is somewhat ambiguous when it comes to the value of positioning relations as part of reflective practices, and on specifying which kind are considered helpful: Some authors emphasise the role of collective reflection as a transcendence of the individual-focused, cognitive-heavy reflection approach (e.g., Kandiko et al., 2013). Here a group of co-students is considered the entity to relate to, for example in the context of a service-learning design and reflections on students' professional identities (Reed & Koliba, 1995). The same and other authors have also pointed out the importance of adequate support and facilitation by a supervisor, who can serve as a role model and guide reflections through posing questions (Foong et al., 2018; Koole et al., 2016). However, there is not all too much theoretical underpinning about why social relations are so important in order to reflect, or which kind of relations should be prioritised. Based on theories on facilitation as instrumental for reaching new zones of development (Tharp & Gallimore, 1995; Vygotskij & Cole, 1981) it can be argued that more experienced peers or supervisors should be considered specifically as helpful for reflections (for the scaffolding role of teachers cf. also Siemon et al., 2018).

This assumption is supported by the evidence we were able to collect during the project. Especially when it came to condensing the reflective activities that took place during the second semester into more durable documentations to be presented to external stakeholders, it became very clear that the students needed more than just support in performing the tasks. They needed a reaction from the research team, that would help them to progress in their reflective process and specifically to transform their world views, for example about what a competence is for them, personally. A very impressive example of this took place during one of the semi-formal talks that were offered to the students between semester two and three. Here participant Kasper met with two members of the research team and discussed how to present himself and his competences. As one member of the research team present at this meeting noted in their field notes:

> *"One of his most important questions was how he as a third semester student can talk about competences that he only will have acquired at the end of his studies. (...) it was nice to see how also during the talk reflective processes were going on and he grasped the idea of what we are aiming with in the project."* (Fieldnotes researcher 2 on talk with Kasper, February 2019)

In this sense helpful relations (especially with more experienced counterparts such as members of our research team) can also be understood as instrumental in facilitating students towards more metacognitive and transformative reflections about the nature of competences, their own trajectories and ultimately their own reflective processes. Of course this requires a certain degree of (mutual) trust, which in our project was achieved by the fact that students knew that their participation was not tied to any formal assessment or grading. As a conclusion we can say that, from what we discovered during the project, the helpful relations in many cases were the instance when reflections started to become personally meaningful to students. In this sense, they can serve as scaffolding towards more complex or thematically different reflections and enrich more cognitively structured approaches with social and emotional value.

Inspiration and impulses from the outside world

Students, as autonomous individuals, will bring in their own experiences into the formal educational context, and whether intentional or not their reflections will be influenced and inspired by this. Therefore as a supplement stemming from our work, we want to propose consideration of inspiration and impulses from the outside world when fostering reflections, since these happen in interaction with an environment that is not part of the pedagogical architecture in itself. Some suggestions to foster reflections take this into account, already, by integrating challenges created through real-life situations. This is the case specifically in the context of professional education and in-practices studies. For example, prompts and questions directed at reflecting upon one's professional identity, community and role have been used (Zarezadeh et al., 2009), as has reflecting on critical incidents (Larkin & Beatson, 2014) or reporting on experience during practice placements (Deslandes et al., 2018).

Our project made use of impulses from the outside world, for example when, at the beginning of the project we asked students to draw a mind map about themselves and their competence, and use their previous education, family, hobbies etc. as possible inspirations. However, students also contributed their own inspirations, which surprised the research team more than once. For example, student Johanne made several references to their personal beliefs and values as both source and target of their competence development, and student Henriette would draw a cartoon in response to one of our impulses, making use of drawing skills that were not originally communicated as a tool within the project's methodology. Finally, and although this lies outside the empirical information we gathered during the project, we think it must be assumed that reflective dynamics will also feed back into the outside world. We have decided to integrate this into the model in order to remind teachers, educators and educational designers working with reflections that what is happening during reflections might well have impacts beyond the formal educational context.

CONCLUDING REMARKS

In this paper we have presented our suggestion for a model on how to foster reflections in higher education. The model was conceived on the basis of our own iterative reflective work and process analyses with students from different education programmes and varied study years, which gave us an understanding of elements that can be instrumental in a pedagogical architecture regarding reflections which are not specifically tied to set educational goals or disciplinary learning outcomes. In this sense, we would like to propose our model as a general framework of elements and their interplay which can be applied and amended in different directions.

Our model was developed based on multimodal data and iterative process analyses. Whilst this has been an enlightening journey, our findings are still limited to a relatively small, self-selecting group of students in an extracurricular activity. It needs to be further explored how similar reflective dynamics play out when the OCTR elements are being used as part the formal curriculum. Also, in its current form, our model did not find a clear positioning for one element in reflection described in the literature, i.e., the use of *activities* such as role plays (Runnel et al., 2013) or reflective group discussions (Reed & Koliba, 1995), possibly because our project did not prioritise these types of activities. However, we do not doubt that reflective activities such as those mentioned are a relevant element in the process, especially in the context of collective reflections and when stressing the social nature of this process. For the future, there needs to be a discussion of their place in a holistic reflective model can be.

Another point for future research and elaboration should be that an element within a reflective pedagogical architecture can sometimes serve more than one function. For example, it is somewhat ambiguous whether the concept mapping described by Kandiko et al. (2013) is a challenge (i.e., stimulating the reflective dynamic) or a tool (i.e., documenting the reflection). Also, the model by Runnel et al. (2013) can be read as integrating challenges, tools and opportunities. However, here we want to stress again that also in our conceptions the elements of opportunities, challenges and tools are to be seen as intertwined, and that for reflections to take place they all three need to be present, although not in any specific order. Their analytical separation should be seen as serving the design of a pedagogical architecture and the provision of reflections within a programme or curriculum.

As a last point we want to draw attention again to the fact that reflections within a formal educational setting such as higher education always walk a tightrope between engaging students in meaningful conversations, and engineering assessment-oriented affordances to which students will only extrinsically react to. However, we hope that a model such as ours can help to create a relevant pedagogical architecture that can help to prevent the creation of mere "reflective zombies" (de la Croix & Veen, 2018, p. 1).

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Progression of Self-Directed Learning in PBL: Comparing Consecutive Semesters at AAU

Nicolaj Riise Clausen *

ABSTRACT

The purpose of this article is to describe the results from an investigation of the development of students' attitudes and behaviours conducive to self-directed learning (SDL) in problem-based learning. The article reports the results from an application of a newly validated statistical instrument to measure self-directed learning on bachelor students in sociology and data science, comparing first-, second- and third-year students. The results are analysed through factor analysis and by comparing mean scores across the three generations of students. The results suggest that the students develop their SDL attitudes and behaviours through their first three years at a Problem-based learning (PBL) university, but also show that this is not a linear or uniform process. The results of the factor analysis show that the students develop their ability to be self-regulating during their second year and move towards a more internal locus of control during their third year.[1]

Keywords: Self-directed learning, Problem-based learning, Quantitative, Statistics, Locus of control, Self-regulation

Many modern educational practices incorporate self-directed learning elements to some degree. Recent developments such as the COVID-19 pandemic, as well as the rise of hybrid learning models incorporating opportunities for digital and online cooperation, have emphasised that having a student population able to self-regulate is very advantageous. While we will not fully understand the impact of COVID-19 on the education of current students for a long time, theory and previous research on the practices in use let us

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hypothesise about potentially mitigating factors that could help students manage while separated and learning primarily through digital means. One key factor that might alleviate the negative impact is the ability of students to direct their own learning, allowing them to rely less on the authority and support of teachers.

One of the educational models purported to cultivate self-direction in students is problem-based learning (PBL). Several different conceptualisations have highlighted skills for lifelong learning, self-regulation or self-directed learning as an advantageous learning outcome of PBL (de Graaff & Kolmos, 2003; Hmelo-Silver, 2004). Students in PBL environments have been found to attain more deep-level learning, stray further from their teachers' authoritative guidance when seeking information and become continuously more self-reliant throughout their studies (Dolmans & Schmidt, 2000; Loyens et al., 2008). However, these advantages have also been found to be contingent upon the students' developing better self-directed learning (SDL) skills, such as information seeking, personal learning strategies, handling of group discussions and reflecting on their learning (Blumberg, 2000; Blumberg & Michael, 1992; Evensen et al., 2001). Therefore, self-directed learning skills have long been seen as one of the most central learning goals for PBL institutions, essentially an antecedent for many of the other advantages, as well as one of the most significant benefits.

While many efforts have been made to investigate the connection between PBL and SDL, two key factors set our study apart. First, most studies have focused on case-based PBL models often applied by medical and nursing programs. In contrast, our efforts will focus on the project-oriented PBL practiced at Aalborg University (AAU), which is applied mostly by engineering programs. One of the most significant differences between the models is the length of the typical self-directed learning cycle; while cases are often completed within a week, a typical student-directed project at AAU spans a full semester. Second, most studies, especially those conducted within project-oriented models, have investigated PBL implementations at a course or semester level, while students at AAU are exposed to an institutionalised implementation of PBL.

One study that looked at SDL development within an engineering PBL context showed mixed results. The study concluded that a statistically significant increase in readiness for SDL could be found in the students, but that upon further analysis the outcomes were found to be very ambiguous, some students even reporting significantly lower readiness for SDL (Litzinger et al., 2005). Another study, applying the same statistical instrument as in this article (the OCLI) in an institutionalised PBL environment at the University of Toronto Faculty of Medicine, found no significant correlation between the students' progression of study and level of SDL (Harvey et al., 2003). These studies show that the proposed correlation between SDL and PBL is not always present, and lead us to ponder further about what the development of SDL might be contingent on.

The AAU model has often been highlighted because of its role as one of a few reform universities that have implemented institutionalised PBL across all study programs; as such, a lot of research has also been done into this particular institution and its approach to PBL. One of the special elements that have been highlighted at AAU as essential to the model is the first-year course that introduces students to the problem-based project-oriented approach. This course is supported by an explicit focus on learning collaborative skills, process competences and what is otherwise conceptualised as PBL skills (Kolmos et al., 2019; Spliid, 2011). Previous evaluations of the progression of skills related to PBL, such as SDL, at AAU, have found that among all the problems first-year students faced, the ones they rated the hardest to manage were to structure and regulate their work and to collaborate in groups (Kolmos, 1999). One way of managing this is to help the first-year students by simplifying the task of operationalisation. Staff often provide students with a catalogue containing project proposals in the first and second semester, gradually directing continuously less of the process of problem identification and analysis, until the students are able to fully self-direct the process, being given as little as a theme for the semester (de Graaff et al., 2016).

The purpose of the study is to test the hypothesis that students develop attitudes and behaviours conducive to self-directed learning through their education at Aalborg University, where they are engaged in a PBL curriculum. We focus on the first few years of the students' education, elaborating on individual aspects of SDL, developed from year to year. We achieve this through the application and analysing of the results of the Oddi Continuing Learning Inventory (OCLI) on five cohorts of students from two bachelor programs in sociology and data science. The OCLI has recently been translated into Danish and validated in an effort to evaluate its properties in the cultural context of Denmark. During the validation, a confirmatory factor analysis revealed a revised factor structure with three factors that we will apply in this article: (1) internal locus of control (ILoC), (2) ability to be self-regulating and (3) avidity for learning (Clausen & Hansen, 2022).

BACKGROUND

Self-directed learning in Problem-based learning

In problem-based learning, self-direction is often seen as a critical component, as both an advantageous learning outcome of the approach and as a specific goal. One of the perceived advantages of PBL is that students gain a deep and complex understanding of the subjects of their projects. There is, however, the inherent danger that the students might lack the broad knowledge of their field. SDL has often been seen as a learning goal for PBL to mitigate such issues, making sure that students have the means to attain whatever shortcomings of knowledge they might have (de Graaff & Kolmos, 2003).

Counterintuitively, one of the elements highlighted as conducive to developing good SDL skills in PBL is group work. Group work has been found to promote the development of competencies needed to ask good questions and give explanatory feedback. The correlations between the methods of PBL and the skills needed in SDL have also been emphasised by research. Students of PBL tend to develop strategies and plans for their work and manage to integrate a lot more new information in their problem solving, As long as they are allowed to define their learning objectives (Evensen, 2000; Hmelo & Lin, 2000).

A highlighted issue for PBL in connection to SDL is that of less mature learners, who tend to have difficulty engaging with self-direction and require a higher degree of external scaffolding and structuring of their work (Hmelo-Silver, 2004; Knowles, 1980; Tough & Knowles, 1985). A related issue is that this particular type of learner tends to be less reflective about their learning, a characteristic that is crucial for developing and modifying personal learning strategies to be effective (Evensen et al., 2001).

In an attempt to evaluate the synergies between SDL and PBL, Loyens, Magda, and Rikers (2008) found that PBL fosters at least some of the SDL skills encompassed in what Brookfield conceptualised as the techniques of SDL (Brookfield, 1985, 1986). They found, among other things, that students in PBL environments applied a more comprehensive range of resources and information relating to their learning goals than their peers in traditional programs (Loyens et al., 2008). These findings are very similar to those of both Evensen and Blumberg (Blumberg, 2000). Schmidt and Dolmans found that during the span of their education, PBL students become continuously more self-reliant, depending less on lectures but increasingly on group discussions (Dolmans & Schmidt, 2000). Results that to some extent mirror these are those of Kivela and Kivela who studied students during an implementation of PBL in Hong Kong. They found that the students relied on the teachers' guidance to a lesser extent after having been subject to PBL. In their first semester they tended to rely on their fellow students, but this tendency seemed to have lessened in their second year, where they seemed to have developed self-direction and autonomy to some extent (Kivela & Kivela, 2005).

Through a literature review, Blumberg looked into the evidence that problem-based learners are also self-directed. She found that PBL students become very active library users compared to students in traditional education. Blumberg also found that the students of PBL generally seek many more sources of knowledge and tend to stray further from the teacher-assigned literature than traditional students, self-directing their literature search (Blumberg & Michael, 1992; Blumberg & Sparks, 1999). They seemed to develop what she referred to as 'library skills', self-directed information-seeking behaviour. Another finding was that PBL students tend to employ learning strategies that secure their deep-level learning, seemingly resulting in more learning for meaning instead of recitation. A general observation was that this same strategising for learning and reflection seemed to give them an advantage in assessing materials and structuring their work and studies (Blumberg, 2000). Evensen also found that in first-year medical students in a PBL learning environment, there were indications that they had developed skills for dealing with reflections on learning, environmental influences, goal setting and self-efficacy and had developed strategies for information seeking (Evensen, 2000).

Self-directed learning

The origins of the concept of self-directed learning (SDL) in modern learning research is often attributed to either Allen Tough, who in 1967 first conceptualised the SDL project, or his contemporary, Malcolm Knowles, who had a more theoretically-oriented approach and argued for assumptions specific to the adult learner. Some would contend that Carl Rogers was an initial influence, because as early as 1958, he famously concluded that ‘I have come to feel that the only learning which significantly influences behaviour is self-discovered, self-appropriated learning’ (Rogers, 1958; Tough, 1967).

Another central figure whose importance is difficult to overemphasise is Cyril Houle, of whom both Allen Tough and Malcolm Knowles were students. In 1961 he authored *The Inquiring Mind*, in which he described the characteristic behaviours, activities and motives of adult learners who could readily be identified as such by their surrounding community, and identified three characteristic groups of learners based on the orientation of their motivation (Houle, 1961). With *The Inquiring Mind*, Houle sparked a trend of explorative research efforts within SDL, seeking to describe and outline adults' self-initiated learning efforts and attempting to define and delimit it as a research subject, establishing a tangible focus for investigations. Through his authorship, Houle contributed notably to SDL's collective knowledge base, but he arguably had an even more significant impact by inspiring his two aforementioned students, Malcolm Knowles and Allen Tough.

Malcolm Knowles focused primarily on the distillation of theory, and while he is acknowledged as having worked extensively with SDL, he primarily conceptualised it through the term ‘andragogy’, which he popularised, understanding it as a ‘model of assumptions about learning or a conceptual framework that serves as a basis for an emergent theory’, and as one end of a continuum, opposite pedagogy (Knowles, 1989). Andragogy roughly translates to ‘leading men’ in the same way that pedagogy translates to ‘leading children’. Knowles initially theorised that pedagogy and andragogy were diametrical opposites and directly correlated with the learners' age, children being malleable and dependent upon strong teachers for direction and guidance. Knowles thought that this was because of their limited experience, making them less critical about what to learn and how it would benefit them afterwards. Adult learners, on the other hand, were understood to be self-directed and motivated by the immediate application of new-found knowledge (Knowles, 1970). Knowles later arrived at the opinion, through correspondence with primary-school teachers who had applied the tenants of andragogy and reported excellent results, that the assumptions about learners in pedagogy and andragogy were not necessarily linked to age, but rather to a set of characteristics, some of which usually, but not necessarily, correlated with age (Knowles, 1975, 1980).

Allen Tough had a very different and much more empirical approach. His developed methodology has had an enormous impact on the research field of SDL, primarily through the design of his highly structured interview scheme, which has been replicated extensively over the years. It is among the most influential methods in the field and makes up one of the most obvious of the previously mentioned research efforts inspired by Houle. While Tough's methodology can hardly be said to have been explorative, his findings played a large part in outlining SDL as a research subject and proving the extensive prevalence of self-directed learning projects. The obvious strength of Tough's interview scheme is its highly structured nature, which has allowed researchers worldwide to replicate his studies, supplementing the already disclosed results with their own. Tough's approach was to study particular learning projects undertaken by a given individual, defining learning projects as 'a series of related episodes, adding up to at least seven hours' where 'more than half of the person's total motivation is to gain and retain certain fairly clear knowledge and skill, or to produce some other lasting change in himself' (Brockett & Hiemstra, 1991; Tough, 1971).

Tough and his associates initially conducted 66 interviews, finding that the learners themselves planned 68 % of all learning projects. Along with the monumental finding that less than 1% of the initiated learning projects were motivated by attaining particular institutional credits, this was very surprising at the time, seeing that earlier scholars had assumed that a majority of projects were instigated institutionally. Another curious finding of his initial study was that although learning projects were planned and thought out individually, the actual learning rarely took place in isolation (Tough, 1966, 1967).

Given these significant findings, learning project studies played a considerable role in SDL and adult education research, to the point where later researchers in the field have suggested that any further iterations should be avoided, considering the methodology applied in such a vast number of studies that any further uses would be redundant at best (Caffarella & O'Donnell, 1988). Other critics have pointed out that the deductive approach along with the rigid interview structure might help reproduce misconceptions cemented in the underlying conceptions of the interview scheme that other new approaches to the field might otherwise help dispel, further emphasising the need for different approaches in the research of SDL (S. Brookfield, 1981). It should be noted that Allen Tough originally developed his learning project approach to illuminate how widespread the phenomenon of SDL is, an objective his efforts absolutely succeeded in accomplishing (Tough, 1971).

SDL and Statistical Instruments

One of the research methods to take up the mantle from Tough's learning project research was statistical instruments designed to measure SDL in different ways (Brockett & Hiemstra, 1991). To this end a number of self-reported questionnaires were developed, most successfully the Self-Directed Learning Readiness Scale (SDLRS) in 1977 and the OCLI in 1984.

Lucy M. Guglielmino developed the SDLRS for her doctoral dissertation to, as the name suggests, ascertain how ready individuals were for self-directed learning. She was motivated by prior studies, which had revealed high attrition rates in independent study programs. These studies found that this was likely caused by a misalignment between the requirements the students had previously experienced and those set by the self-direction needed by the independent study programs. Another key motivation for Guglielmino was the experiences of Dunbar and Dutton (1972), who had attempted to convert a traditional business school to a more self-directed learning approach, but had apparently failed because of the students' unpreparedness for the transition. Guglielmino reasoned that a statistical instrument designed to assess students on several skills and attitudes related to SDL would allow facilitators to better identify students ready for SDL, as well as help the individual student recognise areas for improvement. The SDLRS was thus developed primarily as a predictive instrument for people preparing to begin academic self-directed learning at a high-school, college or graduate level (Guglielmino, 1977). The resulting instrument was a 58-item questionnaire, applying a 5-point Likert scale.

Another instrument that was developed to measure the concept of SDL, though with a slightly different approach than the SDLRS, is the OCLI, which was created partly as a reaction to some of the criticisms of previous instruments of measurements. Lorys Oddi adopted a new perspective in developing the instrument in that she conceptualised SDL not as an instructional process, but rather as a personality trait that determined certain behavioural tendencies characterised by initiative and persistence in learning over time and which often correlated with the maturity of the learner (Oddi, 1984).

Lorys Oddi developed the OCLI by deducing three underlying theoretical dimensions from a review of the literature and findings on SDL. The three dimensions of personality exist as continuums, each end representing a trait either conducive or nonconductive to SDL. The dimensions were theorised to be overlapping and mutually reinforcing and were described by Oddi as:

- Proactive drive versus reactive drive: 'This dimension focused on the learner's ability to initiate and persist in learning without immediate or obvious external reinforcement.'
- Cognitive openness versus defensiveness: 'Salient characteristics of CO/D included openness to new ideas and activities, ability to adapt to change, and tolerance of ambiguity. The opposite pole included attributes such as rigidity, fear of failure, and avoidance of new ideas and activities'.
- Commitment to learning versus apathy or aversion to learning: 'Salient characteristics of CL/AAL included the expression of positive attitudes toward engaging in learning activities of varying sorts and a preference for more thought-provoking leisure pursuits. The opposite pole included expressions of indifferent or hostile attitudes toward engaging in learning activities and reports of less engagement in activities commonly regarded as promoting learning'. (Oddi, 1986)

Oddi then formulated 100 items representing the three dimensions, gradually reviewing and reducing the number of items through content validation by getting law, nursing and adult education graduate students and a panel of adult education experts to review them. This resulted in 65 items that were subsequently reduced to 31 through a pre-pilot study with 30 respondents, including an evaluation of individual items, item analysis and evaluations of item-total and item-subscale score correlations. The 31-item instrument was then administered to 287 law, nursing and adult education students and reduced to 26 items through a factor analysis, obtaining five interpretable factors accounting for 44.5% of the total variance. Through further validation, Oddi found that two items correlated negatively with the total instrument score and they were therefore removed, resulting in the final 24-item instrument.

The OCLI has subsequently been extensively validated, initially by Oddi herself, who conducted several construct validations, testing the instrument against other, thoroughly validated instruments of theoretical constructs that she reasoned the OCLI would either correlate with, correlate negatively with or not correlate with (Oddi, 1984).

In addition to the construct validations, studies of the factor structure of the OCLI have also been conducted. Most of the studies reveal similar factor structures, indicating that the factors are mostly stable across contexts and cultures (Harvey et al., 2006; Oddi, 1984; Six, 1989; Straka, 1996). For a thorough analysis of previous validation efforts and a validation of the factor structure, see (Clausen & Hansen, 2022).

METHOD

Sample

This article presents findings from a study of students' self-directed learning conducted in 2019. The OCLI was sent to 754 students, of whom 400 replied with a complete response. Sociology and data science were selected as cases because of the high number of students in each program and the perceived diversity between the two studies. It was a priority for the authors to research the development of SDL skills in two very different groups of students, making the common denominator the application of project-oriented PBL. Professors responsible for lectures for the students selected for the study were contacted, and all but one offered the authors time during a course lecture for data collection. The students were all in the first month of their second, fourth, or sixth semester when they answered the survey, so the sample from the first-year students must not be considered a pre-test before they started their university education, but can more accurately be viewed as a measure of their development through the first semester.

	Responses (n)	of total	Response rate
1st Year	101	25.25 %	67.3 %
2nd Year	203	50.75 %	58.5 %
3rd Year	96	24 %	37.4 %
Total	400	60 %	53.1 %

Table 1. Response Rate.

Data Collection and Management

The students were informed about the study during a lecture; immediately after the presentation they received the questionnaire by email and were given time to answer it during the class. The questionnaire used was a Danish translation of the OCLI, which had been validated on a separate sample of students (Clausen & Hansen, 2022). The researcher's presence ensured that all the students received the same information about the questionnaire, had adequate time to answer and experienced no technical difficulties. The students' answers were subsequently loaded into IBM SPSS Statistics 25.0, which was used for all analytical purposes. The authors have not removed any respondents as outliers or otherwise invalid.

Analysis

A few factor structures were initially tested on the data in an exploratory effort to ensure that the model with the best fit on the data would be presented in the article. The most recently validated factor structure was expected to result in the best fit on the data, and analysis confirmed this assumption. The factor structure in question has three factors: (1) internal locus of control, a measure of a student's general belief in their ability to successfully influence their work, including items like *I successfully complete tasks I undertake* and *When I do a job well, it's because I have been prepared and have put in* *personal effort*, (2) ability to be self-regulating, comprising of reverse-coded variables like *I'm not comfortable with my performance on an assignment until my supervisor, teacher or colleague says it's acceptable* and (3) avidity for learning, with questions like *I have been an eager reader since childhood.* The validation and reinterpretation of the instrument along with the revised factor structure is explained in greater detail in author (year). The derived factors, as well as the total scores of the OCLI scale, will be used to compare students across semesters. They will be analysed as independent samples; means, standard deviations and two-tailed tests of significance are reported and discussed when relevant. Two-tailed tests are preferred over single-tailed because of previously reported results not supporting the theoretically backed notion of correlation between progress in PBL education and OCLI-score (Harvey et al., 2003).

Levene's test for equality of variances is applied to ensure that appropriate adjustments can be made if the observed variance in the compared parts of the population are not approximately the same (Brown & Forsythe, 1974; Schultz, 1985).

RESULTS

All results from the statistical analysis will be briefly presented in this section and discussed in the subsequent. This format has been applied to allow for as much transparency as possible, allowing the reader to see any and all results, before engaging in the discussion. In this presentation of the results, all significant differences (p-value < 0.05) will be described.

The scores will be presented chronologically, initially examining the differences between the first- and second-year students, then the second- and third-year students. Lastly, we will look at the results from comparing the first- and third-year students, summarising the two years as a whole. For all comparisons, the scores for the total OCLI score and each of the factors will be presented.

Differences Between First and Second-Year Students

The only factor with a significant difference between the populations is the ability to be self-regulating, which sees a rise in mean score from the first (M = 12.87, SD= 4.29) to the second year (M = 14.12, SD= 4.47) $t(302) = 2.332$, $p = 0.020$.

	Means		Standard deviation		P-value	Levene's test for equality of variance		Degrees of freedom	T-test
	1st year	2nd year	1st year	2nd year		F	Sig.		
OCLI total score	106.91	108.38	13.33	12.94	0.355	0.129	0.720	302	0.926
Internal locus of control	31.48	31.23	4.6	4.91	0.678	0.323	0.570	302	0.416
Ability to be self-regulating	12.87	14.12	4.29	4.47	0.02*	0.352	0.554	302	2.332
Avidity for learning	28.79	28.95	5.26	4.98	0.798	1.323	0.251	302	0.257

Table 2. Differences Between First- and Second-Year Students.

Differences Between Second and Third-Year Students

Scores on the total OCLI scale were significantly higher for third-year *(M* = 111.57, *SD*= 12.95) than for second-year students *(M* = 108.38, *SD*= 12.94), $t(297) = 1.989$, $p = 0.048$. The results also show a significant rise in the internal locus of control of second-year *(M* = 31.23, *SD*= 4.91) and third-year students *(M* = 32.83, *SD*= 3.74), $t(238) = 2.829$, $p = 0.002$. Levene's test for equality of variance was significant, so a correction of degrees of freedom was made.

	Means		Standard deviation		P-value	Levene's test for equality of variance		Degrees of freedom	T-test
	2nd year	3rd year	2nd year	3rd year		F	Sig.		
OCLI total score	108.38	111.57	12.94	12.95	0.048 *	0.038	0.846	297	1.989
Internal Locus of Control	31.23	32.83	4.91	3.74	0.002 **	5.687	0.018	238	2.829
Ability to be self-regulating	14.12	14.47	4.47	5.49	0.591	12.213	0.001	157	0.579
Avidity for learning	28.95	29.32	4.98	5.57	0.562	2.607	0.107	297	0.581

Table 3. Differences Between Second- and Third-Year Students.

Differences Between First and Third-Year Students

As seen from Table 4, third-year students have a significantly higher OCLI score *(M* = 111.57, *SD* = 12.95) than first-year students *(M* = 106.91, *SD* = 13.33), $t(195) = 2.488$, $p = 0.014$. We can also note that there is a rise in the students' internal locus of control from their first year (*M* = 31.48, *SD* = 4.6) to their third (*M* = 32.83, *SD* = 3.74), *t*(195) = 2.265, *p* = 0.025. The students additionally report a significantly improved ability to be self-regulating from the first year (*M* = 12.87, *SD* = 4.29) to their third (*M* = 14.47, *SD* = 5.49), *t*(180) = 2.269, *p* = 0.024 (Levene's test indicated unequal variance (*F* = 12.696, *p* < 0.001) so degrees of freedom were adjusted from 195 to 180).

	Means		Standard deviation		P-value	Levene's test for equality of variance		Degrees of freedom	T-test
	1st year	3rd year	1st year	3rd year		F	Sig.		
OCLI total score	106.91	111.57	13.33	12.95	0.014*	0.020	0.887	195	2.488
Internal locus of control	31.48	32.83	4.6	3.74	0.025*	2.976	0.086	195	2.265
Ability to be self-regulating	12.87	14.47	4.29	5.49	0.024*	12.696	0.000	180	2.269
Avidity for learning	28.79	29.32	5.26	5.57	0.492	0.203	0.653	195	0.688

Table 4. Differences Between First- and Third-Year Students.

DISCUSSION AND CONCLUSION

From the comparisons presented above we can see that that the overall hypothesis that the students develop attitudes and behaviours more conducive to SDL as they progress in their studies at AAU seems to be confirmed by the data, in the sense that third-year students have a significantly higher OCLI total score than the first-year students. Most of the rise in total scores happens from the second to the third year, resulting in a significant difference between those student groups, compared to a non-significant one between the first- and second-year students. While the difference between the first- and second-year students is non-significant, Table 2 shows a slight rise in the mean score. The most obvious inference is of course that the students seem to develop attitudes and behaviours conducive to SDL between their first and third years at AAU. This is especially interesting because of the results from Harvey, Rothman, and Frecker who applied the same instrument on a cohort of medical students in a PBL environment and found no significant rise, even seeing a fall in total OCLI scores from one year to the next, thereby proving that PBL does not guarantee a rise in OCLI total scores (2003). Looking more closely at the results, we can see that the difference in OCLI total scores is mostly a product of two independent significant rises – the ability to be self-regulating from the first to second year and internal locus of control from the second to third year.

One factor that might help explain the progression is that students have recently transitioned from a typically very traditional classroom setting, with an asymmetric power relation between students and teachers, to a project-oriented setting with more symmetric power relations, where they are often met by supervisors who offer more questions than answers as the students themselves become specialised experts within the subject area of their projects (de Graaff et al., 2016; Kolmos et al., 2008). The management of such a transition from a learning environment where the students can rely heavily on their teachers as authority figures who either approve or reject their work to one where they act more like a member of the group and that supports student group autonomy might be essential to the progression we observed. Studies have found that thrusting students into a more self-directed learning environment without adequate clarification of expectations and time to prepare can negatively affect students' retention and learning (Dunbar & Dutton, 1972; Margarones, 1961; McCauley & McClelland, 2004). Rogers remarked that for such a move to be successful and not cause the students too much anxiety, learners must gradually become accustomed to the added responsibility for their learning (C. Rogers, 1969). One could theorise that the drop in internal locus of control from the first to the second year, although non-significant, might be related to this notion of transition. Our data suggests that this transition is handled appropriately at AAU, as we see the students develop self-regulating behaviour and attitudes as well as a heightened affinity towards SDL, unlike what we have seen from other studies in PBL environments (Harvey et al., 2003). Our results support previous studies showing that students engaged in a PBL environment supported by SDL had developed a preference for self-directed learning by year two of their education. One of the same studies also found that students moved from dependence on their lecturers and groups to be much more independent and intrinsically motivated, having a higher internal locus of control (Kivela & Kivela, 2005). This notion also supports the second result from the factor analysis, namely, the move to a more internal locus of control from the second to the third year of study.

This type of student development has previously been theorised in the literature on SDL, maybe most notably by Knowles in defining the set of assumptions about learners that define andragogy. Knowles saw pedagogy and andragogy and the assumptions about the learner derived from each as two ends of a spectrum (Knowles, 1970). An interpretation of our findings based on this notion could be that what we perceive as a rise in SDL is the learners' maturing from pedagogical to andragogical learners. This would entail them becoming less dependent on teacher guidance, approval and extrinsic motivation, and instead developing a preference for self-regulation, becoming critical of their teachers' authority and craving intrinsic motivation and control. Knowles remarked in later writings that for a transition to SDL to be successful, the students initially need direction and facilitation (Knowles et al., 2005). At AAU, a part of this facilitation is the first semester PBL course, which introduces the students to the AAU model, offering them tools to better engage in problem-based projects and making them reflect on their previous and current practices. Another key aspect is the gradual transition of responsibility for defining and analysing the problem at the centre of projects to the students themselves, allowing them to ease into directing their own learning step by step (Kolmos et al., 2008, 2019). Taking this and our results into account, another interpretation could be that the first semester course, gradual transition into self-direction and experience with PBL and project work initially allows the students to self-regulate their projects, learning and practising the craftsmanship of problem analysis and project work. Subsequently, based on experiences of success in project work, they then gain belief in their ability to work well within the AAU model, moving them to a more internal locus of control. This interpretation would explain the sequence of the students' developments in our data.

There are certain limitations to our study that future research should address. Most notably, our research design does not, by design, yield results which allows us to elaborate on students' experiences of their transition to the self-directed learning environment of a PBL institution and the development of SDL. Qualitative studies should be conducted to gain these insights. Although access to the respondents might be limited, a true pre-test, conducted, if not before, then as close to the start of the students' enrolment at AAU as possible could also help improve the reliability of our conclusions. An iteration of the study with longitudinal data across three years on the same cohort of students would also remove some doubts as to whether or not fluctuations between the generations might have affected the statistics, although we have no reason to believe such fluctuations exist within our data. A data collection where each student could be followed individually would also allow researchers to check for selection bias, e.g., whether what we measure as a rise in mean scores is actually an effect of the students with the lowest scores dropping out.

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Disagreeing About the Problem in PBL: How Students Negotiate Disagreements Regarding the Problem in PBL

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ABSTRACT

An essential part of Problem-Based Learning (PBL) is the students' groupwork. What happens in students' group work when no tutor/facilitator is present is normally a hidden land. Thus, there is limited research on students' interactional way of doing PBL, this study tries to amend this by looking at how students conduct group work without any tutor/facilitator present. In this study, our research question is: How do students negotiate disagreements in their decision-making regarding their problem construction, and which element(s) in the interaction establishes if the decision is made or not? With a focus on students' interactional work, we used video-observation to gather data of a 3rd semester Engineering Group at Aalborg University, Denmark. Our findings indicate that the conversation's structure has a profound impact on whether a decision proposal is accepted. Thus, the individual's ability to hold on to their position and answer questions towards one's proposal determines if other group members follow your suggestion. The study provides knowledge to an under-researched area of PBL and recommends a focus on PBL students' interactional work in relation to near future cases of PBL.

Keywords: Problem-Based Learning, PBL, Higher Education, Problem, Problem Identification, Problem Design, Problem Construction, Decision-Making, CA, Ethnomethodology

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INTRODUCTION

Problem-Based Learning (PBL) first emerged in Canada at McMaster University's medical education in 1963 (Barrows & Tamblyn, 1980). Today more than 500 higher education institutions around the world use PBL (Servant-Miklos, 2019). An essential part of PBL is students working in groups where the learning process starts with a problem (Barrows 1996; De Graaff and Kolmos 2003; Kek and Huijser 2017; Servant, Schmidt, and Frens 2016). According to Hung, "Problems are at the heart of PBL" (Hung 2009:199). While considerable research attention has been directed towards developing problems in PBL (Holgaard et al. 2017; Hung 2006, 2009, 2016, 2019; Hüttel and Gnaur 2017), there is limited research investigating the interactional work students do concerning the construction of their problem.

As PBL is characterized by students working in groups to a great degree, one could argue most of their learning takes place in group work; thus, to understand what goes on in this group work, the interaction between the students becomes a relevant focus. In this context, we define learning as a social process situated in particular social and material ecologies (Jordan and Henderson 1995). Consequently, the way to examine these ecologies is by focusing on the dialogue in the collaborative construction of shared understandings (Benwell and Stokoe 2002). In this perspective, language is viewed as a site of action rather than transmission (Benwell 1999). The focus becomes to explore the studied interaction's conversational features, practical accomplishments, and discursive organization. We know that most of the PBL studies we see today rarely focus on the students' interaction (Koschmann, Glenn, and Conlee 1997). However, it is important to have this focus as a great deal of PBL is students doing the work for themselves. To quote Schegloff, we are left with a sense of "how the world works, but without its detailed specification"(Schegloff 1992:106). According to Koschmann, Glenn, and Conlee (1997), these kinds of studies will also provide us with a better understanding of PBL. As this paper is submitted to a special issue dealing with the next practice within PBL, asking what kind of theoretical and methodological frameworks we need to understand, analyze, and envision PBL, we hope to show how looking at students' interactional work is a relevant and much needed theoretical approach to researching PBL. This becomes especially important regarding the students' development of the problem, which will be the focus of this paper.

In the PBL literature an emphasis is put upon how the learning takes its point of departure in a problem (De Graaf & Kolmos 2003; Savin-Baden & Major 2004; Barrows 1996). Thus, as the problem becomes the starting point, a greater emphasis should be put on how these problems are constructed. At Aalborg University (AAU) students are allowed to construct the problem and find their own case on the condition they align with the learning goals of the semester (Servant et al. 2016). The learning goals always require the problem to be explored academically. The term problem construction is applied concerning Markauskaite and Goodyear (2017), who quotes Belth (1977), stating that problems are: "what we form them to be, and thus are as unique as the individual minds that create them" (Belth, 1977; Markauskaite and Goodyear 2017:4). In the literature, terms like problem design or problem identification are often used (Holgaard et al. 2017; Hung 2019). We believe problem construction more adequately describes the process of how the interlocutors in engagement with their specific field construct a problem that adheres to their learning goals and the specific needs of other relevant stakeholders. The question thus becomes, how do students engage in this process? We will argue that problem construction is a decision-making process located in the interactional work of the students.

Problem Construction as a Decision-Making Process

As Hung states: "PBL problems require undergoing an instructional design process that is a rigorous, systematic, and analytical decision-making orchestration" (Hung 2019:250); although this design process is meant for instructors in their design of problems for students, we want to emphasize his focus on: "analytical decision-making orchestration". Constructing (or as Hung formulates it designing) a problem requires rigorous, systematic, and analytical decision-making. One could argue these three adjectives are often associated with the social practice of academics. These adjectives describe the specific contextual way of how decisions should be made in academic practice.

Reviewing the literature on decision-making, numerous interaction studies (Arminen 2005; Heritage 2005; Jones and Corsby 2015) refer to Garfinkel's research in juror's decision-making practices. First, Garfinkel stated that specific institutions encourage certain ways of decision-making that differ from how decisions are made in daily life. However, when we are engaged in the specific institutional practice, we do not adhere 100% to how that practice encourages our decision-making. On the contrary, he claims that 95% of our decision-making process in institutions is determined by how we make daily life decisions. What does then determine if we orient towards the institutional way of making decisions and how we make decisions in our daily life? According to Garfinkel (1967) the two ways of making decisions are performed in parallel. Thus, it is not one way or the other, but the management of the ambiguity of the different practices that characterize a specific social practice (Garfinkel 1967).

As decision-making is deemed important in constructing the problem, our aim becomes an exploration of how the students, through their interaction, make decisions regarding their problem. Accordingly, our focus will be on the socially shared decision-making taking place in the group. In this paper, we define decision-making as a commitment to future action (Huisman 2001). We will argue that decisions, where the students disagree, are the most obvious point to start. In a university setting, we teach students they have to argue for their decisions and why they think their approach is the right one. When the students disagree about a problem, ideally, what should happen is that scientific debate should start in which the students argue for the merits of their belief. The best argument (which often should be the most scientific) ought to be the one the group follows.

Consequently, examining how the students argue in a disagreement can shed light on what kind of knowledge they utilize in their group discussions to accomplish a certain decision. This illumination of the knowledge they utilize thus allows us to examine the potentials of the student-centered problem construction process. Thereby, our focus will be on the students' decision-making without any supervisor/tutor present.

This paper will contribute towards what potentials can be derived from the decision-making processes regarding the negotiation of the problem, providing us with a better understanding of PBL. What happens interactively when a disagreement occurs? And what determines the outcome of the disagreement? In other words, what determines whether a decision is made or not made? Is it the academically best formulated argument as we try to teach the students?

Thus, our research question becomes:

How do students negotiate disagreements in their decision-making regarding their problem construction, and which element(s) in the interaction establishes if the decision is made or not?

In other words, we would like to examine why some decision proposals gets accepted even though there are disagreements while others do not. What does the interactional structure state about how some decisions are accepted while others are not?

THEORETICAL FRAMEWORK

Conversation Analysis as our Theoretical Framework

To answer our research question, we use Conversation Analysis (CA). The purpose of CA is to identify structures that underlie social interaction (Stivers and Sidnell 2013). This is done by producing detailed transcriptions of the interaction taking place. Thus, by analyzing different instances of interaction you can elucidate generalizations while being open to the fact that you are not describing the "one way" or "only way" of performing this kind of interaction.

Another central element in CA is it examines what an utterance does in relation to the preceding one(s) and what implications an utterance poses for the next one(s) (Arminen 2005), as such CA links to ethnomethodology (Garfinkel 1967), a sociological approach studying members' way of being-in-the-world. An essential part of ethnomethodology is that even the smallest amount of interactions can provide general insights into the nature of social interaction (Garfinkel and Rawls 2002). When examining interaction and how the students negotiate disagreements in their decision-making, CA provides us with a theoretical framework that enables us to study their dialogue's micro-processes to illuminate what kind of knowledge they utilize in their group discussions to accomplish a certain decision. This illumination of the knowledge they utilize thus allows us to examine the potentials of student-centered problem construction. In the following, we will define some specific concepts used in CA relevant to our analysis.

The concept of Turn Construction Unit (TCU) indicates a speaker's turn in which they can construct an utterance (Sacks and Jefferson 1995). Transition Relevant Place (TRP) marks the transfer of speakership, which normally only happens at certain specifiable junctures (Clayman 2013); in our extracts, this will be especially relevant in the pauses shown in the transcripts by a punctation. Preference indicates the principles participants follow, often implicit, when they act and react in various interactional situations (Pomerantz and Heritage 2013). One can answer in a preferred way (accepting an invitation), and one can answer in a dispreferred way (not accepting an invitation) (Sacks and Jefferson 1995). Another term used in CA is repair, which is defined as the interlocutor's practice where they interrupt the ongoing course of action to attend to possible trouble in speaking, hearing, or understanding the talk (Kitzinger 2013). This can happen by a co-participant; other-initiated repair, or by the speaker's self-initiated repair. Although CA contains more than the above-described concepts, these will be the most relevant for our analysis. When examining interaction, it is equally important to have an embodied view of the interaction (Goodwin 2018; Heath and Luff 2013). The term embodied should be understood as:

"the ways in which the production and intelligibility of action are accomplished in and through bodied action, the spoken and the visible, and where appropriate, the use of various objects and artifacts, tools and technologies*"* (Heath and Luff 2013 p. 295).

Our focus will also be on the embodied nature of the interaction. This will be shown in the analysis with direct screenshots of the video-recordings embedded in the transcriptions.

VIDEO-OBSERVATION

As our research question is centered around students' interaction video provides an ideal source of data as it allows us to study in detail how the students negotiate and reach an agreement towards the content of the problem they wish to work with. As we aimed to study what happened in detail, we used 360-degree cameras to collect video. According to McIlvenny (2020), 360-degree recordings: "allows a viewer to see a flat 2D visual representation of the *totality* of a scene from a single location but in all directions at once" (p.3, original emphasis). In other words, the researchers can view the interaction taking place from different angles and can zoom in on specific participants in the recordings.

The data collection procedure

We collected our data at Aalborg University, Denmark, following a 3rd semester Engineering group in 2018-19. We followed the students from their first day of the semester until their last day. At AAU, all educations use PBL. At the Engineering studies students choose an initial problem or case and form a group based on their mutual interests. They write a project over a semester while simultaneously following coursework. When the students do not attend courses, it is expected they work on their projects. The group is provided with a group-room, where they gather when they are not following courses. It is up to the students to negotiate how often they meet. This group chooses a working time between 8:00–16:00 every day; if not participating in lectures or other courses, they would be in the group room. Two cameras were placed in the room. One backup camera in the corner of the room and one 360 degrees camera in the middle (Fig. 1).

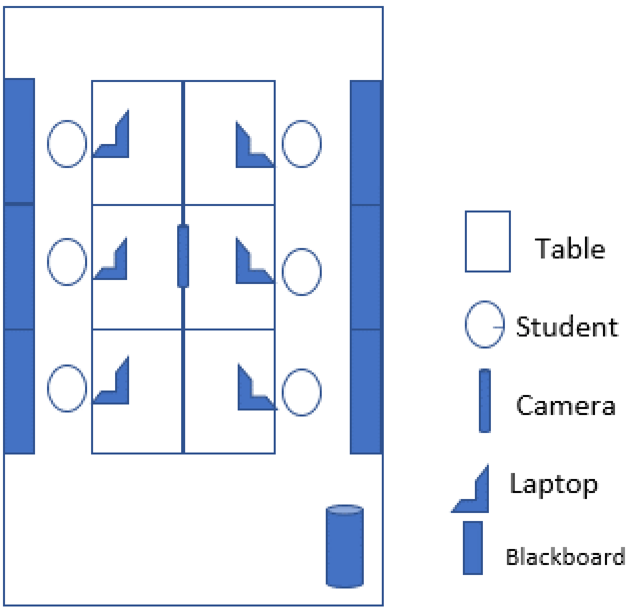


Figure 1. Layout of the room.

The 360-degree camera was placed on a stand in the middle of the tables. This meant the focus was on the students' facial expressions. It also meant we did not focus on the content of their laptop screens.

Ethics and Collection of Data:
To collect our data, written consent was given from both the students and supervisor to follow, record, and present the data in journals, teaching activities, and workshops without any kind of anonymization. They were all provided with the opportunity to withdraw this consent if they came to regret their decision.

Selection criteria for analyzed segments:
Following group work over a semester produces a vast amount of data. At the time of this publication, the first two months of video were indexed. This meant the video was watched, and a short log was written describing the contents of the video. During this process, it became clear that the problem was most actively discussed during the first month. We focused on clips where there was an active negotiation of the problem fostered by an internal disagreement in the group. Focusing on specific cases of interaction is also termed "hot spots" by Jordan and Henderson (1995), which is defined as: "sites of activity for which videotaping promises to be productive" (Jordan and Henderson 1995:43). The detailed understanding provided by the microanalysis of interaction informs on a general understanding of the practice studied. During the first month, the group met 16 times. During these meetings, there were a total of eight examples where the problem was addressed. Out of these eight examples, there were three examples where the group disagreed about a decision concerning their problem's content. It is these three examples we will be looking into in this paper.

Presentation of data in this paper – Jefferson Transcription System
To present our data, we will use the Jefferson Annotation system (Jefferson 2004). What is important to remember in this regard is that normal grammatical conventions are not used and lines with punctation means small breaks in the interaction. At some relevant points, an arrow will link the utterance to a picture of the nonverbal action performed at the end of that specific utterance.

FINDINGS

As will be shown, the interactional structure in the three examples might seem different. Still, a precise conversational structure of which factors establish what kind of decision the students make, will be evident in all examples. Thus, our concern becomes how the conversational structures establish whether a decision proposal will be accepted or not.

The group consists of six members:

P: Patricia
S: Stine
J: Jacob
M: Magnus
F: Franz
T: Teitur

Figure 2. Student names.

Shown in the pictures below

Figure 3. Picture of students.

The first instance was recorded with a handheld camera. The students communicated in Danish, but the transcripts were then translated to English by the author. Only the English transcripts will be shown in this paper.

Extract 1:

In this sequence, we jump into the group's first meeting. It is their first day of a new semester. They have just formed the group, been assigned a group room, and brainstormed towards a more concrete subject for their project. They formed the group on the notion that they wanted to write a project about storing energy produced from sustainable energy sources; the brainstorm focuses on which sector of energy storage they should choose; private or business. Stine is writing on the blackboard and is asked by Magnus to draw a house on another blank blackboard. We enter the interaction after she has drawn the house. As the example will show we see how Magnus proposes a decision that is questioned by Stine, Magnus then addresses these questions, and his decision proposal is accepted without much debate. A conversational structure is then presented showing how the decision was made.

15 M: and then how would we like to get our energy
16 (.)
17 M: should it be wind turbines or solar panels
18 S: >well have we ↑chosen have we chosen shouldn't we ↑choose if we
19 would choose it first< ((turns around towards the other blackboard))
20 M: we do that
21 (.)
22 M: we have chosen
23 (.)
24 J: ha ha ha:aah that is a veto right there
25 S: ↑does everybody [agree or]((looks towards Franz))
26 F: [y:::es]
27 S: are there anybody who would rather do something else
28 (2.0)
29 S: °I am looking around now° ((looks around))
30 F: well I think private storage also

Figure 4. Extract 1.

In the interaction shown above, we see a disagreement on whether a decision regarding their project's subject has been made. The discussion has centered on whether to focus on private energy storage or business energy storage. In line 15, after Stine has drawn a private household (as told by Magnus to draw), Magnus asks how they would like to get their energy and ends his Turn Construction Unit (TCU), creating a Transition Relevant Place (TRP). Nobody else takes the turn, so Magnus takes another TCU in line 17, where he performs a repair of his utterance in line 15, making his question more concrete by offering different options to his question. Stine infers he is talking about private storage, so while replying in a rapid talk, she turns around, orients her hand, and gazes towards the other blackboard with the subject, and then afterward, at the end of her turn, directs her gaze towards Magnus, choosing him as the next speaker. As Goodwin (1980) states, the speaker should obtain the gaze of her recipient during the talk; however, in this instance, one could argue that Stine allocates a turn towards Magnus as she is directing her question towards him by orienting her body towards him (see picture at line 18). However, before this, she orients towards the blackboard. One could argue that by pointing towards the blackboard, she is directing the whole group's attention towards the discussed subject; the blackboard thus serves as an artifact to collect the attention of the participants in the room and creates a form of cohesion or focused attention towards one single point of attention. In that way, she is including the rest of the participants in the room in her questioning of Magnus. He replies in line 20 by stating, "first; we do that". Although not that clearly shown in the transcript Stine now shifts her gaze from Magnus towards Franz in line 25 before Franz replies, Magnus repeats his utterance resulting in laughter from Jacob and Stine. Stine now verbally asks if people agree, and Franz replies immediately in line 26, which could be due to the previous gaze or turn allocation Stine tried to allocate towards him. Stine then tries to make sure everybody agrees on the subject, which they do (although not shown in the presented extract).

In the above instance, we have shown an example of one type of decision-making regarding the students' problem or subject area. One student makes the decision, which is then questioned by another. The initiator of the decision defends the decision, and the rest of the group agrees with the decision, as such the following sequence can be made:

1. One member initiates a decision (line 15 and 17)
2. Another questions the decision (line 18)
3. The initiator addresses the questions (line 20 and 22)
4. The other members agree with the decision (line 26 and 30)

In this example, we see how the discussion about a given topic is formalized into a discourse of procedure (did we or did we not choose that subject) instead of a more academic discourse such as; "what are the arguments for choosing this topic instead of the others?". As such, it lacks the use of academic or theoretical discourses. The argument thus becomes whether or not the other group members agree with the topic and not why or what in that given topic, they wish to examine further. As such, one could state that the students make decisions like they would do in their daily lives, focusing on whether all agree with the decision instead of the decision's academic merits.

Extract 2

In the next example, we will see an instance where a decision towards the problem is presented, but not picked up by the group. We finish by focusing on the conversational structure again to see what have changed from the first example.

A week has passed since the first meeting analyzed above. The group has decided to write a project about private energy storage from solar cells in batteries connected to the household. A discussion about the battery's size has led to a discussion about where the battery should be placed in the household (as the placement decides which sizes are relevant to work with). We enter when Patricia proposes an idea:

```
P: °like ↑if you put it down in the floor then you could make so:::me
   (1)
F: but if you put [it down in]
P:                [heat in it]
F: if you put it down in the floor then it is difficult to remove
```

Figure 5. Extract 2.

Patricia introduces the idea of putting the battery down in the floor for it to be able to produce heat in line 2, followed by a pause, which seems to be interpreted as a TRP by Franz as he produces a turn in line 3. However, it seems like Patricia does not see it as a

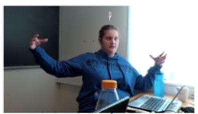
TRP, as she is overlapping Franz in line 4, making Franz stop his turn, wait until Patricia has completed hers, and then resume his turn. The suggestion is turned down because you have to switch the battery every 5–10 years, and you cannot do that if the batteries are in the floor. Patricia responds by providing an option of how to deal with that difficulty:

```
P: couldn't you but you can have like a[do::::or thing]
M:                                     [yes yes ye:ah]ye::s
P: if you had like a giant
S: a do:::or thing ↑ like in the floor
F: yes like a hatch
   (0.5)
F: a hatch in the floor
   (1)
M: like a trapdoor in the floor
F:                    [like und]er under a carpet like you see in the old movies
M:                                                                   ((laughs))
S                     [YES YES]
   (1)
F: where they have that safe underneath
P: [yes]
S: [yes]
F: you could do something like that
```

Figure 6. Extract 3.

The above transcript will not be analyzed in detail but is included to show how Patricia in line 11 introduces the concept of a "door" (both verbally and nonverbally), with her body movement from down to up as shown in line 11, imitating a door/hatch being opened. It is interesting to note here that M in line 12 produces minimal response towards P's previous utterance, and after explaining what they mean to Stine, Franz states: "you could do something like that" in line 27. Nobody has criticized the idea of placing the battery in the floor with a hatch to produce heat; however, Patricia now changes her suggestion/idea:

```
(1)
F: where they have that safe underneath
P: [yes]
S: [yes]
F: you could do something like that
P: like you you could also [do it like have a giant closet]
M:                                   [°a dungeon]((laughs))
(0.5)
P: and then have like some small battery packs that like is taken up and down
(1)
P: then you don't have to have a big battery but it is like small components
F: yes then you don't neee need batteries in a series
M: [e::::::::::::::::::::::::::::::::::::::::::::hm] but you would like to get
the batteries'
(0.5)
M: cells drained
(1)
M: e:::qualy  to get like when it is finally drained then it is the whole
battery you just switch
(2)
```



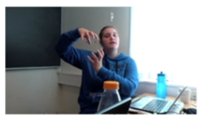
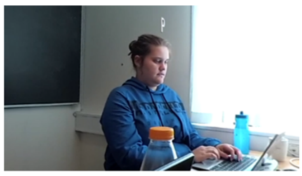


Figure 7. Extract 4.

In line 29, Patricia is adjusting or providing an additional idea to the group. Instead of having the batteries on the floor, you could have them in a giant closet as she shows nonverbally in line 29 as well, where the width of her hands figuratively symbolizes the size of the closet. This gestural representation of her utterances continues in line 32, where she figuratively shows the size of the small batteries. Her suggestion thus becomes to switch the batteries little by little. It is interesting to note that nobody had turned down her previous idea of having the batteries in the floor, if there was a hatch in the floor, that idea was complimented by Franz in line 28. Patricia's new suggestion seems to be an orientation towards the idea of switching batteries, so she is developing her idea by incorporating the other group members' feedback to her first idea. Franz' utterance in line 5 and Stine's utterance that followed (which is not shown in the extracts) mentions the requirement of being able to switch the battery. By introducing a "giant closet" where switching batteries or part of a bigger battery is easy, Patricia orients more towards the problem of switching batteries than her first idea of providing heat in the floor. The idea is, however, put down by Magnus in line 36. Notice his long way of formulated his e::::hm, this could indicate that he knows his response might be a dispreferred response as he is criticizing the idea, arguing it cannot be done because batteries of the size they are working with contain multiple cells and you want those cells drained equally, you cannot just take one cell out. The fact that his response is dispreferred can also be seen by the two-second pause following his statement. Stine then questions this statement by Magnus. After Stine questions Magnus, Patricia suggests testing her idea:

61 P: but it is not something we could test on
62 (0.5)
63 P: we could see if li:::ke if maybe two batteries in a series is the same as one
64 battery that should have the same capacity like the two
65 M: but it is
66 (2)
67 P: does it drain like what what drains more what is better
68 F: what
69 M: o::::h
70 S: THEORETICALLY I think it doesn't matter
71 P: [yeah theoretically] but like
72 S: [((laughs))but]
73 M: but [I know]
74 F: [in prac]tice



75 M: like
76 (1)
77 S: like it [helped]
78 M: [if] you buy a battery a bbbb bigger battery then it is not one
79 then it is not one cell
80 (1.5)
81 M: then it is several cells that are connected
82 F: it is
83 (3)
84 F: they are connected in some sort of way
85 S: and it is like if you have it in ONE box or what you say then you would like
86 to have it all drained e::::qually for then you switch the whole battery
87 otherwise you have to switch something if some of it is too drained and some of
88 the cells is not too drained then you will have to switch a battery where some
89 of it is actually all right

Figure 8. Extract 5.

In line 61, when Patricia suggests they test her idea, a TRP occurs afterward (line 62). No other person initiates a turn, which then prompts Patricia to elaborate on her testing idea, which Magnus questioned in line 65. One could again argue his response is dispreferred as a 2-s pause follows. However, Patricia continues to elaborate her idea in line 67, to which Magnus replies: o:::h in line 69, giving the idea that Magnus can now follow Patricia's notion of thought. Stine then states that, theoretically, there should be no difference. This utterance is quite interesting because Stine is criticizing the experiment. Thus the problem Patricia suggests, like Magnus has done several times before, but it is not treated as a dispreferred answer by the participants, as no longer pause follows. So why is Magnuses' statement followed by a pause when Stine's is not? Looking at the transcript, one could argue that it is his short-determined answer in line 65: but it is, where Stine in line 70 states, THEORETICALLY, I think, thus her statement: "I think" downgrades the contents of her utterance, making it easier to challenge. Then Patricia in line 71 utters: "yeah theoretically but like", after which Magnus states: "but I know" and Franz continues Patricia's utterance from line 71: "in practice" however nonverbally, something interesting is happening. P starts to orient towards her computer, as seen in line 74, and she does not produce any further utterances. Nonverbally, she thus might have withdrawn from the conversation as she lets the other team members discuss her suggestion and reject it. In line 78, we see Magnus repeats his previously uttered comment about bigger batteries containing more cells; this is backed up by Franz and Stine, who give a longer explanation for why the idea/decision will not work. The suggested decision is thus abandoned.

Interestingly enough, the students seem to take what they believe are theoretically informed decisions (line 70). They state that theoretically, there should be no difference, and one battery contains multiple cells; thus, P's idea of changing parts of the battery will not work. From the example given above, we can present this structure:

1. Initiator of a decision introduces a decision (P line 1)
2. The decision is questioned by another (F line 3 and 5)
3. The initiator addresses the questions (P line 11)
4. One member of the group states that could be done (F line 28)
5. The initiator changes the decision (P line 29)
6. This decision is then questioned (M line 36-42)
7. The initiator addresses the questions (P line 61-67)
8. The questioning of the decision continues (M line 78-81, F line 82, S line 85)
9. The initiator withdraws from the questioning (line 74)
10. The decision is abandoned.

We can see that questioning a decision proposal seems to be the preferred way to deal with disagreements towards a decision. However, this example also shows how the initiator changed her decision-proposal in the process. As such, she started with one initiation that received questions that were answered and, even though this decision then received praise, the initiator came up with a different decision proposal, to which new questions were raised, and an elaboration happened, but it was in the end declined. We also saw how the initiator withdrew from the interaction and started orienting towards her computer. From this, we can conclude that persistence seems to be of the essence when you want your decision to go through. You need to be able to argue for the merits of your decision.

Looking more qualitatively at the content of the discussion, we can see that different kinds of designs are discussed; batteries in the floor or a giant closet; what seems to be evident by the group in these discussions is not the visual layout, but the practical accomplishments of a given product. Batteries in the floor are good because they can provide another practical feature by producing heat in the floor. Batteries in a giant closet are a good idea because they might help with the practicality of switching the cells in the battery, thus reducing the costs of a battery switch. However, this is not possible due to larger batteries containing multiple cells that you want to be drained equally. According to the theory, there does not seem to be any difference between multiple batteries or one large battery. Thus, the decision taken here is more theoretically informed than the first one, as they cannot find a theoretic argument to justify their lab experiments.

In our last example, we will focus on an instance where no questioning is directed towards a decision proposal. However, at the last point of this interaction we see how they return to the structure described in the last two examples.

Extract 3

A week has passed since extract two. In the following example, we will only focus on the verbal transcripts as we are incorporating a long example. The group has just discussed a questionnaire by the semester coordinators on whether their project is suitable for this semester. They agree that it is according to the learning goals, but Jacob questions whether it is in accordance with the coursework. The other members quickly agree it is. However, later on, Jacob asks if he can elaborate on why he thinks it is not, which is when we enter the conversation:

```
J: so can I try to come with a for example of why I don't believe
   (1)
J: that we will like go in depth and look at stuff like that
S: yeah
J: it is for example that
   (1)
J: if we talk about err
   (2)
J: >it is the whole system right and also if now for example when we talk about
dimensioning or our analysis of in relation to err or simulation of in relation
to err when will the power be used and so on<
S: yes
J: it is more about
  (1)
J: the concrete units like how
  (1)
J: big this battery should be
  (1)
J: in relation to err how much power in relation will ehh how much power will be
used and so on it is not okay
  (1)
J: it is relvan that it is
  (1)
J: detailed okay like it is because it is from AC to DC
  (1.5)
J: for example
  (1)
J: it is more like the system of wha where the ussage is
  (1)
J: and effect and the effect necessary for it for example
  (1)
J: it is not
  (2)
J: the w:::::ay it is used if that makes sense
S: [yeah]
  (3.5)
S: it does maybe
  (2)
J: yeah I don't know
  (0.5)
J: but ° (unclear) °
M: no °I can see your point° you you think more like that it will become an ehh
J:                 [it will]
```

Figure 9. Extract 6.

Although this extract is pretty long, we want to draw the attention to the number of turns Jacob has even though numerous points of TRPs occur (lines 2,6,8, 14,16,18,21,23,25,27,29,31,33,36). We can see that Jacob's reaction to the lack of turn initiation by the other participants is a continuing elaboration of his point. In line 9-11, he talks very fast as well, which might indicate that he is nervous. Therefore, he speaks faster, backed up by line 12 when Stine utters yes, and Jacob then slows the speed of his talking. In line 34, we see that Jacob is directly requesting a response with his utterance: "if that makes sense". This follows a 3.5-s pause, which might further indicate Jacob being done with his elaboration. Afterward, a small acknowledgment is provided in line 37. However, in line 39, Jacob states: "yeah, I don't know" which might seem a bit contradictory given his numerous previous turns where he elaborates on his point. This might be due to a dispreferred answer from the group. Although Jacob does initiate a turn in line 41, we do not know if he intended to argue further for his proposal or downplay it. However, in line 42, Magnus states that he can follow Jacob's point.

This extract shows that feedback to one's decision proposal seems important to examine whether the decision can be made. However, as no response is coming, the initiator seems to backtrack for a moment, shown in line 39 above. In the continuing interaction, we see that it returns to a previously described conversational structure where the decision is questioned:

```
M: yes but we get like ehh we get like the AC power that we can describe with a
sinus or a cosine curve
J: that we can of course do but
M: shouldn't we be able to do that
S: yeah
J: but how much
  (1)
J: it needs to be done because we should still like what we are >thinking on it
is like if we just say like okay it needs to transformed to AC power because it
needs to get out of our power sockets for example< and >THERE are some different
devices that runs with different effects for example<
  (2)
M: so that we THAT WE
S:    [when]
M: should make sure that maybe we will write a
  (1)
M: problem
  (1)
M: what is it ca::led it no what is it called
S: >problem statement<
M: a problem statement THAT makes sure we can't
  (1)
M: e:::r settle with
  (1)
M: and
  (0.5)
J: yeah that can
S: yeah
M: and look at e:::h
  (2)
M: that which you are talking about
J: ehmmmm
```

Figure 10. Extract 7.

Magnus formulates a question towards Jacob in line 67-68, which is supported by Stine in line 71. Jacob then elaborates on his decision proposal in line 74-77. After that a new TRP occurs, and Jacob does not take the word. Magnus does, and the result is that Jacob's proposal for a decision is met, and they are now discussing how to account for his objection. The overall structure of this decision-making process can thus be summed up in the following way:

1. Initiator proposes a decision (line 1-25)
2. No reactions from the other group members (line 21, 23, 25)
3. Initiator elaborates his decision and asks for a response (line 26, 28, 30, 32, 34)
4. No reactions from the other group members (line 36)
5. Initiator questions the knowledge of his decision (line 39)
6. Group members support the initiator (line 42)
7. Initiator elaborates (line 45, 49, 52, 57-58)

8. Group members question the decision (line 67-68, 70, 71)
9. Initiator elaborates (line 74-77)
10. Decision is met and worked into the project (line 81-95)

Although this decision structure is again structurally different from the others, more academic discourses seem to be put into play by discussing what kind of power (AC or DC) they use and whether they go in-depth with the coursework in their project. As such, we see a gradual increase in the theory used in the students' work.

CONCLUDING REMARKS

Our research question for this paper was:

How do students negotiate disagreements in their decision-making regarding their problem construction, and which element(s) in the interaction establishes if the decision is made or not?

We analyzed three discursively different instances of internal disagreement toward a decision in the students' group work. However, at some point all three examples contained this structure:

1. Initiation of a decision
2. Questioning of the decision
3. Initiator addresses the questions
4. Decision is either met or declined depending on the initiators ability to address the questions.

We find it interesting that even though the discursive content of the three examples shown are so different, they all in some way contain or return to the same structure regarding decision-making marked by a disagreement. As we studied the conversational features, practical accomplishments, and discursive organization of the students' interaction, we found a conversation structure present in all examples regarding how students interactively state their disagreements towards a suggestion. Instead of stating directly; "I disagree with what you are saying", they start asking questions about the suggested decision. Even in the third example, where no questions were asked, they returned to a formula where they asked questions about the decision proposal. This questioning could mark a non-alignment towards the decision proposal, which is then negotiated in the following dialogue. We also see what determines whether a decision proposal is accepted or not is the ability to hold on to your suggestion and elaborate on the merits of that suggestion. As shown in example two, Patricia changed her decision proposal and withdrew from the questioning with the result that the group did not accept her proposal.

Although we couldn't find other studies that relate to decision-making among students in higher education, we would like to relate to the famous I-R-E form found in educational institutions (Mehan, 1979). Here a structure into which there is an Initiation by the teacher to the student (by asking the student questions that the teacher knows the answer to), Response by the student, and Evaluation of the response by the teacher. In the same way we argue disagreements have the following structure: Initiation of a decision (by proposing a decision). Questioning towards the decision (marking non-alignment towards the decision). The initiator addresses these questions (determining if the decision is accepted or not). Decision is then either met or declined. An interesting finding in this regard is that the strength of the argument did not seem to be the most important factor into which the decision was met, but the ability to hold on to the decision and keep arguing for it.

From a critical point of view, one could question if it makes sense to draw these conclusions on the limited amount of data, we have of one group's work. Although this is accepted according to our ethnomethodological framework, that states social actions are part of both micro and macro structures (Garfinkel & Rawls, 2002) we welcome further studies in this area, especially in other higher educations could be interesting to see if the structure is the same. Another critical point is the lack of academic discourses utilized in the students' discussion and decision-making in relation to their problem. However, suppose we see these instances as a gradual academic development of the students' theoretical knowledge and, thus, a more qualifying problem construction, as time progresses. In that case, it might look a bit different. As mentioned in the introduction, Garfinkel stated that when engaged in a specific institutional practice, only 5% of the institutional way of making decisions are evident in the social interaction. Within this framework, if we look at the interaction, it could seem surprising that the first example shows no deep discussions about the content of the problem. Thus, one could argue the students approach this, not from an academic angle, but from how they would approach this in daily life. However, what also seems evident is that the discussions become more academic and theoretical informed as the students progress with their studies. Thus, the students engage from what they know, and as their knowledge increased, they incorporate more theory in their discussions as they progress. For example, two, they discuss the merits of batteries and how they drain; in example three, they discuss what kind of power they will use in their project; thus, we see a gradual academization of their discussions.

What relevance does this study have for Near Future Cases of PBL? The study provides an insight into how students make decisions and what seems to determine the outcome of whether a decision is met or not. In this regard it is worth noticing that a questioning or non-alignment towards a decision proposal is not equal to a decision-proposal not being accepted. Thus, to prepare the students for their PBL work we need to encourage them to actively discuss the merits of their proposal and emphasize how questioning towards their proposal is not equal to a proposal not being met. In other words, we need to strengthen their ability to argue for the merits of their decision. Some would state this is already an essential part of PBL and nothing new. In that case this study shows exactly how it is done and what might determine a decision's outcome.

Furthermore, we want to emphasize that students constructing their own problems has been a practice for nearly 50 years. To our knowledge, this is the only research looking at the interactionally work of this practice. Additionally, the problem will consistently be relevant for Problem-Based Learning. In near future practices, knowledge of how the students approach the problem will be relevant to further develop these practices. We hope our study provides knowledge for how PBL is done in practice. Thus, it gives us a better foundation for developing both near future cases and inspiring others to focus their research on students' interaction.

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Creating Landscapes of Practice through Sequential Learning - A New Vision for PBL

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ABSTRACT

In the current conceptualisations of Problem Based Learning and how we practice it, the students are expected to possess the necessary academic competencies in order to study through PBL. However, a desk research reveals that students in many cases don't have the necessary understanding or conceptual comprehension of disciplines such as problem formulation, analysis, exploration, literature review etc., which prevents them from unfolding an explorative approach to their professional practice. This article thus discusses Dewey's concepts of sequential inquiry processes to create new forms of learning designs to bolden further students ability to work problem-based. The article discusses through the development of iterative learning design how structured sequences of activities can provide a descriptive language to qualify a methodology for PBL. The study is based on Educational Design Research (EDR) as the overarching framework where the methods of Design thinking inform the design activities through iterative processes. Through a period of two years a total of 400 students at the education of ATCM, at University College of Northern Denmark has participated. The data collection included results from observation, reflective portfolios and sound recordings from

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the students' group work in combination with sketches, drawing and artefacts from the iterative design process.

Keywords: Landscape of practice, PBL, Sequential learning, inquiry, exploration

INTRODUCTION

A prerequisite for PBL is that the students have an autonomy that enables them to work analytically and critically concerning a professional problem. However, a PhD study (Gyldendahl-Jensen, 2020) has revealed that students in many cases don't have the necessary understanding or conceptual comprehension of disciplines such as analysis, exploration, critical thinking, reflection, process, literature review, method etc., which prevents them from unfolding an explorative approach to their professional practice. Very often, the student needs to figure out by themselves how to create a bridge between theory and practice through analytical disciplines. The students lack specific learning strategies for how, through a curious and investigative behaviour, to create an in-depth analysis of the presented content that leads toward meaningful learning experiences. It means that they often are brought into situations where they do not know what the next step is.

This perspective challenges the current conceptualisations of Problem Based Learning and how we practice it, where students are expected to possess the necessary academic competencies in order to study through PBL. Based on the danish model of PBL and from scholars originating from Aalborg University, this paper thus argues that there is a need for new theoretical and methodological frameworks that through a scaffolded approach develops the student autonomy that enables them to work and learn through a problem-based learning environment.

With an inspiration of Practice Theory's understanding and interpretation of learning, this article suggests that education instead should be designed as complex and personal learning trajectories by considering learning as a complex landscape of personal learning trajectories. To better facilitate learning trajectories it can be argued that there is an opportunity to think in terms of design strategies that more effectively facilitate students through meaningful learning processes built around an explorative approach to the traditional academic disciplines. Within the Practice theory, it is said that learning occurs as gradual, cumulative or anticipated developments that follow predictable paths (trajectories) but that it is the sudden obstructions and disturbances that trigger reflection and thereby an innovative development of knowledge (Schatski, 2016b; Dreier, 2015). For example, Theodore Schatzki (2016) describes learning as a process that follows a path that in a metaphorical sense consists of different knowledge and experience episodes that overlap and build upon each other. In practice, it would be a series of multimodal activities that are constantly challenged by obstructions and disturbances (Schatzki, 2016). The chosen path will over time reflect possibilities for achieving specific learning based on the dependency relationship between the two concepts: ***Proceed*** and ***depends -*** how are the students going to proceed, depending on what they have already learned (Schatzki, 2016b).

This article, therefore, discusses whether a systematic approach to Dewey's concepts of sequential inquiry processes can create new forms of learning designs that strengthen the students' ability to work analytically and exploratively (Dewey 1933, 1980 and 1991). Based on Educational Design Research (EDR) as the overarching framework, The article discusses through the development of iterative learning design or design schemas how structured sequences of activities can provide a descriptive language to qualify a methodology for PBL (Stolterman, 2008; Davidsen, Konnerup, 2016).

The study is based on Educational Design Research (EDR) as the overarching framework where the methods of Design Thinking formulated by Stolterman (2008) inform the design activities through iterative processes. Based on ELYK's phase model for EDR (Christensen et al., 2012), this study addresses the first two phases; "Problem and theory identification" and "Designing the prototype" to develop conceptual designs of learning sequences based on the following three academic concepts; theory work, literature review, and conducting an analysis.

First, the following chapter presents a critical view of the current understanding of PBL. Next, the theoretical framework for how to understand PBL through the lens of practice theory is elaborated. Then the research design is described followed by an elaboration of how the iterative learning design can create structured sequences of activities to provide a descriptive language to qualify a methodology for PBL

Challenging the current understanding of PBL

There is a general agreement in the literature that the basic and supporting principles for PBL must be about problem identification, time and project management as well as group work based on authentic and often interdisciplinary problems. (Holgaard et al., 2014; Stentoft, 2017; Davidsen, Konnerup, 2016; Hüttel, Gnaur, 2017). Also, the student must have the freedom to influence which academic topics they choose to immerse themselves in. It means that learning through PBL is an active process that requires a high degree of commitment from the student (Holgaard et al., 2014). The theoretical learning intention behind PBL is thus that the student through an exploration of problems, among other things, achieves critical thinking and analytical competence. Also, PBL is often based on a high degree of interdisciplinarity, where the students' focus on a specific problem *"promotes an integration of ways of thinking, doing and being in different disciplines, which are isolated in the traditional approach to university teaching"* (Hernandez, Ravn, Valeo, 2015, p. 22). It means that PBL creates a deeper understanding of the nuances that characterise a practice-related problem where it may be necessary to navigate across many different disciplines to create a link across different perspectives. Stentoft (2017), describes it in the following quote as the ability to work and investigate at a higher level of abstraction.

Having said that, it seems to be common that there is a division of the theoretical learning principles that relate to PBL, where learning outcome that deals with profession-specific competencies or general study competencies are not part of the basic pedagogical "DNA" that characterises PBL (Davidsen, Konnerup, 2016; Holgaard et al., 2014). Several texts speak about, for example, that methodical skills are only relevant as transferable skills or to achieve transferable skills and hence not something that can be characterised as a consequence of PBL (Kolmos, 1996; Holgaard et al., 2014). It reduces PBL only to include problem orientation and project management and collaboration/group work. (Davidsen, Konnerup, 2016; Holgaard et al., 2014; Kolmos, 1996). Thus, a prominent agenda is seen that PBL must adapt in a way where the epistemological, theoretical and methodological intentions and educational considerations must not be restrictions that hinder how students navigate concerning a self-directed problem (Stentoft, 2017). Here, in particular, the combination of PBL and project-based learning challenges this agenda. Kolmos (1996) points out the risk that the often teaching-centred process of project work becomes an obstacle for the student agency to explore a problem. In this regard, the concern is mainly about what significance the teachers have on the students' *choice of disciplines and methods and the problem itself arises from the problem-oriented theme"* (Hüttel, Gnaur, 2017, p. 4). It raises the question of whether the basic idea that PBL is the shift from teaching to learning is challenged by the fact that teachers support students' learning through a focus on method awareness. Several texts speak in this connection about the teacher's role as a process-oriented supervisor where the task of the teacher is altered from the transferring of knowledge into facilitating learning (Kolmos, 1996; Hüttel, Gnaur, 2017; Holgaard et al., 2014).

There is thus in PBL a basic assumption that the problem itself can constitute the learning process born out of inner motivation. And the question is whether it is an illusion that learning is constituted only from within, especially in an educational system where a specific curriculum is determined and described. It must therefore be relevant to be critical of how we understand a "problem" and for whom it is a problem? In addition, whether the student's inner motivation drives the study behind the problem, or whether it is possible to reach a higher level of abstraction and academic depth if the students are more methodically supported - that PBL is not seen as something independent of general study competencies or transferable skills.

We comprehend with the concepts we have

A prerequisite for PBL thus seems to be that the students have an autonomy that enables them to work analytically and critically concerning a professional problem. However, as stated in the introduction, in many cases the students don't have the necessary understanding or conceptual comprehension of disciplines such as analysis, exploration, critical thinking, reflection, process, literature review, method etc., which prevents them from unfolding an explorative approach to their professional practice. Through a systems theoretical analysis of PbL, Keiding (2008) points out that a prerequisite for the student to be able to communicate, for example, process understanding and thereby actualise their exploration of a problem, must be observed in a participant's mental system. It means that the student does not necessarily achieve learning though the project development (Keiding, 2008). That this is the case is backed up by several texts that describe how the students experience that PBL is challenging and chaotic, especially without knowledge of working methods (Holgaard et al., 2014; Hüttel, Gnaur, 2017; Stentoft, 2017). It is followed by a concern expressed by the teachers telling that the students do not get hold of challenging and ambiguous problems and that there is a lack of involvement of theory and method (Hüttel, Gnaur, 2017).

Another challenge is the extent to which students can work interdisciplinary with their problems, where they must possess the right competencies to be able to process and explore complex and situated problems at the intersections of disciplinary boundaries and conflicting epistemologies. Stentoft, 2017 points out, among other things, that" *interdisciplinary learning cannot be taken for granted in problem-based settings, and only if issues of interdisciplinary learning are specifically addressed can problem-based learning be considered a pedagogical approach adequately scaffolding interdisciplinary learning in higher education"* (Stentoft, 2017, p. 51). The challenge for the students arises as the educational organisation around PBL does not, as described in the previous section, include a disciplinary scaffolding of the learning process. As Stentoft (2017) points out, there is a need for strengthening a general procedural scaffolding of the learning process without compromising with students' active and self-directed learning (Stentoft, 2017).

Researchers in the field of learning design, in particular, have worked to find this balance between scaffolding and self-directed learning. Here it is said that learning design can be seen as a form of descriptive language or pattern that can form the basis for being able to facilitate, among other things, reflection and discussion. Davidsen, Konnerup (2016) uses in the following quote an example of how a sheet music system provides a common language, rules and form of how music is developed, but that it is the performers who through their interpretations make the music unique and personal. Working problem-based thus involves travelling along a trajectory created by the choices the students make around method and subject based on the problem (Hernandez, Ravn, Valeo, 2015; Kolmos, 1996). When it comes to the development of a self-directed learning trajectory, the students must be able to initiate the right activities concerning being able to explore the complexity of a given problem, which requires that the students can visualise and actualise the learning process (Keiding, 2008; Stentoft, 2017). It means that a clear scaffolding strategy to a greater extent must be created for PBL based on a strategy which does not only focus on letting students explore through problems (Stentoft, 2017). This means that the students must be supported at several levels that go beyond finding a problem, time and project managing and group work. Keiding (2008) describes, for example, how it is possible through various reflection programs to reduce the complexity within one or more dimensions of meaning-making, thereby relieving the students, without this in any way depriving the students of the responsibility to organise themselves (Keiding, 2008).

In the following section, the idea that through an explication of a specific language or pattern is possible to create greater depth and level of abstraction in problem-based learning processes is unfolded. By supporting students in developing competencies within as critical thinking, learning how to learn, integration of theory, the goal is to strengthen the students' ability to respond to changing contexts that have become central to higher education practices (Stentoft, 2017; Hernandez, Ravn, Valeo, 2015; Hüttel, Gnaur, 2017).

THEORETICAL FRAMEWORK

There seems to be a consistent pattern for how to work with PBL pedagogically, namely a focus on formulating problems, planning and time management of project work, as well as handling the challenges that arise in connection with group work. On the other hand, a pedagogic coupling of academic and methodical skills with the PBL principles is almost absent. Several texts speak about, as described earlier, that methodical skills are only relevant as transferable skills and to achieve transferable skills and hence not something that can be characterised as a consequence of PBL or something that can promote the intended learning that arises based on PBL (Kolmos, 1996; Holgaard et al., 2014).

In the following sections, practice theory is unfolded as a suggestion and inspiration for a re-description of the theoretical foundation of PBL, where a more significant effort is made to reconcile academic and methodical skills with the PBL principles to be able to guide and facilitate the students gaining an understanding of the applied project methodology to mobilise systematic knowledge-based research approaches. A basic understanding of what characterises a methodology for exploration and experimental learning is crucial for students to achieve the learning objectives (Hüttel, Gnaur, 2017). If the students do not have the right competencies concerning being able to formulate a specific problem and afterwards unfold it through an exploration process, it isn't easy to achieve the intended learning potential that is expected through PBL - especially in terms of depth and reflection

Problem-based learning and practice theory

To contribute to corroborating the existing knowledge about PBL and as a result of this challenge and provoke a new way of Thinking and Design PBL in the near future, it's meaningful to revisit some of the theoretical positions that characterise PBL. Based on the presented literature, it is found that PBL to a large extent is described within the constructivist domain with a bias towards a more socio-cultural perspective. Based on that, this article will challenge PBL through the ontology of Practice Theory's, as it argues that learning arises from designed learning spaces where a combination of different activities and social relation strengthens the theoretical learning intention that characterises PBL (Schatzki, 2016, Schatzki, 2017; Dewey, 1933; Kjær, 2010; Elkjær & Wiberg, 2013; Buch & Elkjær 2015). Within the Practice theory, it is said that when learning is considered as a complex landscape of personal learning trajectories, it creates an opportunity to think in terms of design strategies that more effectively facilitate students through meaningful learning processes built around an explorative approach to the traditional academic disciplines. Here, practice theory offers several design principles that can support the development of PBL patterns where problem-solving is supported and mediated by procedural artefacts and procedures. For example, Dewey talks about how students(re)construct meaning and actions through an experimental approach through the use of tools and artefacts were the social context acts as stimuli that elicit particular reactions (Dewey, 1933; Kjær, 2010; Elkjær & Wiberg, 2013; Buch & Elkjær 2015). By mapping these complex trajectories, it is possible to shape what Keiding (2008) calls "systems of actions" (Keiding, 2008).

Based on the theoretical position of practice theory it is especially when learning trajectories that occurs as gradual, cumulative or anticipated developments that follow predictable paths (trajectories) are exposed to obstructions, disruptions and disturbances that a reflective behaviour is created which creates new meanings and knowledge (Dreier, 2008; Schatzki, 2016; Schatzki, 2017). It means that practice theory explicitly talks about how it is possible to consciously work with the student being able to challenge specific actions and its consequences, to be able to consider alternatives and critical analysis of underlying assumptions (Hüttel, Gnaur, 2017).

Problem-based learning as sequential learning trajectories

A significant aspect of practice theory's understanding of learning is the idea that the learning process should be understood as sequential (episodic) and complex learning trajectory (Dreier, 2008; Schatzki, 2017). It means that the educational challenge is to create a learning design where the problem-based project is broken down into smaller iterative sequences. Schatzki (2017) describes it as learning understood as a process that follows a "path" that is formed as a progression where different episodes of activities are overlapping and building on previous ones. Dewey's concepts of sequential inquiry can be used to elaborate how to understand the concept of sequential learning trajectories.

Dewey describes inquiry as an emotional encounter in an experience with an embedded conflict. It is a feeling that something is difficult; an uncertain situation where inquiry is the method to resolve this conflict and make sense (Dewey, 1933; Elkjær & Wiberg, 2013; Buch and Elkjaer, 2015). To do this, it is necessary to activate past similar experiences by experimenting with different possible paths to make sense of the situation (Gyldendahl Jensen, 2020).

In the learning process, these different possible paths or trajectories are constantly challenged to create processes of inquiry with a high degree of reflection and critical thinking (Schatzki, 2017). The students chosen path will reflect opportunities for learning through situations that are determined by practice-related challenges and disturbances. Inquiry can, therefore, be understood as a looping process where past experiences create the prerequisite for being able to overcome difficult situations. Experience is, therefore, a series of interconnected situations that Dewey calls organic circles. All situations are interconnected while each has its unique characteristics (Elkjær & Wiberg, 2013; Buch and Elkjaer, 2015; Gyldendahl Jensen, 2020). Working with PBL through sequential learning trajectories will thus intuitively and intentionally help the students to perform new activities in a particular practice (Dreier, 2008; Schatzki, 2017).

Understanding learning as sequential and complex learning paths opens up for an exploration process, where the student needs to find the "right" path by linking and combining the learning activities in a way that new realisations arise through reflection (Dreier, 2008). The process of inquiry thus assumes that there is an intrusion that needs to be figured out or something unclear that needs to be solved by means of thinking (Dewey, 1933; Frega, 2011) In order to operationalise this process, there must be a particular order of thought. The consequence of one thought sets in motion the next (Gyldendahl Jensen, 2020). To find these paths, the student must be able to carry out research processes by reflecting and analysing the events that affect both intentionally and unintentionally and by that disrupt the learning path and create a temporal conception (Dreier, 2008). The sequential processes of learning, therefore, has an experimental nature and Dewey argues that education and teaching are the elements that underpin and guides experience through a systematic approach to produce "intelligent actions" (Dewey, 1933, 1938a, 1938b; Tashakkori, Teddlie, 2010; Elkjær & Wiberg, 2013; Buch and Elkjaer, 2015; Gyldendahl Jensen, 2020). In such a situation, it is the ability to reflect and investigate that systematically provides the opportunity to react flexibly and well-considered to the consequences certain activities entail (Dewey, 1933; Kjær, 2010; Gyldendahl Jensen, 2020).

To do this, the students must, through a clear PBL learning design strategy, based on descriptive patterns for how to work analytical, critical and reflective, learn how to proceed depending on what they have already learned (Schatzki, 2017). Schatzki (2017) describes it as a chosen path that over time will reflect possibilities for achieving specific learning when the student faces an unclear situation, or dilemma (Dewey, 1933). Dewey thus places the initiative on the learner, pointing out that a prerequisite for creating an inquiry is that there is a curiosity to discover and investigate something (Dewey, 1933; Brinkmann and Tanggaard, 2010; Gyldendahl Jensen, 2020).

Curiosity is thus expressed as an exploration of intellectual purposes through sequences of studies and observations and ties experiences together. In order to create an inquiry process characterized by being both reflective, explorative and innovative, it is necessary that the process contains some form of coherence and continuity (Dewey, 1933; Gyldendahl Jensen, 2020). It means addressing the situation, activity, or curriculum from multiple angles, like through data- and knowledge collection, evaluation and assessment, asking questions, discussions, and arguing (Dewey, 1933). Thus, Dewey contributes to ”practice theory” ideas about the importance of thinking as he offers a conceptual apparatus that transforms intellectual thoughts into a form of practice. According to Kjær (2010), through this argumentation, it becomes apparent how thinking is an integral part of the action (Dewey, 1933; Kjær, 2010; Gyldendahl Jensen, 2020).

Problem-based learning as Landscape of practice

By considering learning as a complex landscape of personal learning trajectories, this article argues that there is an opportunity to think in design strategies that to a more considerable degree can help the students through complex PBL processes that point to new knowledge insights, and thereby inspiring new innovative representations of the academic (Dreier, 2016; Schatzki, 2016b; Davidsen, Konnerup, 2016). It is a way of thinking that still moves the educator's focus from the dissemination of knowledge, but at the same time offers a possibility to challenge the previous understanding of how to support the student learning process. By deliberately facilitating selections of academic activities that form an arrangement of learning trajectories it is possible to maintain the self-directed problem identification and at the same time ensuring that the student can navigate in their learning process, both analytically, critically and reflectively.

Only when the student can identify the processual and multimodal activities that are necessary to carry out a PBL project, are they given the opportunity to challenge the content through obstructions and disturbances. The teacher thus sets the framework for a learning design consisting of "landscape of practices" that reflects the student's opportunities to create trajectories full of interruptions or discontinuous. As a result of this the student's agency, capacity and ability to act in the learning process are being brought into play (Dreier, 2016; Schatzki, 2016b; Davidsen, Konnerup, 2016). Within that framework, students have the freedom to independently and actively mix activities, and with this create learning trajectories that follow individual problem formulation or project description.

METHODOLOGY

The study is based on Educational Design Research (EDR) as the overarching framework with a pragmatic Mixed Method approach as the primary epistemological foundation. Methods of Design Thinking formulated by Stolterman (2008) informs the design activities through iterative processes. Based on ELYK's phase model for EDR (Christensen et al., 2012), this study addresses the following phases; "Problem and theory identification", "Designing the prototype", "Intervention through the design" and "Reflection and concluding".

It is essential to be critical of the term 'Learning Design' that are used in educational design research as one of the core elements of the research process. Another important aspects are the issue of not being able to design learning but instead, it is a matter of being able to design tasks and tools that can support the learners (Davidsen, Konnerup, 2016). A review of the relevant literature of Educational Design Research that the term design is spoken of in general terms, but no directions or methods are given for how these designs occur. Nor is there any explanation for how the theoretical perspectives, which in many ways are the basis of what is being investigated, are being translated into concrete designs.

One of the few examples related to the design process in Educational Design Research is the book "Conduction Educational Design Research" of Susan McKenny and Thomas C. Reeves (McKenney, S., & Reeves, 2018). In the section "Design and construction" they try to give several suggestions on design methods. However, there is still a tendency for the discussion to be reduced to discuss the "necessity of design", and very little about how to conduct it. Even when Mckenny and Reeves in the book of Educational Design Research (2018) become more specific about what activities a researcher can initiate, it is limited to simple brainstorming techniques and idea-generation methods. The design problem is then being boiled down to concepts such as exploring, idea-generation and mapping solution. It skips central parts like synthesis as an abductive sensemaking process that merge and manipulate different elements into a cohesive structure through sketching, drawing and making artefacts. Instead, there is a focus on solutions that must be assumed to be the end product of a design process (McKenney, S., & Reeves, 2018; Gyldendahl-Jensen, 2020; Akkerman and Bronkhorst, 2013; Amiel, and Reeves, 2008; Majgaard, Misfeldt, and Nielsen, 2011; Engeström, 2011).

The underlying problem is the methodological description of EDR with a focus on **Design requirements** that specify the criteria of the intervention tied to the long-range goal and then **Design propositions** that guide how to achieve the long-range goal. But there is no methodological insight into how these Design requirements are derived or how they are used to inform the design. When idea generation is coupled with a detailed list of requirements and wishes, there is a risk that the design process does not create new insights but more creates.

This study is, therefore, based on an iterative design process in which several design schemes have been developed based on theoretical design principles as well as practical teaching sessions (Stolterman, 2008). Design schemas can be seen as graphical abstractions that allow discussing, defining, and embracing the thoughts and reflections that the first design principles create (Kolko, 2009). Kolko (2009) describes it as a way to organise the complexity of finding clarity in chaos through; (1) translating thoughts and reflections into images, (2) creating small graphic models that combine design principles into new ones, (3) creating an overview of the ongoing knowledge acquisition by visualising abstract theories, (4) developing graphical models that describe the ongoing recognition process in a structured way, (5) visualising the exploration process driving the project forward, by linking design schemas to beginning unique new designs. The different perspectives that design schemas express causes the designers to follow and examine different trajectories that ultimately influence the final design. The graphic representations that make up the design schemas enable thus in practice that a process of“composing and connecting which pulls a variety of elements into relationships one another that are then formed into functional assemblies“ can be created (Nelson and Stolterman, 2014, p 21).

Based on Davidsen, Konnerup 2019 understanding of educational design, the development of design schemes has thus aimed to create a common descriptive language that can qualify the teaching activities. It means that the development process has been focused on the following three aspects:

- Learning Design as a form of conceptual mapping that describes the overall pedagogical Landscape, regarding key components within PBL.

- Learning Design as a common language that can describe and visualise teaching and learning activities

- Testing of the specific learning design to see the consequence of the individual design schemas or concepts.

The development of design schemas is thus regarded as a form of data collection that contributes to the development of specific conceptual learning designs. The individual design schemas have been continuously qualified and reviewed through practical teaching sessions at the education of ATCM, at University College of Northern Denmark. The interaction between the development of design schemas and practical teaching sessions has taken place over two years in which a total of 324 students participated. The study is thus based on a case study that aims to develop conceptual designs of learning sequences. The study focuses on whether the development of conscious learning sequences can support PBL so that the students can develop learning strategies based on an exploration of a professional topic. In addition to the development of specific design schemes, the study also included results from observation and reflective portfolios based on the students' group work.

	2017			**2018**			**2019**			**2020**			**2021**		
Semesters	3 sem	4 sem	5 sem	3 sem	4 sem	5 sem	3 sem	4 sem	5 sem	3 sem	4 sem	5 sem	3 sem	4 sem	5 sem
Number of students	28	-	-	85	82	57	94	87	79	90	92	85	30	53	37
Number of groups	5	-	-	23	20	16	24	23	23	23	26	24	8	14	10

Table 1.

The case is based explicitly on a teaching course where the student can shape their study in a conscious academic direction through immersion and qualification of a selected profession-relevant topic. The purpose was for the student to be able to independently participate in the professional and methodological development of the profession through research and development-based knowledge within one or more profession-relevant topics.

The project's data collection focuses on the students' reflective experiences, thoughts, feelings in relation to through a sequential learning framework in a PBL setup. Thus, the primary focus will be qualitative, in which the quantitative data is processed descriptively and used as a supplement. Thus, the focal point of data collection aims to collect and analyse data through iterative processes, where theoretical assumptions are continuously modified through iterative phases. Therefore, data collection is primarily characterised as exploratory with an understanding and explanation perspective.

The purpose of the analysis is the construction of theoretical ideas based on empirical data through a continuous pragmatic coding process of puzzling pieces together (Timmermans and Tavory, 2012). The theoretical constructs of the analysis thus occur through a dialectic between theory and empirical finding (Timmermans and Tavory, 2012). The strategy for analyzing the data is based on abduction, where the coding process alone is a tool for creatively understanding and brooding the patterns of the phenomena (Timmermans and Tavory, 2012; Brinkmann, 2014).

The coding process has thus a sensitivity towards the possibilities of spontaneous categories emerging detached from the theoretical assumption. It means a focus on categories that emerged through both an explorative data-driven inductive approach to students' narratives while the design principles of the project are used as clues. The coding process is based on the number of frequencies of specific descriptions of the student experiences within their reflective reports. Based on that, representative statements have been selected where the following criteria have weighted high; (1) comparable statements from different students, (2) Overall tendency in the different project groups, and (3) statements repeated in all iterations. To ensure clarity around these three criteria the data from each iteration is assigned a colour code. Through an investigation of the found categories, new theories have emerged through an abductive resonance by a comparison with existing theories. The analytical reflection is created through sketching techniques describing interesting patterns and contradiction. The sketches act as a kind of memoir that summarises the reflections and thoughts that together create an abductive resonance. Through an axial coding of the found categories, coupled with the outlined sketches, several statements are identified. This statement provides a framework for writing up the analysis (Charmaz, 2014)

Sequential learning trajectory	**176**
Sequence of activities (overlapping episodes of experience) - *examples where the students describe how the individual learning activities are connected*	45
Procedural retorik, deskriptiv sprog - *examples that describe that the students have developed a descriptive language in relation to being able to explain the content and context of the activities. Also, a description of how the activities can be related to the learning process*	54
Proceed and Depend - *examples of situations where students describe how one prior activity had a direct impact on the next*	27
Learning strategies - *examples where students describes what strategic considerations they have had in their work*	23
Inquiry processes - *examples where the students describes a focus on exploration, analysis and reflection*	15

Iterativ process - *examples showing that the students have worked iteratively with the academic disciplines*	12
Changes in normative behaviour	**109**
Changes in normative behavior - *examples where the students unfold how they have changed, for example, their perception, workflows or their understanding of working problem-based because of the organization of the teaching activities.*	78
Transferable skills - *examples of students being able to describe how the learning outcome and methods can be used in other contexts and future learning processes*	31
Problem Formulation	**322**
Practice related problems - *examples of students describing issues related to practice*	69
Problem identification - *examples of students paying attention to identifying and describing issues at a general level*	58
Depth (delimitation) - *examples of the students having a strategy for making a demarcation in relation to an issue in order to create a greater depth*	49
Critical thinking - *examples of students taking a critical stance on their own work, especially in relation to sources and literature*	125
Different perspectives - *examples of students being aware of seeking more perspectives on their problem*	21
Disturbances	**113**
Obstructions - *examples in which the students describe difficulties in relation to work problem based and situations where the academic content brings them out into unfamiliar terrain.*	60
Broken space time (trial and error) - *examples of students describing disturbances in their process that cause them to experience a form of iterative trial and error*	43
Innovative development of knowledge - *examples where the students describe that their knowledge has developed on the basis of a creative process.*	10
Collaborative learning process	**117**
Experience (inductive approach) - *examples of students describing how they have taken their own experiences as a starting point and hence had an inductive approach to working problem based.*	46
Dialogue - *examples of students highlighting the group's dialogues as being the reason for progression in their process, as well as the reason for a greater academic breadth and depth.*	71

Miscellaneous	**123**
Doings and saying - *specific descriptions of how the students have carried out the individual teaching activities.*	88
Overview of the process - *description of how the structure of the teaching has contributed to a greater overview of the content and contexts of the learning process.*	35

Table 2.

DESCRIPTION OF THE SEQUENTIAL LEARNING DESIGNS

Phase 2 of Educational Design Research is called prototyping, where educational design is developed based on theoretical insight. However, no matter what kind of synthesis process used to combine and connect the theoretical concepts and keywords into a final design, the design process according to Kolko (2009) still appears to be something magical (Kolko, 2009). The challenge is how to transform design principles into design schemas in a way that both externalises and memorises that process in order to create transparency within the research process. Through sketching techniques, it is possible to translate design principles based on different perspectives into a coherent design where theoretical and practical relationships and patterns can be combined in design schemas. In this way, design schemas become graphical abstractions that allow discussing, defining, and embracing the thoughts and reflections created by the design principles (Kolko, 2009; Gyldendahl-Jensen, 2020).

In practice, it can be challenging to say precisely which steps in the development, or what design schemes lead to new specific insights. It means that there will always be iterative processes that weave in and out with each other. However, the described systematic approach supports that essential connections can be drawn between immediate unrelated elements, and thus it is key to link research to design (Stolterman, 2008; Kolko, 2009; Nelson and Stolterman, 2014; Krogh, Markussen and Bang, 2015). The different perspectives expressed by the design schemas causes the designers to follow and examine different trajectories that ultimately influence the final design. The decisions that draw these design trajectories can, according to Nelson and Stolterman (2014), be regarded as a centre between intuition and logic or imagination (Nelson and Stolterman, 2014).

The purpose of this section is to describe some of the most prominent and significant steps of the development process that has formed the framework for creating a sequential learning design. It is not an actual analysis of the individual design schemes but more a brief conceptual review of the procedure that has formed the basis of the work. The design process has been focused on the development of conceptual designs of learning sequences based on the following three academic concepts; literature review, problem formulation and research design. The selection of these specific concepts is based on an initial review of the 118 students previous assignments at their final semester where only; (1) 28 % of the students manage to create a problem-oriented question, (2) 3% had a systematic approach to their literature studies, and (3) 40 % had a description of their study design in relation to explore their problem

Mapping out concepts, theoretical position, activities

A theoretical mapping of concepts, theoretical position, activities etc. that are related to PBL, where initially developed with the purpose of being able to create a landscape of practice. Here, there has been a particular focus on distinguishing between the elements in the literature that are pointing directly into a PBL pedagogy originating from Aalborg University and then the activities that are described as general study activities.

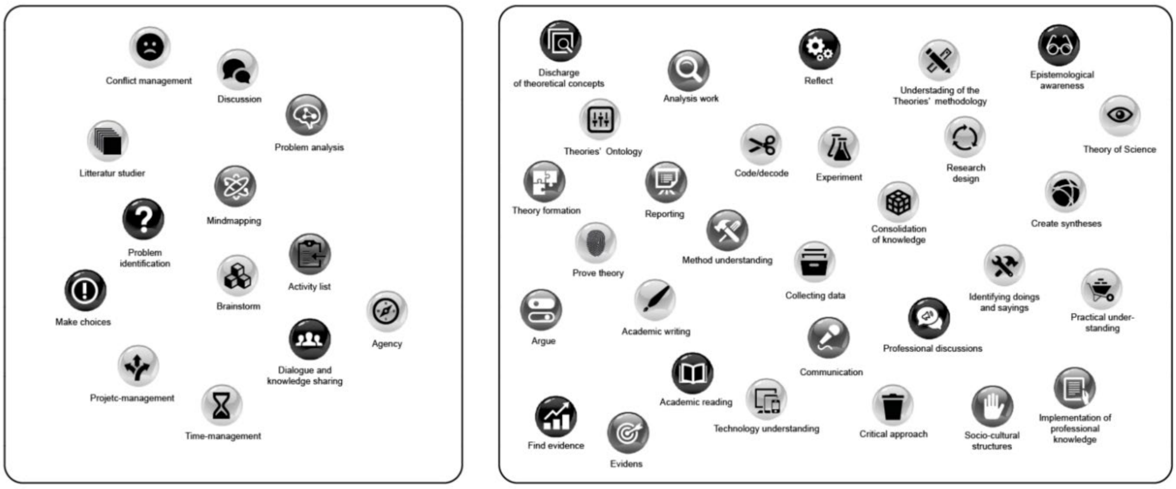


Figure 1. The box on the left shows the activities that are pointing directly into a PBL pedagogy originating from Aalborg University, while the box on the right shows the activities that are described as general study activities.

Through this mapping and a further division and categorization of the activities into a landscape of practices, it is clear that PBL contains far more learning activities that go beyond finding a problem, time and project management and group work. It means that a one-sided focus on these three areas in a pedagogic planning phase creates situations where the student is left blinded regarding finding the" right" combination of learning activities to create their personal learning Trajectories.

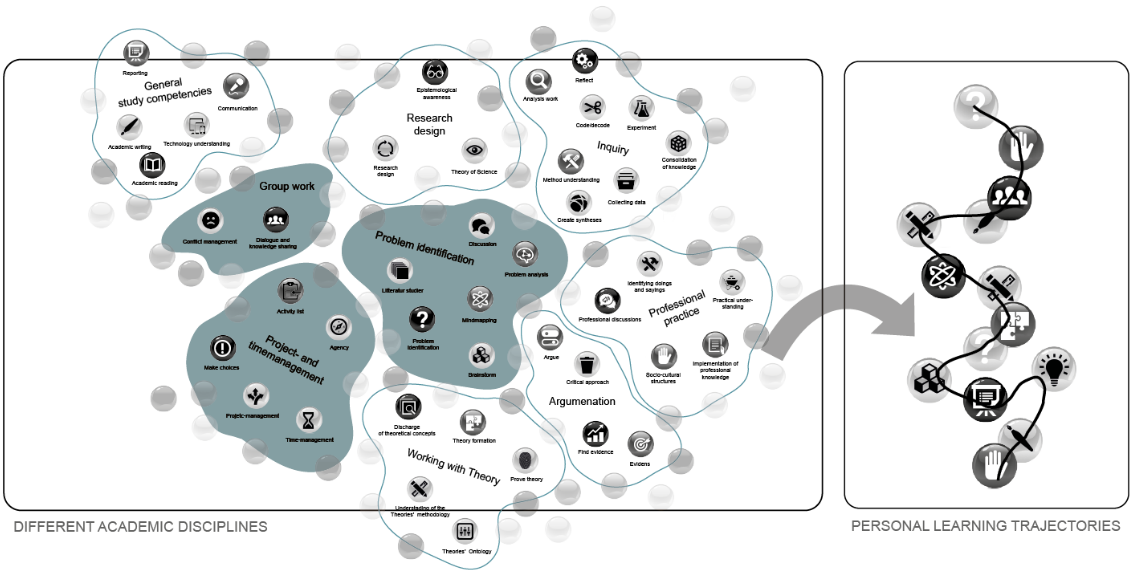


Figure 2. The activities associated with PBL can be organized as a landscape of practices from which the students must independently develop a personal learning trajectory. However, a desk-research reveals that only a small area of the activities are explicitly formulated as being PBL.

Based on the initial mapping and a derivation of concepts, theoretical position, activities, have been made for within the three main areas; literature studies, problem formulation and research design. Through processes of sketching, a number of design schemas have been developed for how to translate learning activities that support working problem-based into coherent learning trajectories or sequences of learning. The outline of the various design schemas includes conceptual patterns or tools with a focus on supporting the students' autonomy concerning the PBL.

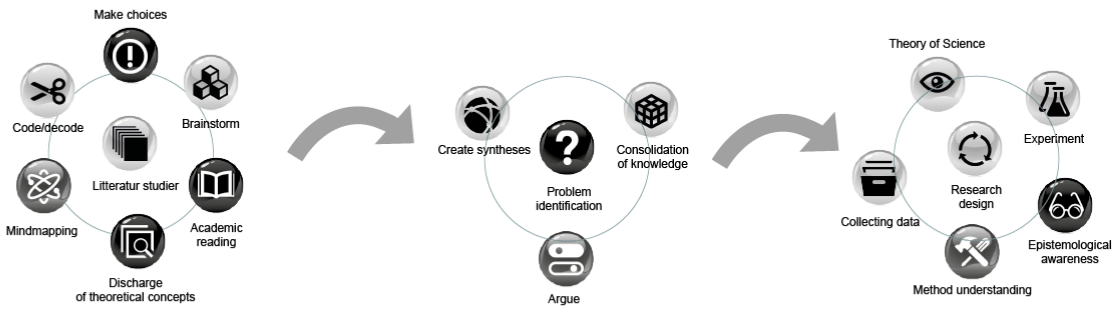


Figure 3. Based on the initial mapping and a derivation of concepts, theoretical position, activities, design schemes have been developed for selected learning activities that support working problem-based.

These conceptual patterns or tools can be seen as specific methods, instructions for actions, techniques that form the foundation for an exploratory PBL process. It means that the students through the tools are helped to create the necessary mental notions that, for example, are associated with formulating a problem statement. A large number of the disciplines or activities that characterise a PBL process share the same characteristics that make them difficult to comprehend. Likewise, academic disciplines often require a level of abstraction that cannot be conveyed through the dissemination of superficial knowledge. Here it is essential to break down the process into smaller action-oriented steps of doings and sayings. For example, the following six elements are included in the concept of academic reading: Orientation, skimming, normal reading, intensive reading and selective reading. Based on practice theory, the specific steps within each learning activity can be defined as a unique and individual learning path. The combination of the different learning trajectories described though design schemas make up the pedagogical design. When the individual learning trajectories are repeated during a module, a semester, or the entire study, in parallel with new additions, a sequential learning system is formed based on a landscape of practice. In this study, work has been done to translate selected elements within each learning trajectories into specific tools to support the student in developing specific learning regarding understanding some of the abstract learning concepts that characterise PBL.

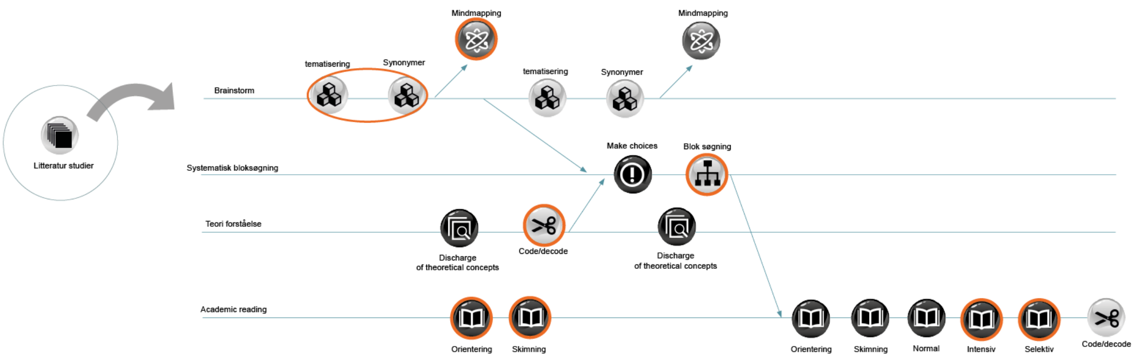


Figure 4. Each area of literature studies has through learning sequences been formulated as action-oriented steps.

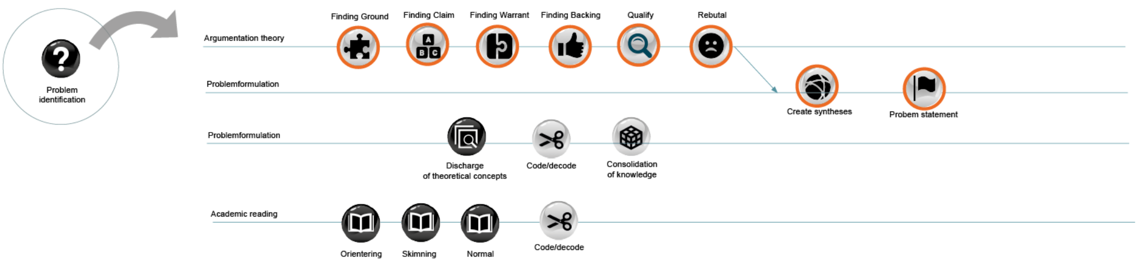


Figure 5. Each area of problem formulation has through learning sequences been formulated as action-oriented steps.

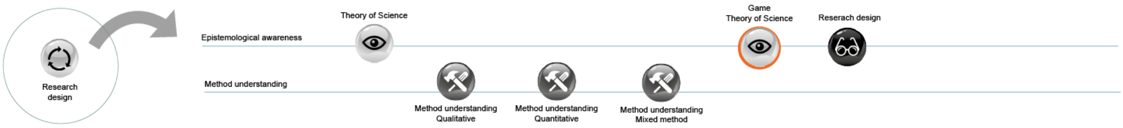


Figure 6. Each area of research design has through learning sequences been formulated as action-oriented steps.

The following example is a learning sequence related to literature studies Where the students through dialogue create a learning trajectory that combines initial thought and problem formulation with a systematic literature search. The final step of the trajectory loops back to the beginning of the process by using the initial headlines or problems as theoretical background for coding the found literature. The structure of breaking down the process into smaller steps of how to conduct a literature review creates a descriptive language that supports the student in qualifying a methodology for PBL.

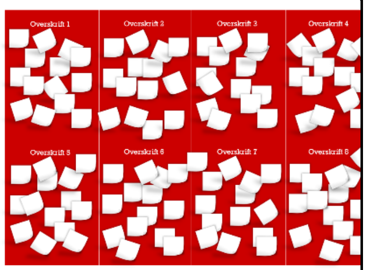
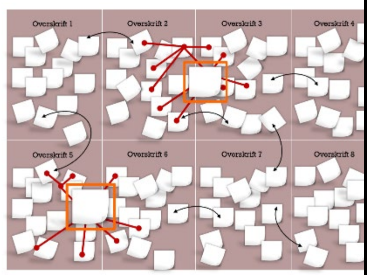
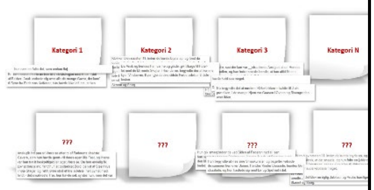
<table>
<tr><td>Finding relevant headlines or problems within the topic through dialogue</td><td>Brainstorming problems related to the headlines</td><td>Exploring the connections and relationship between the different problems through Mindmapping</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Turning brainstorms and mindmap into Blocks that can be used to carry out a systematic literature review</td><td>Search for literature within relevant databases based on the created blocks</td><td>Coding the text according to the initial headlines or problems</td></tr>
<tr><td>Blok 1: Bæredygtighed; Integreret bygningsdesign; Værdi baseret
Blok 2: Social; Mennesker; Livet; Brugere
Blok 3: Arkitektur; Bygning; Materialer
Blok 4: Management; Proces; Beslutning; Ledelse
Blok 5: Model; Integration; System; Energi desig</td><td>(Sustainability * OR “integrated Buildingsdesign” OR “Value based”) AND (Social* OR human* OR living * OR citizen*) AND (Materials* OR building* OR architecture * OR integration* OR model*) AND (Decision * OR leadership * OR management *) AND (System* OR integration* OR model* OR “energy design”)</td><td></td></tr>
</table>

Figure 7. Examples of the process-oriented tools that have been developed continuously through the iterative design processes.

This specific sequence of activities that draws a descriptive language for literature studies must be seen in connection with a number of other learning trajectories such as academic reading and writing. The many sequencers thus together form a landscape of practice (or learning design) that creates a coherent methodology for how to work with PBL.

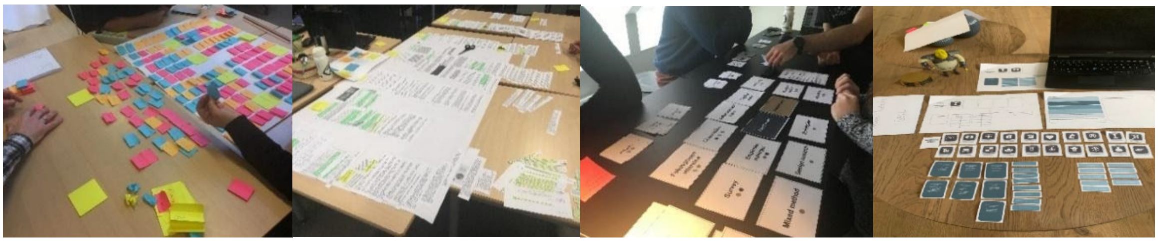


Figure 8. Examples of the process-oriented tools that have been developed continuously through the iterative design processes.

ANALYSIS

The following section analyses the data collected through observation and reflective portfolios from the students' group work. The analysis will focus on to what extent the developed sequential learning trajectories have on the students' learning, including mastery of problem-based learning through the categories descriptive language and self-directed learning.

Descriptive language

In the following two statements, the students talked about how the specific process activities contributed to an increased overview of the complexity of the task, including helping them to be able to identify learning strategies for how they could create coherence in their exploration of a professional problem:

> "Personally, I thought this VUE might be a little long-haired. But despite this, I thought this semester had made me a little positive. I've probably gotten a little more understanding of it. We have been working with games of scientific theory so we could choose the methods we would use for the analysis".

> "All of these tools and methods that we have become acquainted with in this project have helped us to form a comprehensive overview of our topic and sub-topics easily. It has helped us to quickly and efficiently find the best and most relevant literature for the project. Furthermore, it has helped us to quickly find the elements in the literature that contain the information that was relevant to us and our project. The tools have each helped to simplify the process of writing a problem statement and problem formulation".

Likewise, there was a tendency that the students in a subsequent reflection clearly could formulate and make explicit how the process tools enabled them in applying a learning strategy. Because of that, the students' reflections themselves automatically initiate the sequential learning system, as they are continuing and transferring recognisable learning paths to new contexts and situations. The following example illustrates how the students can define the elements that created their exploration process, as well as how the individual activities were part of a larger context:

> "Just as we have used coding in relation to our literature and problem solving, we have taken coding with us in the analysis and discussion. It has provided a better overview for us to break up our studies into smaller pieces, to put it back together into a larger whole. We have done the coding digitally through Word, as we learned last semester that it could provide an equally good overview".

> "We are positive about getting to know the scientific databases. Where, in the past, we primarily used only google and books to search for information, we have now sharpened our searches more scientifically. This new knowledge enables us to seek more quality knowledge, more source-critical and better documented problems. In this way, we increase the quality of our analyzes".

The analysis thus indicates that the students, because of the designed sequential learning trajectories, have predominantly developed a descriptive language that connects to working problem-based. This is clearly seen in the collected data, where the students' in a retro-perspective view can unfold and reflect upon how to work problem based, including giving examples of situations where they experienced how one activity had a direct impact on the next. Also, adequate descriptions of how their literature studies in particular have contributed to an increased depth in the analyzes as well as a more critical stance regarding the academic problems.

Self-directed learning

The students' methodological and procedural reflections provide the students with experiences and insights that can be brought into future project assignments. The reflections are very much about the students' reflections on processes, results and quality, and the study as a result of this revealed how the students recognised the importance of going in-depth with their written work. Working with conscious learning strategies resulted in the students using meta-reflection to express their learning processes. The reflections were not only directed at the educational and the academic elements but were also related to the application of knowledge in practice.

> "It is worth mentioning that the whole research process has been an incredibly good eye-opener for the theoretical approach to be carried out in the practical and professional context. It is because the theory strengthens and forms a basis for how to deal with challenges".

The students' attention to the value of their efforts concerning a professionally-oriented topic suggests meta-reflections on how their acquired competencies can contribute to dealing with similar challenges in future semester projects.

> "It was such a tool that allowed us to debate things and forced ourselves to see the topic from other points of view and angles. It helped us to get the group started from the beginning, and gave us the feeling of success which is good, and helps to motivate the group to move forward with the project."

> "This new approach enables us to seek more quality knowledge, more source-critical and better-documented problems. In this way, we increase the quality of our analyses."

Thus, there is some indication that the step by step way of thinking through the developed learning trajectories in this project coupled with specific action-oriented tools, means that the students to a much greater extent are able to take a critical position for their learning process. Also, because of a more in-depth understanding of the learning processes associated with working problem-based, the students are then able to work more self-directed. The tools and the methods presented thus provide a core understanding of the PBL process that enables the students to have autonomy in their work.

CONCLUSION

This article aimed to discuss Dewey's concepts of sequential inquiry processes to create new forms of learning designs to bolden further students ability to work analytically and exploratively. The study addressed two phases, "problem and theory identification" and "designing the prototype" to create conceptual designs of learning sequences. Work has been done to translate selected elements within problem-based learning into specific tools to support the student in developing specific learning strategies regarding understanding some of the abstract learning concepts that characterise PBL. The study used a specific case based on teaching sessions where data (observation, reflective portfolios and sound recordings from the students' group work) was collected over two years with the participation of a total of 324 students.

The results from the data collected showed various improvements to the student's ability to independently formulate and work with problems through exploration and analysis within selected topics relevant to their profession. The data suggested that the activities that the students participated in contributed to an increased overview of the complexity caused by a problem in their topics. It helped them to identify individual learning strategies that gave coherence in their exploration. The students were also able to reflect and formulate how the tools enable them to apply a learning strategy for how to work problem-based. When students experienced a clear, distinct and recognisable learning strategy, it leads to increased motivation and enthusiasm. The students stated that it is especially the structure and organisation of the teaching as learning trajectories that contribute to strengthen their motivation and understanding of working problem-based.

The students' reflections itself automatically initiates the sequential learning system, as they are continuing and transferring recognisable learning paths to new contexts and situations. Moreover, the students' attention to the value of their efforts concerning a professionally-oriented problem suggests meta-reflections on how their acquired competencies can contribute to dealing with similar challenges in future semester projects. The study also suggests that this approach to learning sets new requirements to the student's ability to reflect over their own learning process critically.

These sequential designs however also present a dilemma between students' self-directed learning abilities and the students' need for scaffolding. A concern could thus be that the sequential designs are inhibiting the students' self-directed learning abilities. However, the collected data indicates that a prerequisite for being able to work self-directed is an in-depth knowledge of what it means to work problem-based. The student statements clearly show that this is not the case, which is why they need to be supported methodically. In addition, the question of self-directed learning must also be seen in the light of an entire educational program. By scaffolding the student in the first semesters helps them to develop a basic understanding of PBL that enables them to develop a greater degree of autonomy.

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Sharing is Caring: Building PBL Coherence Supported by IT to Integrate Semester Courses and Projects

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ABSTRACT

Organizing a coherent PBL semester where courses and project work are integrated and supporting the development of both disciplinary and generic competences is difficult. In this study we investigate how integration can be supported by different IT initiatives. Applying a practice theoretical approach, inspired by Stephen Kemmis, this article analyses how the practice activities and the resources within the practice are constituting challenges and possibilities for an integrated PBL practice. The findings of the study illuminate possibilities in reorganizing a semester structure with focus on creating a shared language to support communication and establishing solidary ways of relating. An important issue is also to have focus on the dispositions to act within the actual IT based materiality.

Keywords: Semester structure, Course and project integration, Practice theory, It-supported education, Problem-based learning (PBL)

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INTRODUCTION AND BACKGROUND

Teaching and studying in PBL environments in the higher education system, implies several constellations of PBL, and different foci for near future dilemmas. In this research study, the *near future* is seen from the binocular of a) framing future digital influences and by b) framing future digitalization strategies. This represents both a need and an opportunity to optimize the enactment of PBL, where digitalization becomes a solution. A dilemma within PBL in general is the balancing act between disciplinary and generic competences. PBL in its widest sense, builds on pedagogical theories of e.g. social and active learning theory, and is known to support the development of more generic and transversal competences. Aalborg University has developed and applied its PBL-oriented, pedagogical *AAU Model* since 1974, which relies partly on its *AAU PBL principles.* These include the principle of how "*the project work is supported by courses*", as a structural part of a semester's inherent coherence design, by how courses should feed tools into the project (Askehave et al., 2015). Some generic disciplinary competences from courses are ideally included as learning objectives in the project modules study plan, as a way to integrate course and project work. In the organization of the different educations, the generic competences support the development of disciplinary competences of the specific education to a variable degree.

In the latest reform of the AAU PBL organization, semester projects have become increasingly detached from the disciplinary learning objectives of courses, and removed focus on integration between semester modules. It is a belittling strategic move on the PBL-centric application of disciplinary knowledge in semester projects. An identity which AAU used to treasure, and would promote itself in the past - to a current PBL structure, which has suddenly become the basis for critique (Hüttel & Gnaur, 2017; Busk Kofoed et al., 2018).

In pursuit of creating more coherence and PBL-centric thinking to the semester structure, a research project was launched in 2017 (PBL Future, 2017), partly studying how the digital agenda may become an asset in context. The result was an initiative to test a reorganization of the semester structure, by the philosophical and practical construction of an "Integrated and IT-supported semester", abbreviated here as 'IITS'. In short, the IITS concept builds on an increased focus on initiating digital tools into the teaching, using a flipped classroom approach to integrate these into courses as lecture activities, as well as different initiatives for integration and coherence across the semester. An example of a digital approach is introducing digital umbrella platforms such as Jupyter Notebook, which is able to combine utilities and utilization of several different programming languages and softwares, practices or tasks, into one. Such initiatives should aid the creation of PBL practices, where generic and disciplinary competences should complement each other to a higher degree, and introduce a higher degree of coherence within the semester modules and activities.

Based on that the research question of this paper is:

> *What are the possibilities and challenges for supporting a PBL teaching and studying practice when reorganizing an AAU PBL-based semester towards an integrated and IT-supported semester structure?*

The reorganized, integrated and IT-supported semester is studied from a practice-theoretical perspective inspired by Theodore Schatzki (2005) and Stephen Kemmis (Kemmis et al., 2014). By studying the inherent *practices*, *practice architectures* and *practice activities* that constitute the *Integrated and IT-supported semester* concept, we look at how the IT-supported practice influences the integration, and which possibilities and limitations that are constituted in the concrete site. As detailed below, the analysis is based on student survey data, teacher interviews, teaching observations, meeting minutes, semester evaluations, and earlier work within the PBL Future research.

INTEGRATION AND COHERENCE OF A SEMESTER

Focus of the study is creating a level of integration and coherence across the organization of a semester. University-based educational programs often consist of a set of disconnected individual courses. Creating better coherence may thus be seen as a way to support students' learning (Hammerness 2006). Coherence can be understood "in terms of shared understandings among faculty and in the manner in which opportunities to learn have been arranged (organizationally, logistically) to achieve a common goal'' (Tattoo 1996, p. 176). In short, coherence refers to a confluence, where several entities align into a shared direction, or where they individually contribute towards a common goal.

In a semester, coherence can play different roles on different levels, from low-level aspects such as organizational routines, to higher level aspects, such as e.g. theoretical or methodological transfer between different academic learning processes. For AAU semesters, coherence as the aim to achieve a common goal can be achieved through a shared understanding, and an arrangement where different courses, student projects, workshops or seminars of a semester can aid and guide students' learning.

In a PBL-based educational system, three types of coherence can be considered: developmental coherence of productive learning across time; horizontal coherence across curriculum, instruction, and assessment; and vertical coherence between classroom assessments and large-scale assessments. Developmental coherence is about the nature of learning and teaching, addressing the structure of science disciplines, students' prior knowledge and experiences, and the integration of knowledge and practices. Horizontal and vertical coherence are about the approaches used to promote productive learning for all students (Fulmer, Tanas, & Weiss, 2018).

Considering the degree of coherency between different curricula within a semester may affect and balance how students learn and familiarize themselves with the field. It may also affect how they understand the value of certain knowledge, or how they are able to anchor their learning. Facilitators of PBL practices should consider whether and how the construction of the semester, the application of the learning goals, or the project proposals and supervision of a semester project, are representing a combined coherency.

Coherence should however not necessarily lead to uniformity. Hammerness points out a concern whether creating a fully coherent program could lead to students not coming to terms with alternative perspectives, and concludes that coherence is not so much an outcome as it is a constant process of adjustment (Hammerness 2006).

One of the initiatives of the teachers at MED4 in relation to creating coherence was for all courses to apply a flipped classroom approach as a shared way of organizing the course modules of the semester. A flipped classroom is generally understood as a reversal of the traditional didactic face-to-face lecture, which is pre-recorded and used as a pre-class activity, thereby instead leaving room in-class for further teacher-student dialogues, student activities and active learning strategies to support student learning (Bishop & Verleger, 2013; Jenkins et al., 2017; Lee & Choi, 2019; Triantafyllou et al., 2016). Flipped learning is not a one-size-fits-all solution, but a continuum of various combinations of teaching, scaffolding, technology use etc. (Tomas et al., 2019).

THE CASE STUDY

The initiative to study the Integrated and IT-supported semester concept was carried out at the Medialogy programme, at AAU. Medialogy is an education within media-technology that combines problem-solving, human-computer interaction, design, and media technology engineering to create specific solutions for specific users, often in collaboration with stakeholders. The specific case took place at the 4th semester of the bachelor (BSc) programme and ran from 2017 to 2020.

The study plan for the 4th semester of Medialogy (MED4) consists of three 5-ECTS courses and a 15-ECTS semester project. The general semester theme is '*Sound Computing and Sensor Technology*'. The MED4 semester relies more on math and programming than previous MED semesters, which makes many students rate it a difficult semester. It also shows by the number of students failing the ordinary MED4 course exams (Busk Kofoed et al., 2018). For years, this trend has frustrated the MED4 teacher team, which made them susceptible to alternative approaches, and agreed to initiate a new semester design.

DESIGN: THE INTEGRATED AND IT SUPPORTED SEMESTER CONCEPT

The *Integrated and IT-supported semester concept* is designed by the following premises:

> A) Supporting the PBL model at AAU. This is done by 'creating time' to support a wider range of possible PBL-oriented activities during in-class sessions (ex. problem-based, group-based, project-orientated, student-led learning). This includes increased student-teacher-interaction, as a benefit of a flipped classroom approach.
>
> B) Supporting a better integration between disciplinary and generic competences. This is done by the use of participatory action research and the collaboration of researchers and teachers. Initiatives have been based on scheduled meetings where all teachers are present and in collaboration have outlined the aim and concept for the integration.

The aim is framed by:

- ❑ Create a 'room for communication on integration', both between course teachers and between teachers and students.
- ❑ Create a practice with activities and exercises that cross-connect courses and consolidate their link to the semester project.
- ❑ Create a practice, in which IT, courses and semester work is connected and accessed across courses and semester work.

PARTICIPATORY ACTION RESEARCH APPROACH

The intervention into and investigation of the MED4 teaching and learning practices, followed a *Participatory Action Research* (PAR) inspired approach. This is best represented as a self-reflective spiral of planning, acting, observing, reflecting and re-planning, enacted in iterative cycles of improvement (Kemmis, McTaggart & Nixon, 2014). Improvements are sought from the knowledge and understanding of participants involved, from discussions and reflections on actions, which leads to new understandings (Greenwood & Levin, 2007). As researchers, we have been very aware of our facilitator roles in the developmental process, as we respond to problems in the field rather than administer a prescribed strategy (Altrichter et al., 2002).

To transform MED4 teaching and learning practices, the PAR approach involved the teacher-team in the pursuit of a pedagogical and organizational change. This organization included teachers and students as active parts of the change process, supporting both planning and implementation with experiences and expertise (Svarre Kristensen et al., 2019).

PAR applies established research techniques - surveys, interviews, observations, project documentation, meeting minutes, etc. - and theories. Meanwhile, inherent to PAR is a dynamic and improvisation-oriented methodology, which can be very dependent on situational or emergent aspects to the phenomena investigated. The action plan for PAR is ideally based on the available contextual evidence, at the time of need (Hammerness, 2006).

The empirical data acquisition for the research project unfolded over a two year period, with the year prior being spent collecting data on past student experiences. The first iteration of the IITS concept took place in spring 2019 at MED4. During this time, the research team conducted observations at teaching sessions, workshops, and semester meetings. Empirical data on students' perspectives was collected during the semester through three online questionnaires with MED4 students, containing both closed and open-ended questions. The teacher perspective was investigated through five individual interviews with the MED4 team, combined with regular status, planning and evaluating meetings for both teachers and research teams, facilitated by the researchers, with teachers as the main contributors to the conversation. In autumn 2019, the research team carried out an additional student questionnaire with the 4th semester students, and held a number of follow-up meetings with the team of teachers at Medialogy 4th semester.

A second iteration of the IITS intervention was initiated in spring 2020, also at MED4, for the subsequent student generation. Here, two student questionnaires were distributed to students, and observations were made at teaching sessions, workshops, and semester meetings. Researcher/teacher team meetings were also upheld, including follow-up meetings with the teacher team after semester completion, autumn 2020. Data used in this research is detailed in Table 1:

Interview 2018	Interview with teachers of courses and project work	One video recorded interview with each of the 5 teachers covering all courses and project work activities. Duration 30-45 minutes
Observations 2019	In-class observations of teaching activities	20-45 minutes observations in classes covering all courses
Interview 2019	Interview with teachers of courses and project work	Video recorded interviews with 4 teachers-covering all courses and project work activities. Duration 30-45 minutes
Survey 2019	Student survey performed in October. Evaluating the semester by quantitative and qualitative questions	40 out of 59 students answered the survey. The questionnaire had 44 quantitative items and 17 open-ended (qualitative) items. This survey was the last evaluating survey out of 4 surveys done in 2019
Meeting Minutes 2019	Minutes from meetings with teachers. The research team set the agenda of discussion	Minutes from 2 meetings. One in March and one in May. Both one hour of duration. All teachers and researchers attended
Survey 2020	Student survey performed in august. Evaluating the semester by quantitative and qualitative questions	36 out of 47 students answered the full survey. The questionnaire had 36 quantitative items and 27 open-ended (qualitative) items. This survey was the second and last evaluating survey out of two surveys done in 2020
Grade statistic 2020	Grading statistics from the administration. Containing statistic on this semester's gradings	Full semester statistics for the 47 students course and project gradings

Table 1. Overview of empirical dataset for this paper.

A PRACTICE THEORETICAL APPROACH

Studying the reorganization of a PBL practice implies not only e.g. a structural analysis of a new semester concept, nor a monoscopic focus on the teachers' individual facilitation of a new (Integrated and IT-supported) semester concept. We apply a practice-theoretical approach that focuses on the analysis of social phenomena, such as a) the support of PBL in a teaching and studying practice and b) the transition of how to collaborate and c) bring disciplinary and generic studying activities together.

The philosopher and practice theorist Theodore Schatzki presents a holistic, theoretical perspective on practices (Schatzki, 2005). This theory is further developed by the educational researcher Stephen Kemmis, who presents a theory of both practices and practice architectures (Kemmis et al., 2014), both of which we benefit from in the analysis of the MED4 intervention. Understanding social phenomena such as MED4 as a practice is done by exploring the context (also referred to as a *site*) where the practice unfolds (Kemmis et al., 2014). According to Kemmis et al., the *Practice* (activities of practitioners) within a site is defined by the *Sayings*, *Doings* and *Relatings* enacted (Kemmis et al., 2014). *Practice Architectures* form the contextual *arrangements* of the practice. Kemmis et al. identifies three types of arrangements: the *cultural-discursive* arrangements (the facilitating context for *sayings*), the *material-economic* arrangements (the facilitating context for *doings*), and the *social-political* arrangements (the facilitating context for *relatings*). The *Practice* and *Practice Architectures* are mutually interdependent. Exploring how they are constituted at MED4 should make it possible to look at how the full organization of IITS is supporting the PBL practice, in its context. The elements of practice and practice architecture, when analysing a site as presented in figure 1, will be used to understand, structure and present our analysis and findings.

<table>
<tr><td colspan="4">Individual side ← Practice → Extra-individual side</td></tr>
<tr><td colspan="2">Projects/teleoaffective structures
How purposes and intentions expressed by practitioners direct activity</td><td colspan="2">Practice landscapes
How practitioners and objects are enmeshed and entangled in activity and how materiality, rules, and procedures prefigure actions by infrastructural sedimentations</td></tr>
<tr><td>Practitioners' characteristic 'sayings'</td><td colspan="2">← How 'sayings' performatively enacts a practice in semantic space through language →</td><td>Cultural-discursive arrangements</td></tr>
<tr><td>Practitioners' characteristic 'doings'</td><td colspan="2">← How 'doings' enacts a practice through the medium of activity and work →</td><td>Material-economic arrangements</td></tr>
<tr><td>Practitioners' characteristic 'relatings'</td><td colspan="2">← How 'relatings' enact power and solidarity →</td><td>Social-political arrangements</td></tr>
<tr><td colspan="2">Dispositions/practical understandings
How actors are attuned to participate in practices, how they have a 'feel for the game', and how they know how to 'go-on': practical knowledge, skillfulness, and appraisal of specific values.</td><td colspan="2">Practice traditions/general understandings
How current practice is enacted to reproduce or transform the traditions and history of the local practice or—more broadly—in relation to the traditions and history of practices that span multiple sites.</td></tr>
</table>

Figure 1. Elements of practice and practice architechture in a site (Buch & Andersen, 2015, p. 30; adaptation from Kemmis et al., 2014, pp. 38-39).

In the analysis, we do not only pay attention to the teachers' and students' individual sayings, doings and relatings, but also look at how their activities are framed by the arrangements constituted in that context. We look at what Kemmis et al. call *practice traditions* or general understandings (see lower right corner of figure 1) (Kemmis et al., 2014). When analysing the practice of MED4, the analytical focus on practice traditions is an acknowledgement of how the practice is constituted by its historical entanglements. The PBL practice and the integration of courses and project work is constituted and (re)produced within the MED4 site. Thereby, both are made possible, but also limited by this site of practice activities and practice architecture. The historically embedded constellations of arrangements on the site will be investigated to see how certain aspects in the practice architecture (such as found limitations) may support the PBL practice. Further we will look at how the organization of practice makes it possible for teachers and students to contribute within their *dispositions* (lower left corner of figure 1) (Kemmis et al. 2014). New IT material is entangled in the reorganisation of the 4th semester, and this might change teachers' and students' opportunities for action. This will be a focus of our practice theoretical analysis using Kemmis et al.'s concepts. A third focus of the analysis is the concept of *practice landscapes* (upper right corner of figure 1). Looking at the practice landscape within the IITS concept puts focus on how rules and procedures of activities within the practice constitute and support PBL activities.

By using the practice-based lens by Kemmis et al. (2014) we aim for an understanding of the organizational *transformation* of social phenomena such as change in the PBL-supported teaching and studying practice. The practice-based theory presented by Kemmis et al. (2014) draws our analytic attention to a duality of individual and social phenomena, which constitutes both the individual's agency and the structures in social activities, and requires reflection on both when investigating social phenomena. We use Kemmis et al.´s conceptualization of practices to investigate the constitutions of the 4th semester, not just from the perspective of a leader, teacher or student, but from that of a dynamic and holistic site.

ANALYSIS: PRACTICE TRADITIONS FEEDING INTO THE REORGANIZED PBL PRACTICE

The revisions made to the AAU PBL model have followed developments in society and latest in 2010 a bigger reform changed the constitution of the AAU PBL model. Harmonization of university accreditation, adjustments to the Bologna Directive and a new grading scale put pressure on the PBL organization, and a new PBL model was developed. Before the changes, courses and semester projects were much closer connected and often examined together, and disciplinary course knowledge was naturally supported in the more generic competences developed in the project work. After the changes to a new PBL model, courses and semester projects are largely assessed separately (Dahl & Hüttel, 2015) and the focus on practicing the PBL principles has been criticized for being diluted (Hüttel & Gnaur, 2017). Problems with routinisation of the project work has been pointed out (Hüttel & Gnaur, 2017), along with problems integrating course content to project work (Busk Kofoed et al., 2019). Due to courses working in isolation from both other courses and project work, the possibility for applying knowledge in a transversal fashion, and building those competences in general has weakened in the historically anchored practice architecture. A survey study done in 2019 covering the entire Aalborg University, showed that the most important issue with practicing PBL, as rated by teachers across all faculties, was creating better connections between projects and courses (Clausen & Kolmos, 2019).

As such, the social-political arrangements from this have constituted a number of problems in the practice landscape of PBL at 4th semester Medialogy. Rules and procedures rooted in the practice tradition of regulations done in 2010 are limiting a coherent PBL practice. At the 4th semester Medialogy site, interviews with teachers describe an historically anchored silo-organized practice between courses and project work (Interview 2018). This practice tradition is one that has fed the 4th semester for years, where teachers from each course have worked in complete segregation from teachers of other courses (Interview 2018).

Looking at the present re-organized practice of 4th semester we see how practice traditions are still feeding in the IT-supported and integrated concept and still constitute limitations in the practice and practice architecture.

SAYINGS AND THE CULTURAL-DISCURSIVE ARRANGEMENTS

Before starting the integrating and IT-supported intervention (spring 2019), MED4 teachers' communication level was generally low, and especially concerning discourses relating to integration prospects, or other holistic approaches to the semester's coordination. As a result, teachers of the same semester had very little knowledge on the teaching experiences or content material of the other courses (Interview 2018) (Svarre Kristensen et al., 2020b).

To implement an IITS teaching practice, researchers arranged meetings with teachers, with agendas on IT and semester integration (Meeting Minutes 2019) (Busk Kofoed et al., 2018). A shared language was established with two distinct discourses; a language on teaching subjects, and a language on programming approaches (Meeting Minutes 2019). To enable integration of course content and project work in a teaching practice, teachers directed the practice towards what can be called "a common third", as the 'third' (often interdisciplinary) space, besides their two individual perspectives or disciplines, where parties are able to share and combine impressions, knowledge, experiences or plans. This space can work as a common starting point. The academic theme of MED4 focuses on audio processing, but this common starting point was in practice not very prominent. Lectures, exercises, practical examples, homework and work with IT-applications needed a shared trait, as a centerpoint that was commonplace, and applicable across all courses and project work (Observations 2019; Interview 2019). The 'common language of the subject' was narrowed down to only concerning a language of audio (Meeting Minutes 2019). A common language of audio thereby became legitimate for teachers, as a focal point in the teaching practice. More so than otherwise common academic areas for Medialogy, such as languages of game design, film theory, or virtual reality. In practice, this meant that certain course activities, which would previously be legitimized through different discursive subject foci, would now focus on only one. For example, a workshop in electronic systems, which in previous generations asked students to design a game, as the thematic vehicle for the electronics workshop, now focused the workshop on instrument design, while maintaining the overall learning objectives of the workshop (Observations 2019).

The legitimation of audio as the core and shared subject, as a transcending theme and language, made it possible to integrate and transfer knowledge, e.g. from the electronics course to the audio course. At the audio course, students were now able to create sound datasets, relate it to their experiences from the electronics course, and relay it into their own creation (the instrument) from the workshop (Observations 2019). So while learning about audio processing, students would need to revisit and contextualize the electronics course theory and application. The legitimation of an audio discourse at the semester level, makes the application between different courses and project work possible. Thereby, it actively represents the classic AAU PBL principle of *courses supporting project work*.

A common language to facilitate integration thereby works as a supportive arrangement. Thus the legitimation of audio also allows the audio discourse a specific privilege, for instance in the constitution of the teaching practice. This had a mixed impact on studying practices. From not experiencing any connection between courses and project work in 2018 (Busk Kofoed et al., 2019), students now understood and explicitly stated how suddenly 'there was a clear connection between courses and project work' (Survey 2020). A student survey from august 2020 showed that, on average across all courses, 19 out of 25 students rated the integration between courses and semester project as *good* (Survey 2020) (Bruun-Pedersen et al., 2020). However, motivation was becoming an issue among some students (Survey 2019). Medialogy works with media technology from a holistic point of view, so audio is only a part of the academic profile. MED4 students who did not study Medialogy based on interests in audio, now criticized the IITS approach for its narrower practice, leaving these students with a perceived loss of flexibility for projects and courses (Bruun-Pedersen et al., 2020). This reaction is logical. The freedom of self-chosen problems for learning is one of the most prominent promoters of students' intrinsic motivation. When a semester organization changes the culture midway into the undergraduate program, by introducing a highly privileged discursive subject (here, audio) to direct both teaching and studying practices, it can logically affect self-direction and student-centered learning, and create barriers for individual students' intrinsic motivation.

Another common language discourse, legitimized by the intervention of the MED4 teaching practice, was a uniformed programming language. In media technology engineering, many different programming languages can be used for various purposes. To the uninitiated, a 'programming language' is the method and bricks of how an IT-engineer builds a software program. It's called a language, because it is written 'to the computer' as text-like sequences (lines), which to the programmer forms a construction, of structures, areas, actions, patterns, rules, cross-referential pointers, libraries of information, etc. Individual programming languages differ by their specific practical commands, or specific structural methods. A programming language therefore constitutes the way in which practitioners talk about- or around the subject of programming.

Through the Medialogy education, students are often taught a programming language in one course, and another programming language in a different course, depending on the needs of the course and the strengths of the particular programming style. To support the concept of integration and coherence, MED4 teachers chose to introduce a uniform programming portfolio, which was applicable across courses and project work at the semester (Meeting Minutes 2019). Special electronic equipment was bought and implemented, which was able to receive and process the uniform programming approach for audio work.

This transformation also gave transitional dilemmas. Not all teachers were competent within the new programming language, and needed additional dispositions. The resources (time) for this were not available, and would have to be taken from a null pool of work hours. As such, optimizing the semester through a transformation to new systems and routines - in this case IT and programming language updates - showed costly. It placed pressure on the teachers' overhead and available competences, which undoubtedly affected the overall execution and subsequent experience and evaluation of the transformation (Svarre Kristensen et al., 2020b).

DOINGS AND THE MATERIAL-ECONOMIC ARRANGEMENTS

Despite a common subject- and programming-language, teaching and studying practice is characterised by diversity, concerning how to act within a certain practice. Practice traditions and landscapes constitute the method of *doing* the integrated and IT-supported semester. It depends on several aspects, including course curricula and study regulations, teachers' experience with IT and different pedagogical strategies eg. experience with the flipped classroom approach which was used to a different degree at all courses. As well as teachers' and students' experience with PBL as an active learning approach.

Recent work has applied Bernstein's concept of classification and framing, as an interpretive framework for the formal curriculum of this specific MED4 semester (Melbye Boelt et al., 2020). Here, it was suggested that boundaries of subject and content classifications appeared blurry, making the MED4 study plan generally appear dynamic and adaptive to certain integration changes, by design. Meanwhile, the classifications differed between some aspects of course and project coherence, and some of the pedagogical framing appeared to hinder some integration opportunities (Melbye Boelt et al., 2020). This underlines how the formal curriculum is part of the recipe, as potentially both an enabler and a limiter on the extent to which integration between curricula is possible.

At the 4th semester Medialogy, different material arrangements are constituting the options and limits to what teachers and students can do within the practice. The flipped classroom approach provides teachers with access to new types of teaching material, and new mediation methods for those materials. Different types of flipped learning material was chosen by individual MED4 teachers (Meeting Minutes 2019; Observations 2019). For example, the *electronics* course (PID) teacher chose exclusively to use open access online resources for his out-of-class teaching, while the *experiment design* course (DAE) teacher produced her own videos (Meeting Minutes 2019). The differences in teaching materials gave students diverse course experiences (Observations 2019), and showed both teachers and students diverging ways of interacting with the material.

The DAE teacher had several years of experience with the flipped classroom approach, and had produced and refined her course material over time (Interview 2018). Student survey responses suggest the experience and teachers dispositions within the approach affected students' perception of the learning material accessibility (Survey 1019). Students also rated the online homework resources as well-balanced, and rated both the in-class exercises, and the proportions between workload and learning material difficulty, as very positive (Survey 2019) (Svarre Kristensen et al., 2020a).

For integration initiatives, students responded that DAE activities were successfully pointing to- and supporting the project work well (Survey 2019) (Bruun-Pedersen et al., 2020). In contrast, the use of open access resources for the two other courses, created issues for the appropriation of learning material, to properly address the learning objectives (Bruun-Pedersen et al., 2020). Student responses considered the learning material too difficult, the workload too large, and only a low degree of cross-cutting

activities supporting the course material integration into students' project work (Survey 2019), (Svarre Kristensen et al., 2020a).
Doing teaching and studying practices within the material arrangement of videos have implied a list of challenges when not experienced and having the right dispositions.

1) Using open access learning material includes the risk of information overload. Students don't know what and how to interact within a too big pile of learning material. Student responses in our survey data (survey 2019) asked for clear and sequential guidance to material, to correctly understand a) learning material purposes, and b) connection between readings and tasks (Bruun-Pedersen et al., 2020).

2) The IT-based material creates new possibilities for interacting with the students, but new ways have to be learned. The quality of in-class activities when having video-mediated learning before the in-class interaction is dependent on the students' preparation. Teachers find it difficult to monitor the level of this understanding among students at a given time (Meeting Minutes 2019). Not doing traditional lecturing creates a different process for teachers, e.g. when sensing students' state of understanding towards in-class exercises. Quizzes and summative testing of students' understanding adds insight, but only to a degree. In an interview, a teacher explained how a student group appeared to make good exercise progress, but actually had fundamental issues: "*when you start to discuss with them, you realize that they don't really have the concepts in place*" (MED4 teacher interview, 2019).

3) The flipped learning material may create better learning possibilities for some students, while creating limitations for other groups of students. In this 4th semester, few students obtained an 'average' grade (Grade statistic 2020). Teachers comment that the flipped learning approach created a clear divide between students performing very well and students performing poorly. This was evident in both in-class activities and assignments, as well as exams (Observations 2019; Interview 2019). When required to work with online video material from home, the students that struggle with tasks based on self-discipline and individual work will be challenged. Student responses show that a portion of students don't watch videos or other learning material, and arrive unprepared at in-class activities (Survey 2019, Survey 2020). Teacher reports mirror this, stating how the transition to the flipped learning material has explicated the learning gap for students who arrive unprepared for lectures. To circumvent the issue, in-class introduction sessions were introduced as small meta-lectures at the in-class session openings, going through some basics before doing exercises to kick-start students (Meeting Minutes 2020). These meta-lectures can be a possible way around the challenges when engaging with PBL exercises heavily depending on homework. Important to add is that a big group of students did respond very positively, and found the pre-class video material directly motivating, and consider the intervened 4th semester as the best coordinated and

integrated semester they have yet experienced (Survey 2019) (Bruun-Pedersen et al., 2020).

RELATINGS AND SOCIAL-POLITICAL ARRANGEMENTS

Relations and interaction in the teacher group was affected by the integration process. Teachers had to increase communication frequency to align teaching content (interview 2019), and gain greater mutual insight into each other's work and teaching content. This consolidated their team and increased the possibility of well-informed, assistive discussions between teachers. During their planning of course approaches or improvements, teachers were able to look at not only the individual courses, but also their alignment (e.g. progression or workloads). As one teacher highlights in an interview: "*thinking about what type of knowledge they should have, and see how you can support that in different stages... Like, at what point does it make sense that we push them more in one course, and at what point do we need to step back, and have a little bit of ease in the other.*" (MED4 teacher interview, 2019). Their communications thereby include planned touch-points, course progression, content developments, and cross-cutting activities (Meeting Minutes 2019). The relations when working with integration, thereby have to be organized in high degree by solidarity and work tasks organized in a shared practice understanding. Subsequent to the reorganization, the teacher group experiences a higher degree of dependency on a) each other, and on b) central coordination (Interview 2019). The semester coordinator especially needed a redefinition to adhere to and lead the additional integration requirements. Responsibility areas include initiating integration activities (for example initiating teacher team meetings), facilitation of cross-course activities (such as workshops), joint project supervisions (including both course teachers and project supervisors), and all semester-level communications on integration activities for students.

While constructive for integration and coherence, a full semester overhaul is time demanding, especially due to the cross-coordination of activities and progressions (Svarre Kristensen et al., 2020b). Therefore it has also been important, while working with a bigger shared practice: more crosscutting communication and shared work tasks, to (re)define and make clearer divisions in teacher roels (interview 2019). This to make the teaching obligations and the integration work tasks manageable.

Relations and interactions between students and teachers were also affected by the integrated and IT-supported semester model, during in-class exercise interactions. Interviews with teachers highlighted some intricate details of this dynamic, for example, how it opens the possibility to relate coursework to project work. However, the prolonged space for interactions during in-class sessions surprised teachers with its foreighn dynamic, which they found 'needs to be properly understood to be used effectively'. One teacher explained the process as "*When you try to check up on what they have had to read, or if they have understood those important points, and have them try out a little bit. And then somewhere after there, you should still have time to actually relate to their semester project and have some useful discussions. I think there's room for improvement there, because it was difficult to know when to do this in a good way*" (MED4 Teacher interview, 2019). In the discussion space, the *relatings* between students and teachers are activated, especially compared to conventional classroom teaching. The in-class lecture space is a central, strategic social space, where integration can be strengthened tremendously. But only if the teacher's semester team is well organized and well informed about the integration points of the semester. Either by touch-points between courses themselves, or their expected applications into the projects.

Acknowledging the need for extra resources towards the semester transformation and integration-oriented approach, a teaching assistant was hired to work on two of the courses, and to supervise project work (Meeting Minutes 2019). This was important for establishing coherence, because it built cross-course experience, and strengthened the relation between the teachers. The teaching assistant further supported the semester communication and the semester coordination, likely being the person with most knowledge about students' practical and learning progression (interview 2019). Another effective priority was to organize supervision to only include course teachers (Meeting Minutes 2019). This provided closer relations to students' knowledge progression in courses according to the expected project progression, and ability to support course integration into project work (as a supervisor) (Observations 2019). Finally, the coordinator asked students to formally deliver a written dokumentation, which lists how each course was used to support the project.

Defining the rules in the practice of how to work with both disciplinary knowledge and more interdisciplinary IT-based knowledge, has brought up discussions and new ways of relating to the professional work of teaching. Among the questions raised by the teacher team to plan the semester, are the following: *When is basic disciplinary knowledge needed to support cross-cutting activities? When is specific knowledge of how to use IT supporting and integrating tools and learning material needed?* (Meeting Minutes, 2020). These reach into the practice landscape of how power and solidarity has been constituted between teachers and their professional work. The MED4 students have been introduced to a range of new IT tools (e.g. the new programming tool, and other technical and mathematical tools). Teachers explain how students have had to develop domain specific competences on how to use the IT tools, to accomplish the disciplinary work tasks, while relying on the IT tools. This should be done at a time where students also need to build basic disciplinary competences, to know why/when/how to work with specific IT tools. Students' IT dispositions within specific tools can not be seen in isolation, but have to relate to the disciplinary competences. Teachers have to plan for this, and spend teaching hours to connect domain specific knowledge to needed IT-specific competences, and acknowledge that the IT-specific competences cannot be an explicit part of the course assessment, as it is not part of the learning objectives.

Teachers at MED4 have always used IT-tools in relation to teaching disciplinary competences, but have had fair freedom of choice. Now that the choice of IT tools need to be supported and applied by the entire teacher team, used for flipped processes and interdisciplinary integration, their role is very different, and so is the time needed for ongoing investments into proper application, procedure management and communication for experience sharing and modification. Teachers have needed to balance the disciplinary and IT domain specific knowledge in new ways under the integrated semester concept, and even ask for institutional guidelines in this manner. When the study plan doesn't accredit the more heavy work with interdisciplinary IT-based knowledge, it is hard to give it focus and power in practice.

DISCUSSION AND CONCLUSIONS

In this paper, we have investigated the research question: *What are the possibilities and challenges for supporting a PBL teaching and studying practice when reorganizing an AAU PBL-based semester towards an integrated and IT-supported semester structure?* Using digital tools to support integration has in many ways supported a more PBL-enacted and PBL-coherent practice. Initiative such as using a uniform, shared and cross-cutting programming language has increased integration between courses and project work. However, using the programming language with this intent, is a demanding initiation, challenging teachers' dispositions with the tool. Programming and IT tools for integration have also shown to be rather time demanding in use, as students may need to learn the IT tool, to enable themselves access to an actual study plan learning objective. Discussions on how to balance the power relations of disciplinary competences and IT domain-specific competences, have occurred in the teaching practice of the 4th semester at Medialogy. It shows a clear need for time to introduce IT-supported, domain-specific competences. This is complicated, as the Medialogy study plan does not accredit IT domain-specific competences.

Flipped learning material has also shown challenges within teaching and studying practices. A risk of information overload when using open access resources, as open access learning material demands a strict control of tasks and exercises. To reach the group of students that infrequently prepare from home, it was necessary for the teachers to introduce in-class intro-sessions, as short meta-lectures before proceeding to in-class exercises. We also see how students who arrive prepared, benefit extensively from the flipped classroom approach. The flipped classroom approach has also shown to be increasingly useful, as teachers become increasingly experienced, and when the learning material is self-produced, or otherwise focused and well produced. When balance is found between out-of-class homework and in-class activities, including successful teacher-student interactions that lead to transversal discussions, the flipped learning approach has shown to enhance the possibility for supporting PBL processes, and supporting integration between courses as well as course-to-project.

Integration initiatives for coherence across the semester has also been done from a perspective outside the digital domain. Creating a discursive legitimation of how to interlink the courses and project work through the semester theme, has made communication across the teacher team possible and valuable. Making 'audio' become the privileged discourse at MED4, even at the expense of other subjects, such as game design, has given the teachers and students a common language to direct integration. The narrowed discursive legitimation has made it possible to coordinate activities across the course- and project work. And hiring a teaching assistant that works in the crossfield, also helped the integration. The increased, cross-going communication and coordination between courses and towards the project, has however demanded clearer definition of roles and responsibilities. An improved structured planning, and aim for communication and coordination has also become extra important. The semester coordinator role is now even more vital, and structural support for the semester coordinator work is necessary. We have also seen how initiatives ensuring that supervision for project work is kept within the course teacher-team, has shown great supportation of coherency. Initiatives making students reflect on the integration by direct mention of courses' role in projects, while framing their self-directed problem statement for their project, has also supported the integration.

All in all, we have seen how historical and political arrangements, concerning how course and project work are integrated, have fed into teaching and student practice for years. It has constituted a practice of silo thinking, and missing coherence in the organization of a semester structure. Change initiatives focusing on reorganizing IT engagement can support a better integration, but the practice architecture needs to constitute possibilities for this transformation. Organizing the teaching and studying practice, at e.g. this 4th semester at Medialogy, to support better coherence, has required the establishment of a common, legitimized discursive language, where engagement in interdisciplinary communication and coordination is possible. Organizing courses and project work, under a semester theme that goes across the entire semester, is a help to create a common language, but it also needs to be actively used and supported by the practice landscape, to actually support an integrated semester organization.

Organizing the learning material within an IT and Flipped Classroom approach, has shown to be most possible, if teachers are experienced and have had time to adjust the learning material to students' need for interaction. Reorganizing the learning material is demanding, and IT-dependent issues have filled a lot at 4th semester Medialogy. But more time for student-teacher interaction, discussion, exercises and active learning has also been found. Organizing more time for active learning in the classroom, if facilitated according to the PBL principles, can support a PBL organized practice. However if too much time is spent on finding solutions for IT-dependent issues, the aim of supporting PBL may fade noticeably. Creating supportive rules and procedures for how to engage and prioritise the use of IT-supported integration, is therefore of great importance. Supporting an organization of communication and coordination across a semester, giving time and economic support to develop integration planning, as well as new learning material - this should be accredited. A coherent semester structure is important, especially when the aim is a transformation into coherent PBL practice, which is supported by IT-organized processes, for a stronger semester coherence, with integration across courses and project work.

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The Power of Problem Based Learning beyond its Didactic Attributes

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ABSTRACT

Hybrid courses with a focus on practice-orientated education and self-guided learning phases are on the rise on the higher education sector. Disciplines in Life Sciences implicate a high degree of practical laboratory expertise. The University of Applied Sciences (UAS) in Vienna, Austria, has thus been endeavoured offering students a high qualitative education integrating hybrid courses based on PBL principles, which consist of on-site (including the transmission of necessary background and practical laboratory training) and off-site (including self-study phases) sessions. As practical laboratory units are central in those courses, the restrictive measures, including the transition to a complete online teaching format due to the first Covid-19-pandemic lock-down, had severe effects on the implementation and the quality of the curriculum. According to surveys made specifically to address this problematic situation, it can be concluded that on-site practical units are fundamental for certain disciplines such as Life Sciences.

Keywords: Hybrid-PBL-methods, Life Science, Covid-19

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INTRODUCTION

A career in life sciences implicates a high practical workload. In order to prepare our students at the University of Applied Sciences (UAS) in Vienna, Austria, for a successful and rapid transition to a professional scientific career, the focus in all study programs of the faculty of "Life Science Engineering" lies in practice-oriented and problem-oriented education. Thus, practical laboratory courses are an elementary cornerstone of the bachelor study program "Biomedical Engineering", and the master study programs "Tissue Engineering and Regenerative Medicine" and "Environmental Management and Ecotoxicology". Especially the master study programs are unique in the European higher education sector, not only due to their high degree in specification, but also due to a high proportion of courses using applied PBL-oriented didactics. The majority of our graduates pursue successful careers in research and development in the public as well as the private sector. In annual meetings, alumni regularly reflect on their career development and how the studies at the UAS contributed to their success, which underlines the high quality of education provided at the UAS as well as the effectiveness of conventional and novel concepts in PBL.

A significant number of courses in the afore-mentioned study programs are based on the classical PBL principle, including the seven golden standard PBL elements (Barrows, 2000). They involve a real or realistic current problem within the field, which has to be addressed actively by students usually within small teams in intensive research and self-study intervals. Especially in the master study programs, project-based approaches corresponding to the Aalborg model are commonly employed (De Graaf & Kolmos, 2003); more advanced students have the ability to elaborate a real-world project autonomously by acquiring necessary background information and then addressing objectives by a practical working phase in the laboratory.

Several practical laboratory courses at the UAS, which aim to train students with fundamental basic laboratory knowledge, are not fully based on PBL-orientated principles. However, a plenary lecture and additional lectures with self-study intervals provide the students with necessary background information, which are then followed by practical units in the laboratory to complete and intensify expertise on certain topics. They allow students, after having received theoretical background in a lecture, to address a topic independently and at their own intensity/speed/preferred method, which can differ individually. In a subsequent practical unit, students then have the opportunity to apply their theoretical background and intensify their knowledge. While theory is often abstract, practical courses enable a better understanding and memory. In addition, practical units grant intensive discussion and interaction with lecturers. Scholars agree that such hybrid-models of guided and autonomous study phases in a laboratory setting have been proven successful to equip students with the "scientific mind-set" and competences needed in order to succeed in their later working lives and thus need to be an integral part of any scientific education (Allen & Tanner, 2003; DiCarlo, 2006; Adams, 2009; Wallen & Pandit, 2009).

The recent crisis around the Corona virus pandemic has drastically changed our lives. Measures to reduce social contacts to a minimum led to a lock-down in spring 2020 and to a complete halt in on-site teaching at universities for almost the entire summer semester 2020 in most countries worldwide. However, the intention of the UAS, as of many other universities, was the continuation of all study programs to enable all students the best possible education so that they are able to finish the semester without any detriment. Therefore, the teaching and administrative staff of universities had to switch from classroom teaching to e-learning at short notice and convey teaching contents online only. Although several study programs already use digital teaching methods - certain distance study programs even entirely rely on digital teaching - the application of online tools is restricted, particular in study programs with a high degree of practical courses.

This was the case for all study programs at the faculty of "Life Science Engineering" and lecturers were facing a myriad of challenges in order to identify, adapt and finally implement digital teaching methods that are adequate for the needs of highly diverse courses. While lectures, seminars and interactive courses could be continued with the help of digital services and online conference tools, courses based on high interaction and participation of students with obligatory attendance presented a more complex situation. The most challenging courses were certainly practical courses requiring special equipment, special safety regulations or another special framework.

A combination of physical and virtual laboratories has been described as beneficial to conceptual understanding and learner flexibility (De Jong et al., 2013). Studies on student's perceptions concerning the implementation of solely virtual labs, however, showed ambivalent results; for instance, in a study by Stuckey-Mickell & Stuckey-Danner (2007) students believed they had learned less in virtual labs than they would have in a face-to-face lab, while Flowers (2011) found that students perceived virtual laboratories to be even more effective than face-to-face labs. Major challenges for conceptualizing virtual PBL environments are to find ways to engage discussions (Boelens et al., 2017) and to develop a collaborative and engaging learning environment (Kebritchi, 2017). Especially, ensuring that tasks are not simply distributed among students, but that collaboration still takes place, can be more difficult when facilitator and PBL groups do not meet in person (Verstegen et al., 2016).

As the major goal of the UAS is quality education, an evaluation of restructured courses and used online teaching formats should pinpoint positive as well as negative aspects. The identification of limitations of e-learning concepts and/or additional problems, especially in courses with a high degree of practical laboratory exercises, is essential to improve courses in future. Since many universities are currently facing similar problems, we intend to share our experiences that we have gained during summer semester 2020 within this report.

We aim to analyze if and how quality teaching despite restrictive measures can be maintained by e-learning tools and to examine putative solutions on two levels:

a) What can be learnt, especially by lecturers and administrative personnel, from the sudden switch from on-site to distant teaching?
b) How can PBL-based and in particular practical courses be implemented without presence units and via virtual classrooms?

To address the first question, we have collected the overall opinion of lecturers as well as students concerning the maintenance of quality teaching during the lock-down in summer semester 2020 within a faculty-wide survey. In the discussion we highlight lessons learnt that will be helpful also in future.

To address the second question, we describe how practice-oriented courses with a high degree of on-site laboratory units had been restructured to pure online courses with virtual laboratory exercises. We have chosen three representative courses, one of each aforementioned study programs.

First, we describe the conventional structure of the courses and how they had been restructured with an emphasis on alternative hybrid-PBL methods including online- and offline tasks. Second, we analysed the opinion of students in an evaluation of the restructured courses. And finally, we conclude our results and give future recommendations on the implementation of hybrid-PBL methods in a framework of pure online teaching.

METHODS

Lecturer/student population and department/course information

The faculty Life Science Engineering at the UAS Vienna offers two bachelor and five master study programs with a total of approximately 730 students per academic year. To assess the situation of spontaneous re-structuring didactic concepts from on-site teaching to a pure online teaching concept, we have designed a faculty-wide questionnaire for lecturers and students. The sample size for evaluating the transition from on-site to pure online teaching of students consisted of 115 students, where 47% were male, 46% were female and 7% other/no answer. The exam evaluation during pure online teaching was asked in a separate survey and the cohort comprised of 80 students, of which 49% were male, 50% were female and 1% did not give an answer. In the survey designated for the lecturers, ten male, five females, one other, participated in the survey with two additional lecturers who did not answer this demographic question. Demographic questions including age, gender, study program, semester, years of teaching, type of employment, difficulty coping with access restriction and additional time loss were added.

Evaluation of adapted hybrid-courses

Evaluation of the chosen hybrid-courses “Biochemistry Laboratory (BCL)”, "Special Applications of Measurement and Environmental Technology (SAUT)" and “Methods in Cell Biology (MIC)” was done at the end of the semester. Out of 80 students attending the BCL course 39 volunteered in the survey (n=39; 48,8%). The MIC course comprised 31 students, out of which 23 participated in the survey (n=23; 74,2%). Finally, 25 students were enrolled for the SAUT course and 13 participated in the survey (n=13; 52%). In addition, information on age and gender was requested. Furthermore, we required a better understanding for certain problems, therefore we have invited three students, one of each chosen hybrid-course, for an interview. The students were asked to think carefully about the questions and then to answer them in written form.

Survey structure, procedure and data analysis

The overall survey structure was designed according to the course feedback structure students and lecturers are used to, in order to ensure re-recognizability. The number of questions was limited to a minimum and questions were formulated concisely. Each survey consisted of several question groups for easier access and overview. The question types single choice, multiple choice, open text, matrix, and rank order were utilised. For the majority of questions Likert scale response options were constructed. Within those no true middle category was offered, wherever possible, with the intention to request respondents to make a decision and to reduce central-tendency bias.

Surveys were performed using LimeSurvey Professional, a web-based, open-access platform commonly utilized for performing opinion and feedback collection. LimeSurvey can be adapted as required for the intended purpose, the source code can be modified. Six surveys were performed at the end of the semester, out of which three evaluated the adapted hybrid-courses and three the unprepared transition from on-site to pure online teaching. Every answered survey was anonymous and could not be led back to individual participants.

Lecturer and student perceptions were collected and then transformed into percentages by LimeSurvey using the number for one answer and dividing it by complete sample size. GraphPad Prism was utilized for creating bar graphs.

RESULTS

Lessons learnt from the sudden transition from on-site to distant teaching

The discontinuation of classroom teaching at universities due to the spread of Covid-19 has forced a sudden and unprepared switch to e-learning in the last summer semester 2020. Importantly, the ministry of education and the directorate of the UAS forbid entirely the access to the university buildings to both, students and lecturers. Rare and highly controlled exceptions were made for only certain personnel responsible for necessary maintenance duties. From the notice to the implementation of a complete lock-down lecturers had less than two weeks' time for the transition to a pure online teaching system of all study programs.

In the study programs of the faculty of "Life Science Engineering", a focus lies in practise-oriented and problem-oriented teaching. Almost all courses contain certain elements, which foresee direct interaction of the lecturer with the students to different extents. Many lecturers include *e.g.* discussions in small groups of students and a presentation phase within their courses. Especially integrated lectures (hybrid-courses with many practical parts) and laboratory courses require the presence of students and lecturers.

We were therefore interested in evaluating this unusual and stressful situation and have analysed how lecturers and students have experienced this unforeseen and unprepared transition of on-site to off-site teaching.

Maintaining quality teaching despite the restrictive measures undoubtedly posed a major problem for lecturers. Importantly, most lecturers at the faculty cover more than one type of course, which required different adaptations to the sudden transformation. Consequently, they are able to assess various difficulties concerning different course types. The different types of courses are lecture/seminar, integrated lectures with large amount of exercises, laboratory courses and supervision of scientific papers of students *e.g.* bachelor and master thesis (Figure 1, Panel A).

Since most study programs rely on various hybrid-PBL methods in courses, a sudden transition can require, amongst other challenges, different amount of time. Therefore, the lecturers were asked if they had to increase their effort and time requirement for preparing lectures, seminars etc. (data not shown). The majority of lecturers claimed to have invested more time into the creation of written documents, teaching material, written feedback (*e.g.* via e-mail, corrections of scientific work or exams), recordings (audio, video, tutorials), assessments, creation and provision of exams.

Next, communication in the respective teaching-forms was assessed. Approximately 90% of the lecturers claimed to have more contact with students in person rather than online (data not shown). For instance, active engagement of students including asking questions, participating in exercises and discussions can be supported more easily in person during class than online. Guidance of exercises and group work as well as coaching and supervising project work is easier to hold in person, since negotiating a meeting online can be more difficult when additional factors (such as taking care of a person, etc.) limit the time frame and concentration. However, around 20% of lecturers judged coaching and guiding project work as suitable for online communication. Feedback and counselling by lecturers was also sufficient by using online communication.

The examination modalities required extensive adjustment. Question types and modalities used before the transition were single choice, multiple choice, open questions, written assignments, and oral exams. After the transition open book assignments with a time limit specified by the lecturer were introduced. At the end of the semester students were asked if the newly provided material had helped them pass the exam. More than half of the students rated the studying with the e-learning material as sufficient to pass the exams (data not shown).

Before the sudden transition to pure online-teaching only 5% of lecturers felt very confident to handle digital technologies to generate e-learning/e-teaching materials (Figure 1, Panel B). After the transition a significant increase in confidence can be observed (36%) and no lecturer felt very unconfident (before = 11%, after = 0%). We cannot clearly discriminate whether lecturers had indeed improved their e-didactic skills or whether simply their critical self-assessment had changed due to the sudden regular use of those tools.

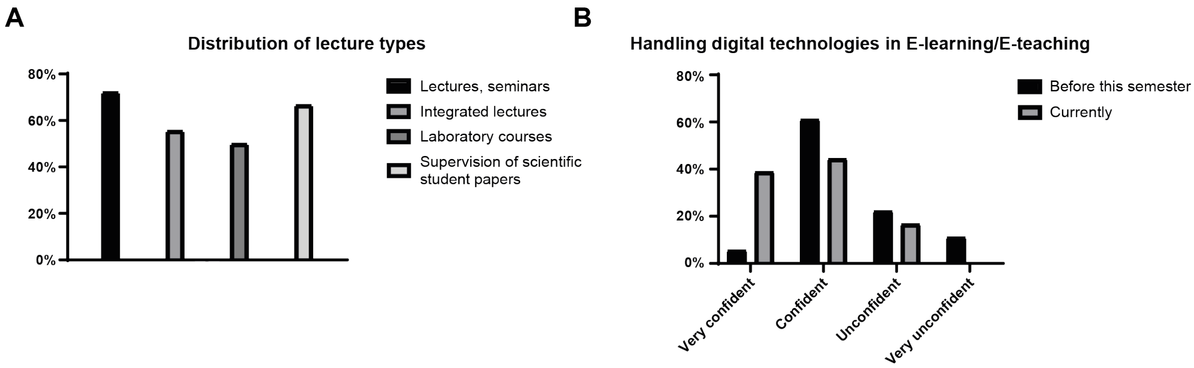

Figure 1: LimeSurvey of lecturers. (A) Distribution of lecture types at the faculty of „Life Science Engineering“ at the UAS, including lectures/seminars, integrated lectures, laboratory courses, and supervision of scientific papers. The statistical analysis was performed by using LimeSurvey Professional (n=18). (B) Confidence in handling digital technologies used in e-learning/e-teaching before and three months after the lock-down. The statistical analysis was performed by using LimeSurvey Professional (n=18).

Remarkably, both lecturers and students were satisfied with the restructuring of courses to a pure online format. Only 11% of the teaching staff did not want to use the newly created online-teaching formats anymore and less than a quarter of the students would prefer that the old presence form is resumed (data not shown).

Interestingly, many lecturers mentioned that they found themselves confronted by a PBL case, facing a new and real problem and identifying possible solutions within teamwork. This led to lessons learnt that are highlighted in the discussion.

Lessons learnt from the restructuring of three hybrid-courses

Although the sudden transition to online teaching has been assessed relatively positive by students and lecturers, we were interested to analyse hybrid-courses with a high degree of practical laboratory work in depth. These practical laboratory courses require a special framework, such as equipment and safety precautions, and were therefore particularly challenging to adapt for online formats.

We have chosen three representative hybrid-courses of different study programs to enlighten how these courses with practical laboratory exercises had been restructured to online courses with virtual laboratory exercises.

Original structure of chosen hybrid-courses

As explained in more detail in the introduction, many courses in study programs of the faculty of “Life Science Engineering” at the UAS are hybrid-courses, which combine self-study phases with conventional lectures and practical laboratory exercises. While self-study phases can be individually and autonomously performed by students, lectures and in particular practical laboratory exercises have usually been held on-site in dedicated classrooms and laboratories, respectively.

The courses “Biochemistry Laboratory (BCL)” in the second semester in the bachelor study program “Biomedical Engineering” (Figure 2) and "Special Applications of Measurement and Environmental Technology (SAUT)" in the second semester of the master study program “Environmental Management and Ecotoxicology” (Figure 3) are structured in a similar way and follow the same didactical concept. The courses aim to introduce state-of-the-art methods in the respective field and to teach students how to write a scientific report.

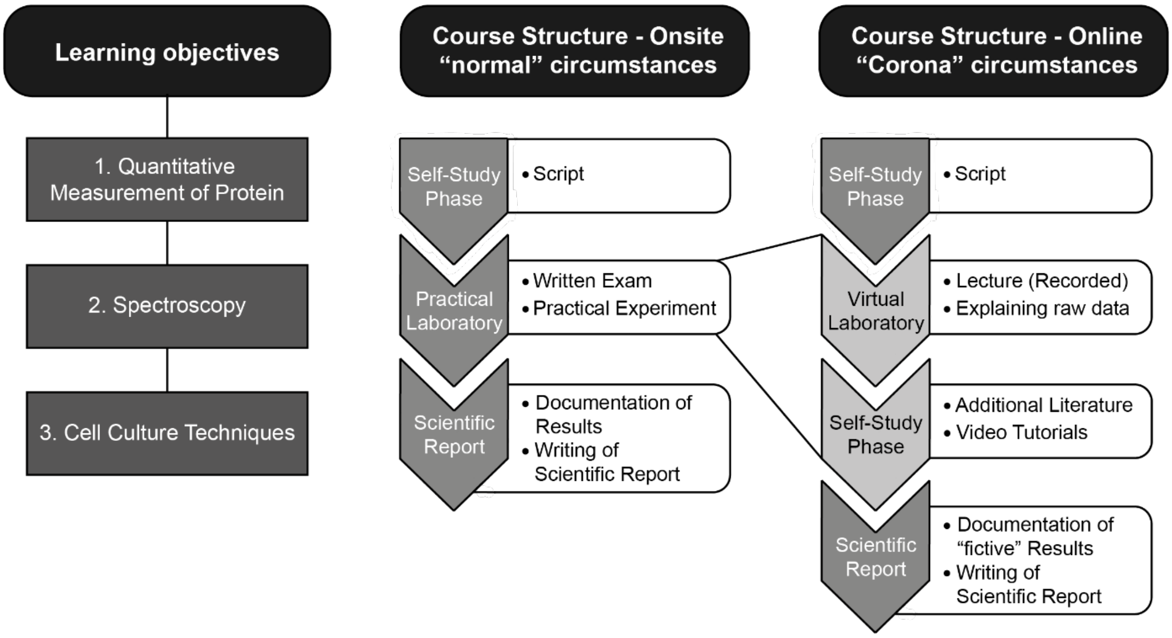

Figure 2: Outline of BCL structure. Three major learning objectives are addressed. The original course was structured in a self-study phase, practical laboratory and writing of a scientific report. The restructured course affected mainly the practical laboratory, which was split in a virtual laboratory and a second self-study phase.

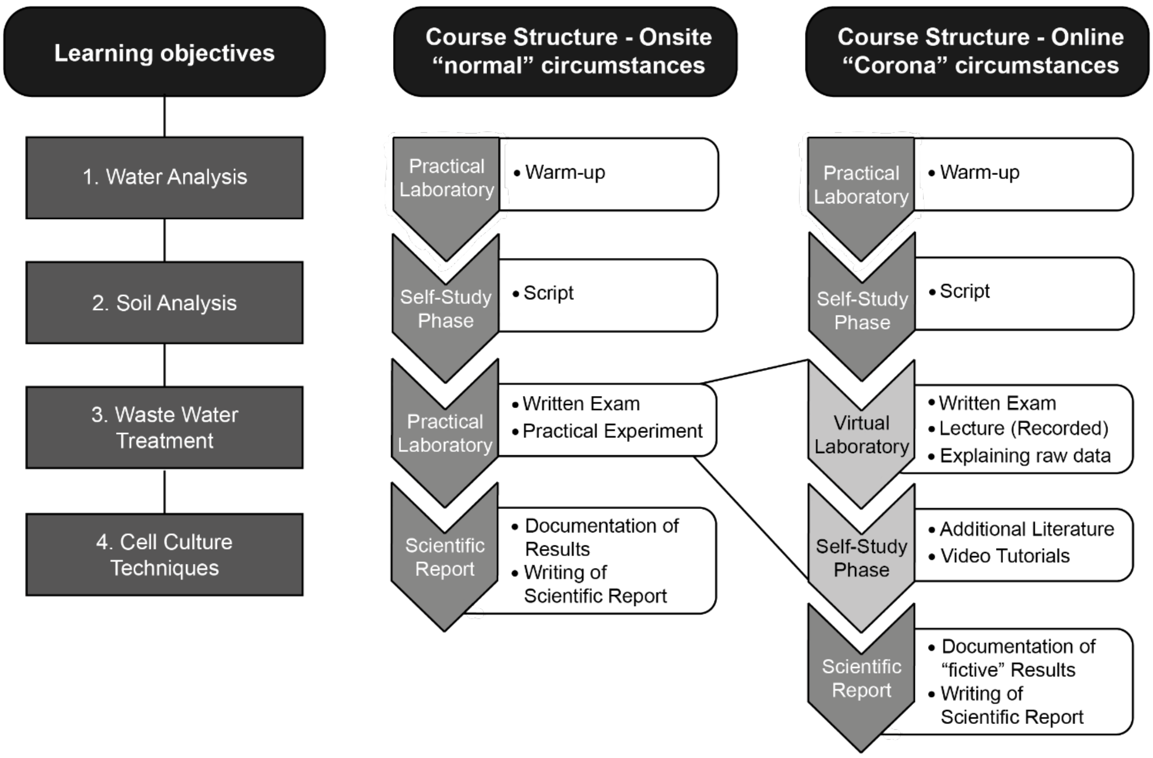

Figure 3: Outline of SAUT structure. Four major learning objectives are addressed. The original course was structured in a laboratory warm-up, self-study phase, practical laboratory and writing of a scientific report. The restructured course affected mainly the practical laboratory, which was split in a virtual laboratory and a second self-study phase.

One difference between the two courses is that at the beginning of the SAUT course students receive a “warm-up” training in the laboratory. As students of this master study program have different educational backgrounds, students with less laboratory experience get the chance in the “warm-up” training to compensate for it. This is not necessary in the BCL course, as students are still at the very beginning of their higher education, thus representing a more homogenous group with roughly the same and rather little laboratory expertise.

The BCL course is divided in three, the SAUT course in four major topics, which are addressed using the same didactic strategy by lectures with profound expertise on the corresponding subjects. First, in a self-study phase the students have to familiarize themselves with the topic and the methods they will practice at a later moment in the laboratory. Therefore, a script is provided and students are encouraged to independently research on the subject. Second the practical laboratory unit is held on-site. At the beginning, the students have to pass a small written exam proving their knowledge of the theoretical background. Only those who pass this test are allowed to participate in the laboratory exercises on that day. Afterwards, the most important theoretical contents are briefly discussed by the lecturer before the practical part begins. A total of about eight students carry out the laboratory on the same day. Usually they work together in teams of two. Finally, after the laboratory exercise the students have two weeks to write a scientific report.

The work load can differ individually, however we estimate an average distribution as follows: 30% self-study phase on the theoretic background of the topic, 10% practical work in the laboratory and 60% report writing, which is also reflected in the grading with 30% exam, 10% participation in the laboratory and 60% report, respectively.

Although only 10% work-load of the courses are accounted for practical training in the laboratory, this opportunity to directly apply theoretical background information is extremely valuable. Practical implementation of acquired theoretical knowledge and collaboration enhance the understanding and the long-term memory of the learnt matter (DiCarlo, 2006; Schmidt et al., 2011). We therefore claim that the benefit of practical courses is not in direct correlation with their actual time investment and want to underline the importance of practical courses.

The course “Methods in Cell Biology (MIC)” in the second semester in the master study program “Tissue Engineering and Regenerative Medicine” (Figure 4) builds on previously acquired advanced knowledge in cell biology, protein chemistry and practical cell culture methods.

In comparison to the BCL and SAUT courses, the MIC course is much more comprehensive, as more diverse topics are covered. It is divided in two parts, of which Part A addresses four specific subjects with similar didactical concepts as described already for the BCL and SAUT courses. Briefly, each subject combines self-guided study of the theoretical background with provided literature and scripts, frontal lecture elements by specialists, and practical application of the acquired theoretical knowledge in the form of laboratory exercises. Students are working in groups of four and have to write a group report after the course. For two of those laboratory courses, students are asked to complete web-based learning exercises followed by online examinations to prepare for the practical work.

Part B of the MIC course comprises four theoretical frontal lectures with homework assignments to consolidate and deepen the knowledge of those topics.

Grading elements of the course include two written examinations (total 50% of final grade), an initial examination covering the theoretical background of the laboratory courses at the start of the semester (Part A) and a final exam covering the topics of the frontal lectures at the end of the semester (Part B), and grading of the four individual laboratory reports and four homework assignments (total 50% of final grade). All grading elements are weighted according to the teaching hours spent on the subject.

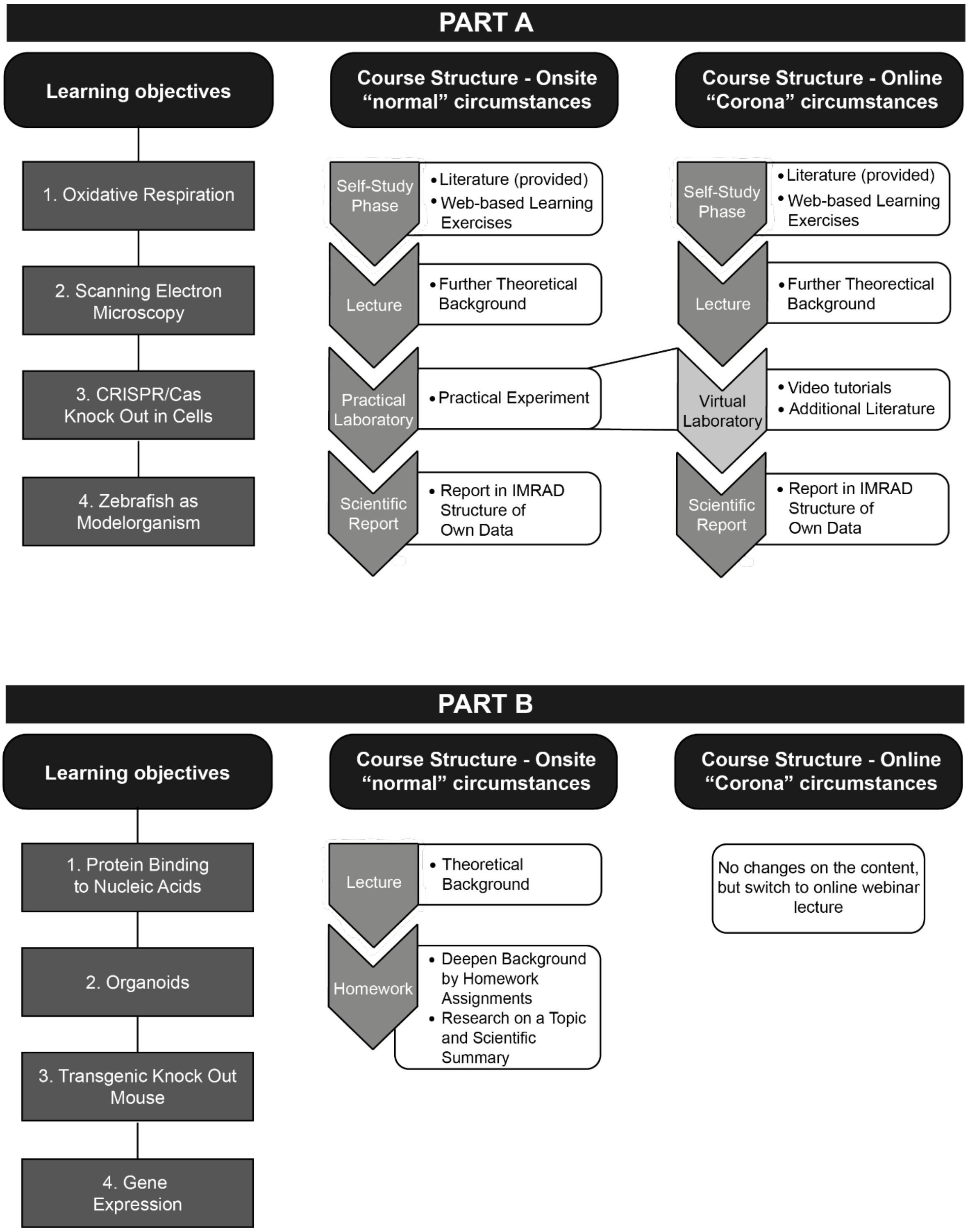

Figure 4: Outline of MIC structure. The MIC course is divided in two Parts (Part A and B), each containing four major learning objectives. In Part A, the practical laboratory was restructured in a virtual laboratory.

Adaptation to pure online structure of chosen hybrid-courses

While the self-study elements as well as conventional lectures were not affected, as they could be held through online tools (BigBlueButton and Zoom), the practical laboratory exercises had to be re-designed.

Due to time pressure, an emergency conference of involved lecturers and PBL-experts was convened. It was decided to teach students practical laboratories online in so-called virtual laboratories, which can differ depending on the respective subjects and methods. However, they usually comprise further specific background information on the subject in special lectures, a detailed guidance through the practical work procedure and finally additional educational material for a second self-study phase.

The guidance through the practical work procedure was usually based on fictive data or data obtained from previous courses with an emphasis on common technical problems, troubleshooting advices, calculations, discussion of equipment and specific computer software. The exercise on scanning electron microscopy (SEM) in the MIC course included an *in silico* hands-on part, thus representing a good example of a real virtual laboratory. Using the virtual SEM simulator (https://myscope.training/) allowed students to navigate a virtual microscope and to generate their own images. Due to the simulator students were enabled to experience an almost real-laboratory situation.

The final aim of the virtual laboratory units was also to write a scientific report. Therefore, students were provided with raw data and additional educational material on certain topics including recordings of special lectures, helpful literature, and pre-existing and open-access tutorial videos, such as provided from the science education platform JoVE (Journal of Visualized Experiments) and certain biomedical providers (e.g. ThermoFisher and SigmaAldrich). If available for certain methods, guidance through the application of *in silico* methods (performance of scientific experiments by means of computer simulation) was also provided. All mentioned information and material for self-study phases was provided on the central website platform on Moodle.

The adaptation to virtual laboratories with the three chosen hybrid-courses is outlined in Figures 2-4.

Evaluation of chosen hybrid-courses

In voluntary and anonymous surveys, we analysed the opinion of the students on the restructured courses in order to obtain an idea of the quality of virtual laboratory courses and the satisfactory of the students.

The majority of students claimed to have been informed sufficiently and in time about the restructuring of the course (data not shown). Most of the students stated that the adapted course contents had been explained and conveyed in an understandable manner and that the quality of the Moodle BigBlueButton video-lectures was satisfactory (data not shown).

As the final goal of all evaluated hybrid-courses was the writing of a scientific protocol, we paid special attention on this particular learning objective. We were satisfied to hear that according to the majority of students the necessary background knowledge and goals of the virtual laboratory exercises were adequately explained in order to subsequently write a protocol. Consequently, 74% of students in the BCL, 60% of students in the SAUT and 59% of students in the MIC course were satisfied with the theoretical background. However, one should not disregard that a significant number of students (20% of students of the BCL, 30% of students of the SAUT and 36% of students of the MIC course) experienced the virtual laboratory exercises as not sufficient to write a report (Figure 5, Panel A). Despite the ambivalent assessment of the laboratory exercises, the students were overall satisfied with the provided documents and online resources on Moodle for the self-study phase (data not shown). Interestingly, lecturers involved in these courses agreed that the quality of reports of all three hybrid-courses was of better quality and above average. Theoretical connections could be better explained by the students during the final examination compared to previous years. This might be due to a special emphasis during the online lectures on how to write scientific reports and explaining in more detail theoretical background. In addition, students were able to listen to recorded lessons more often and go through the learnt matter in their own speed.

Next, time management and workload were evaluated. Comparing to an estimate workload of the course under normal circumstances, one third of the students from all three hybrid-courses estimated a similar workload of the course with virtual laboratory exercises. While the rest of students from the master study programs participating in the MIC and SAUT courses on trend estimated a higher work load of the courses with virtual laboratory, the rest of students from the BCL course (bachelor studies) claimed the contrary (Figure 6, Panel B). These results indicate that certain differences might arise from the different background and education level in bachelor and master study programs.

Most students of the BCL course (74%) and of the MIC course (66%) claimed that the learning objectives “understanding of the theoretical background” and “understanding of practical methods” were achieved in the virtual laboratory exercises. In case of the SAUT course the assessment was more heterogeneous and only half of the students (55%) agreed on having achieved the learning objectives, while the rest (45%) disagreed (Figure 5, Panel C). The positive evaluation could be confirmed by the lecturers due to the high-quality reports, also in the SAUT course, in which students proved their newly acquired skills and theoretical expertise.

After the students had completed the virtual laboratory exercises, we were wondering how students self-assess their practical skills. We were surprised that more than half of the students in the bachelor study program (59%) feel well prepared to be able to carry out the tests and experiments in the laboratory. Students from the master study program attending the virtual MIC course assessed this question differently and the majority (85%) claimed to feel not well prepared to carry out certain experiments independently (Figure 5, Panel D). These opposing results could be explained by the different educational status. Although master students have already acquired valuable practical expertise, they feel less prepared to translate theoretical knowledge transmitted by virtual laboratory exercises. What looks as being a lack in self-esteem is in fact a much more realistic self-assessment of somebody who has enough experience in order to evaluate such a question.

The assessment whether the students experienced the virtual laboratory course more difficult than in comparison to previous courses with practical laboratory units was individually very different, however with a similar distribution within the three hybrid-courses. While students of the BCL and MIC courses experienced the adapted courses on trend more difficult, students of the SAUT course experienced it on trend less difficult (Figure 5, Panel E). Those who had stated that is was more difficult added that due to very limited experience in practical laboratory work, the virtual laboratory was too abstract.

Clearly negatively evaluated was the limited and to a minimum reduced discussion between students and their colleges and students and lecturers. More than 60% of the students attending all three hybrid-courses claimed that the online format affected negatively scientific discussions that would otherwise occur in the laboratory spontaneously (Figure 5, Panel F). Although lecturers encouraged students during the online sessions to actively participate in discussions, the online tools used (like BBB and Zoom) have limited resources. In addition, the atmosphere of the laboratory, where students and lectures work together as small teams, is more friendly and more appropriate for scientific discussions. Most importantly, many questions only arise when performing actively an experiment in real and not when watching passively somebody explaining its principle.

To summarize, the evaluation of the re-structured hybrid-courses resulted in ambivalent conclusions. Several aspects were assessed positively, such as additional teaching material (literature, tutorials and recording of online lessons) that helped to elaborate the theoretical background and therefore the understanding of the learning objectives, while others were criticized, such as the difficulty of translating theoretical knowledge into practical skills and the lack of open discussions. Although the majority of students were satisfied with the restructuring of the course under the present circumstances (data not shown), they clearly expressed their preference towards the conventional mode of the course with practical laboratory work (Figure 5, Panel G). The majority of the students mentioned that additional study material, as it had been provided, as well as a second round of a self-study phase would be beneficial in future courses as an add-on to the practical laboratory exercises.

To conclude, online virtual laboratory exercises cannot replace practical courses. However, in addition to the self-learning phase prior to the laboratory work, sufficient time should be scheduled for a detailed explanation of theoretical concepts and data evaluation by the lecturer.

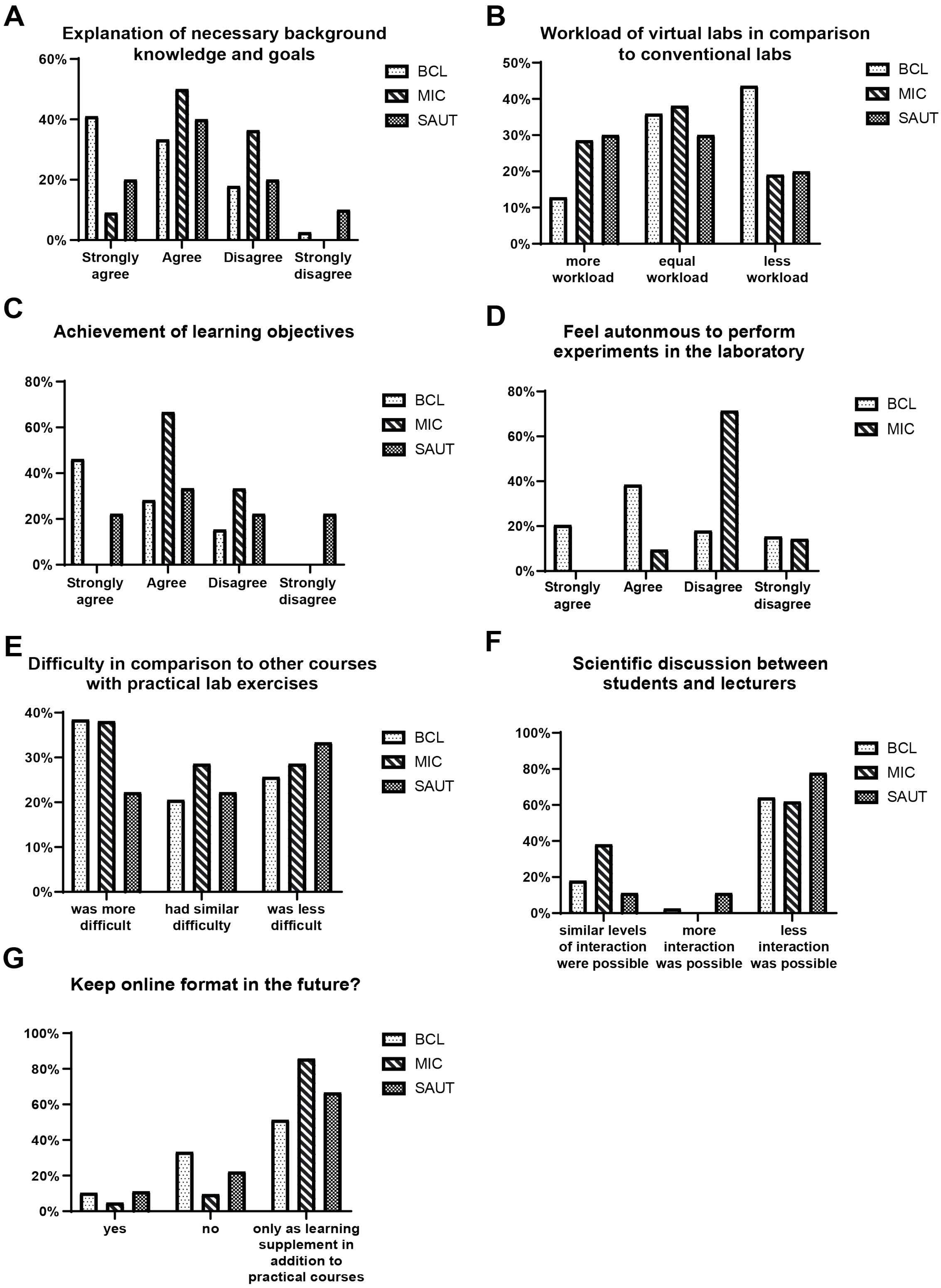

Figure 5: LimeSurvey of three chosen hybrid-courses. The restructuring of practical laboratory to virtual laboratory of BCL, MIC and SAUT courses was evaluated. 48,8% of students of the BCL, 74,2% of students of the MIC and 52% of students of the SAUT course participated. For each question three to four possible answers existed. The statistical analysis was performed by using LimeSurvey Professional. (A) Explanation of necessary background and goal. (B) Workload of virtual labs in comparison of conventional labs.(C) Achievement of learning objectives. (D) Feel autonomous to perform experiments in the lab. (E) Difficulty in comparison to other courses with practical lab exercises. (F) Scientific discussion between students and lectures. (G) Keep online format in future.

DISCUSSION

Lessons learnt from the sudden transition from on-site to distant teaching

Maintaining quality teaching despite the restrictive measures undoubtedly posed a major problem for lecturers. Analysing the solution to this problem from both the student's and the lecturer's perspective with a faculty-wide survey, we come to the conclusion that the sudden lockdown in summer semester 2020 has clearly accelerated the development of e-didactics in the faculty and increased the lecturer's skills to enable learning processes using the new media.

Importantly, the Corona crisis accelerated the future strategy by the UAS to expand blended learning. As investments in infrastructure and teaching support had already been planned before the lockdown, online tools and technical support could be brought forward relatively quickly and are now permanently available. Reactions to the first lessons learnt in the pandemic included, for example, the strategic and sustainable selection and licensing of one online conference tool for everyone, Zoom, and the expansion of a teaching and learning center, which supports students as well as lecturers in technical aspects and by making experiences and practice examples available to improve blended learning concepts. In addition, computer rooms at the university were equipped with professional recording (audio and video) devices and streaming software, in order to guarantee best-quality teaching conditions for blended formats.

Almost everybody agreed that communication in online formats is impaired in both ways, qualitatively and quantitatively. As professional communication is of utmost importance for transmitting a subject as well as for creating a comfortable ambience, this poses a major challenge, especially if online teaching formats will be kept in future. However, we are convinced that with an optimistic state of mind and the use of certain features of online tools, such as video conferences with activated camera, breakout rooms in Zoom, student chats and others, we will be able to circumvent these communication limits.

Although lecturers and students were affected by an increased workload and a more difficult time management, most people believe that with time and more experience with online tools the work load might actually decrease. In fact, several tutorials and online teaching materials that were created are still being currently used. Even though practical exercises are taught back on-site in the laboratory (respecting strict Covid-19 safety regulations and measures, such as limited number of people in laboratories, respecting a two-meter distance to colleagues and wearing FFP2 masks), all other courses are held online. In addition, most exams have been held online, which required the creation of open book exams and of competence-oriented question catalogues. While it is more time consuming for lecturers to develop and correct open book exams, students are encouraged to apply and critically question the course contents as well as profit from detailed and individual feedback. This is in line with the student's assessment of exam questions.

Remarkably, both lecturers and students were satisfied with the sudden transition to online teaching during the lockdown in summer semester 2020. From the current perspective, in which on-site teaching was resumed for practical laboratory exercises only, however all other lessons are still taught online, we are confident that blended teaching formats are a satisfying compromise also for the future.

Lessons learnt from the restructuring of three hybrid-courses

As courses with a high degree of practical laboratory exercises were in particular challenging to restructure to pure online courses with virtual laboratory exercises, we analysed three hybrid-courses in more detail.

From the results obtained by student-surveys it is obvious that students were overall satisfied, but regretted very much not to have had the opportunity for practical work in the laboratory and therefore gaining more practical expertise. Although lecturers pointed out a better performance of students in writing reports and in exams, most probably due to more focus in explaining theoretical background, they agree that practical training is extremely important in the field of life sciences and cannot be adequately substituted by virtual laboratories. However, this also points out that under normal circumstances, even more emphasis should be laid on the explanation of the theoretical background.

Another reason for the better performance in writing reports and in exams might be the fact that students had the possibility to listen to recorded lessons more often and to work on the topics in their own speed. Additional learning material, such as literature, screen casts and/or useful internet links were also provided on Moodle, which certainly supported the positive learning outcome. We therefore suggest that in future, study material for self-study purposes should be provided and actively integrated in the course structure, independent of the course format (online vs. on-site). For instance, a guided study or a well prepared screen cast on the theoretical background summarising the already completed laboratory exercise, common mistakes in protocol writing or common problems in data analysis could be provided one week after the practical work. At this point, most of the students have already started working on the protocols, however would still have enough time to implement information from the guided study materials. It would also lead to a critical reflection on the exercise and the written report.

Due to a complete interdiction of entering laboratories in the university buildings during the lockdown in summer semester 2020, even for lecturers, possibilities for restructuring laboratory courses were very limited and restricted to already existing video tutorials.

Now that laboratories are accessible again, we are currently elaborating which topics and laboratory exercises would be suitable and prepare measures for tutorial videos. However, even though better designed online virtual laboratories might be used in future, our results indicate that neither students nor lecturers believe that solely virtual laboratories should be used. We insist that they should only function as an additional didactic tool as part of an integrated blended learning concept as described by De Jong et al. (2013), or in the case of a similar situation as in spring 2020 as emergency tools. However, they can never fully replace real on-site laboratory courses, due to the specific skills needed to handle equipment in life sciences. In students' interviews, participants also stated very clearly that - if possible - practical laboratories should never be substituted by any other means.

As already mentioned, communication is greatly affected in online formats. This influences critical PBL elements such as the interaction of students in the problem analysis phase as well as guidance from lecturer side. Our observations further underline the fact that an interactive atmosphere, in which lecturers engage students in discussion and debates and that encourages questions, increase the learning outcome (Verstegen et al., 2016; Boelens et al., 2017; Kebritchi et al., 2017). As in current times it is advised to continue online teaching when applicable, we elaborated possible solutions to this problem. We asked students under which circumstances they would feel more comfortable to participate in online discussions. Many stated that working in smaller groups and activating the camera might improve the situation. This indicates, that participation increases when students have the feeling, that their presence is being noticed, generated by virtual eye-contact which leads to a feeling of being addressed personally. We therefore conclude that breakout rooms in Zoom are useful features, which allow a more comfortable setting needed for discussions. This is in particular important in first semesters of study programs when students do not know each other well.

Finally, virtual laboratories were assessed to be more time consuming. In student interviews we wanted to understand why the work load was in average higher and whether students assume that this correlated with a better understanding of the addressed subject. Interestingly, they mentioned that due to recordings of courses, they could go back to lectures several times and at their own pace, which led to a high time amount. While lecturers assume this to be at least partly the reason for a better performance in exams, a way to estimate the learning objectives, students did not see a correlation to that.

To conclude, hybrid-courses with a substantial amount of practice-oriented learning by laboratory exercises can only be unsatisfactorily substituted by online teaching methods. While the implementation of hybrid-methods, such as a combination of self-guided study phases, transmission of theoretical background and practical training, of which the first two parts could be done via online tools, has proven very successful, a complete transition to virtual laboratories clearly affects the learning quality negatively. Hybrid solutions including online and on-site teaching however are a satisfying compromise and have even proven certain benefits, as providing additional study material and guided self-study phases.

Although the Covid-19 pandemic and the complete lockdown in summer semester 2020 have bestowed a myriad of challenges on lecturers and students alike. They have certainly taught us to stay flexible and optimistic, two qualities of utmost importance.

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Facilitating Reflection and Progression in PBL: A Content Analysis of Generic Competences in Formal PBL Curricula

Anders Melbye Boelt, Anette Kolmos, Lykke Brogaard Bertel *

ABSTRACT

This paper proposes a systematic approach to the analysis of the prevalence of generic competences in formal problem-based learning (PBL) curricula at higher education institutions and universities in which generic competences are an integral and integrated part of the curriculum, with a particular focus on how the generic competences are specified explicitly in the curriculum. A case study on the implementation of PBL competences at Aalborg University (AAU) shows, that the dialectic relationship between knowledge and practice is limited after the first semester, with the risk that both knowledge, skills, and competences related to PBL become tacit and thus might be less easily expressed and related to the development of a professional identity. Based on this we argue that revision of the formal curricula must support students with theoretical knowledge on PBL, project management, and group collaboration throughout the study to accommodate a greater variety in types of problems, projects, and complexity. This calls for further elaboration of 'generic' competence frameworks and points to challenges and potentials for near-future and next practice curriculum development particularly with attention to the concept of progression, thus providing a benchmark for future research assessing the integration of PBL competences in formal curricula.

Keywords: Generic competences, Problem-based Learning, PBL, Curriculum Development

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INTRODUCTION

Since the 90's, there has been an emphasis on outcome and competency-based approaches to higher education, and generic competences have steadily been promoted as part of a new paradigm for structuring and organising education in an increasingly complex society (Adam, 2008; Bologna Working Group on Qualifications Frameworks, 2005; González & Wageneer, 2003). The rationale directing this motion are changes in society and economy where new skills and competences are required to contribute to emerging models of economic and social development where knowledge is the main asset for economic development (Ananiadou & Claro, 2009). These competences have many names: transferable skills, transversal skills, employability and 21st century skills or competences. However, they share a general focus on enabling students or learners to apply, share and contribute their knowledge in communicative and collaborative organisational settings (Young & Chapman, 2010). The Tuning Project identifies generic competences in terms of instrumental, interpersonal, and systemic competences that are general and shared attributes of any degree (González & Wageneer, 2003). In a selective review of national and international frameworks of generic competences, Young and Chapman (2010) found 58 competences grouped in six clusters of skills: basic skills, such as literacy and numeracy; conceptual skills such as creativity and pursuit of lifelong learning; personal skills; people skills; business skills such as financial planning and enterprise; other skills in health and safety, motor skills or freedom from substance abuse (p. 19). In line with this, the prospects of future employment are by students no longer perceived to be determined by disciplinary qualifications alone but by a complex of personal, social attributes, academic credentials, and students' ability to assess the market value of the intertwined experiences (Tomlinson, 2008).

Although no single definition exists, frameworks describing attributes needed for future success in the knowledge society are finding political endorsement and ways into the curriculum, albeit with different focus and implementation strategies depending on national policy (Voogt & Roblin, 2012). While policies may vary, Voogt and Roblin (2012) find that inquiry-based and experiential learning approaches are highlighted as viable pedagogical models to support the development of generic competences. This was also noted by Barrows and Tamblyn (1980), who describe how the personal and affective competences needed in medicine could be scaffolded and emulated in PBL.

This paper proposes a systematic approach to the analysis of the prevalence of generic competences in formal PBL curricula at higher education institutions and universities in which generic competences are an integral and integrated part of the curriculum, with a particular focus on how the generic competences are specified explicitly and integrated into the curriculum. PBL is a widely popular pedagogical approach to student-centred learning with a plethora of different applications (Chen et al., 2020; De Graaff & Kolmos, 2003). Rather than seeking to demarcate potential PBL practices, (2003) find similarities in theoretical underpinnings, learning principles, and models. In a similar vein, Savin-Baden and Major (2004) describe and outline eight different curricular models, ranging from a single module approach to a complex model transcending the traditional educational sphere to identity formation in domains of *knowledge*, *action*, and *being* described by Barnett and Coate (in Savin-Baden & Major, 2004, pp. 43-44). Both approaches point out the common theoretical ground and the diverse practice that are to be found under the umbrella of PBL, where rather few institutional models have applied specific principles for a systemic PBL practice institution wide. An identified and authentic problem is central in the students' learning as it is the point of departure for a learning process organised as project work running for weeks or throughout an entire semester (e.g. Chen et al., 2020). PBL then nurture a learning environment where students can develop competences in domains such as problem-solving skills, project management, communication, and collaboration (Du & Kolmos, 2006; Guerra, 2017).

GENERIC COMPETENCES IN HIGHER EDUCATION

The personal and social attributes are as we have seen part of most frameworks describing future competences, and can be supported by inquiry-based pedagogical approaches such as PBL (Barrows & Tamblyn, 1980; Voogt & Roblin, 2012). While PBL has the potential to support the development of generic competences (Hmelo-Silver, 2004), the competences needed in the 21st century ought to be integrated into the curriculum as part of the core of the taught subjects according to Marope (2017). Voogt and Roblin describe three different approaches for implementation into the curriculum:

- an addition to existing content or new subjects;
- as cross-curricular competences underpinning subjects while emphasising wider key competence development;
- as a transformation of existing subject structure rethinking schools as learning organisations (p. 3).

These three strategies corresponds to the three strategies for curriculum change identified by Kolmos et al. (2016) who have built up a framework for change based on Sterling: add-on strategy, integration strategy and the re-construction strategy. The add-on strategy is easy to implement in the formal curriculum as this is just a question about formulating another element. The cross curricular or integration strategy is much more advanced as the generic competences will have to be explicitly integrated into existing elements and integrated in the learning. The transforming or re-construction will require a whole new curriculum, which might be interesting but also will have special conditions such as a new value-set and totally new courses.

Both the PBL societies and the CDIO (Conceive-Design-Implement-Operate) society recommend an integration strategy where the generic competences are learned within the disciplinary and interdisciplinary frames by reflection on experiences (Crawley et al., 2014). However, if the generic competences are not spelled out in the formal curriculum – both in terms of learning outcomes and assessment, there might be few formal initiatives to help facilitate students' reflection and conceptualization of their experiences. Previous research has also found students often being left alone to reflect on their learning with little guidance (Boud et al., 1985), impeeding potential outcomes while Riis et al. (2017) notes that students in their study could reflect if 'properly encourage' (p. 409).

The outcome-based approach to curriculum design is further bolstered by the International Bureau of Education at UNESCO, who argue for a global paradigm shift for curricula. The paradigmatic shift outlines both political and technical elements for a curriculum design supporting and sustaining relevant competences within contexts of rapid change. Central to the paradigm is also a stricter alignment of the official and the taught curriculum, arguing that discrepancies between the two due to too much teacher autonomy can lead to teaching of what teachers know rather than what ought to be taught according to the curriculum (Marope, 2017). Management of education through the curriculum then changes the object of accountability and locus of control. According to Steiner-Khamsi (2009), recurring waves of educational reforms rotate who is responsible for the outcomes of learning: the teacher or the student. Central in this transition from teacher-centred teaching to student-centred learning is the move from content to outcome (Karseth, 2008), or towards 'marketable tokens of accomplishment' as noted by Labaree (2012).

RESEARCH DESIGN

To explore and examine the presence of generic competences in the formal curricula, we have conducted a case study using Aalborg University (AAU) as an extreme case of systemic PBL integration. PBL is an intergral part of all eduational programmes, thus making AAU a suitable case for researching the prevalence and progression of generic competences specifically in formal PBL curricula. We have identified ten bachelor programmes to constitute the basis for our data collection.

Different definitions and conceptions of the curriculum exist, some involving the entire educational system of curriculum, pedagogy, and evaluation, in short, the entirety of the educational experience (Bernstein, 2003; Pinar, 2008). Deng and Luke (2008) describe three levels of curriculum making: the institutional level, i.e. a public policy nexus of influential internal and external actors; the programmatic level of syllabus construction to be transmitted during classroom use; and the mediated curriculum enacted in the classroom (p. 67). In this article we will only address the formal, or intended, curriculum.

PBL Competences

During the first semester of their study, most students at AAU will have one or more courses on study competences as well as introductions to PBL and its practice in their particular educational programme. These courses lay the theoretical foundation applied later in practice during group and project work. After the first semester, the dialectic relationship between theory and practice is completed, and the interpretation of PBL becomes that presented by supervisors and experienced tacitly in practice, where the practitioner may miss valuable insights to improve practice (Schön, 1983). Thus, in 2018 the AAU PBL Academy published an internal working paper identifying four domains of competence which characterize the practice at the first year program at engineering and science (Holgaard & Kolmos, 2019):

- Problem-oriented competence: the relation between students and the problem.
- Interpersonal competence: the relation between human actors involved in a project such as peers, supervisors and external collaborators.
- Organisational and leadership competence: the relation between students and the tools and methods supporting the process of PBL.
- Meta-cognitive competence: the relation between students and their learning process, supporting, connecting, and creating 'innovation' across the three former competences.

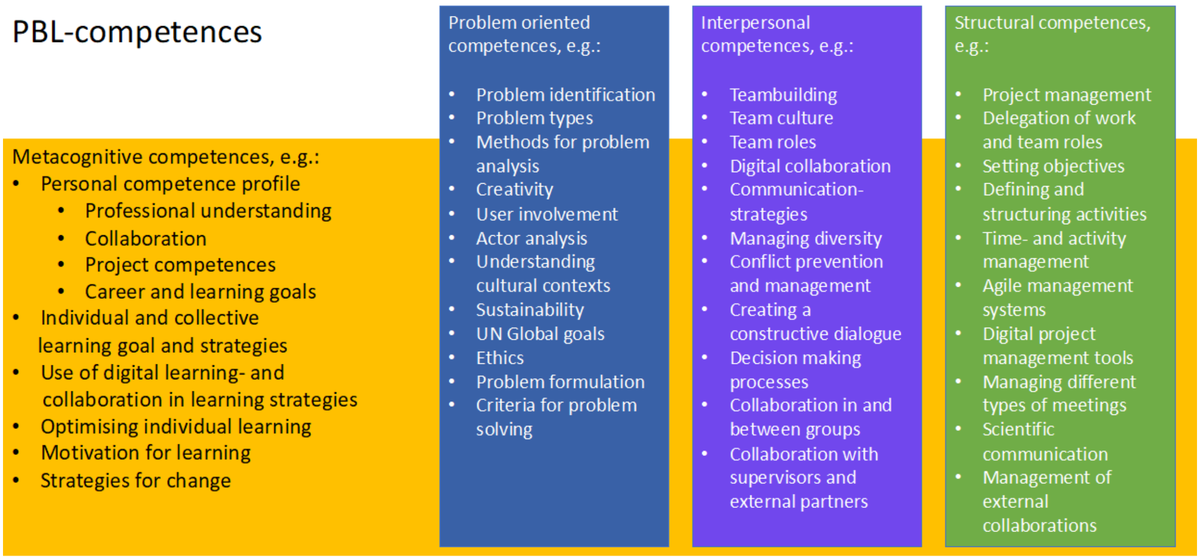

Figure 1. Categories of PBL competences (Holgaard & Kolmos, 2019).

The categories and competences visualized in figure 1 have been deduced from practice in an internal process akin to a delphi panel. These four competences are currently part of the practiced curriculum at the first year program at engineering and science, and has been formally structured in a conceptual framework for PBL competences to aide in integrating these as outcomes in existing curricula. In this study, the framework will serve as a basis for a directed content analysis of the formal curricula as they form a more coherent understanding of what PBL competences can reveal. The formal curricula used for the content analysis has not been structured according to the framework, but an application of the framework will provide a benchmark for future research assessing the integration of PBL competences in formal curricula.

Material Selected for Content Analysis

As mentioned, the selected material is formal curricula from ten different bachelor programmes at AAU. These are all included in subprojects of a larger institution-wide research project, PBL Future (www.pblfuture.aau.dk), of which this research is considered part of a baseline study. While the research in these subprojects addresses one or two semesters, initial readings of formal curricula suggested a limited reading and interpretation of a single semester would be insufficient when assessing the presence of PBL competences throughout an educational cycle. Because the generic descriptions mostly occur on the first and partly second semester, the scope was broadened to include the entire formal curriculum of the selected bachelor programmes. English Studies and Sociology were added to include two cases from each faculty.

Faculty	Educational programme (Acronym)	Additional information
Humanities	Communication and Digital Media (CDM) English Studies* (ES)	**Include electoral part of education, teacher training*
Social Sciences	Sociology (SC) Organisational Learning (OL)	
Health	Biomechanical Engineering and Informatics (BIOM) Sports Science (SP)	
Engineering	Nanotechnology (NT) Energy Engineering (EE)	
IT & Design	Medialogy (MED) Internet Technology and Computer Engineering (ITC)	

The formal curriculum is organised in learning outcomes (LOs) for each subject in domains of knowledge, skills, and competences, showcasing ranges of understanding, declarative university knowledge, or relevant professional knowledge described by certain closed or open-ended verbs (Biggs, 1999). The concrete subject matter is not readily available in every curriculum, meaning the normative selection of 'what-knowledge-is-most-worth' characterising the selective tradition of the curriculum is only visible on a superficial level, at least from a non-disciplinary perspective. To qualify and justify the rationales for the actual selection of subject matter would require engagement from relevant staff and stakeholders considered outside the scope of this study.

The selected material can be considered as the institutional framing of the programmes. This points to a delimitation of the research, as it solely addresses the formal curriculum and intended LOs, and not how the formal curriculum is enacted.

The formal curricula are structured according to the Dublin Descriptors with disciplinary and generic statements of expected achievements in elements of knowledge and understanding, application of knowledge and understanding, making judgments, communication skills, and learning skills (Bologna Working Group on Qualifications Frameworks, 2005). These elements have in the Danish National Qualification Framework found a stricter and more vocational oriented translation (Sarauw, 2011), summarised in 'knowledge and understanding', 'skills', and 'competences.' Each is defined by specific qualifiers such as: a knowledge field, level of understanding and reflection, types of skills, levels of decision-making, communication, action space, and learning and metacognitive abilities.

Methodological Considerations for Content Analysis of Curricula

The direction of the analysis of formal curricula in this study is set by the aforementioned descriptions of PBL competences and analysed by applying a directed content analysis (Hsieh & Shannon, 2005) informed by the framework developed by Krippendorff (2004) depicted in figure 2. Thus, the content analysis, defined as *'a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use'* (p. 18) is scaffolded with five elements aiming to add transparency to the research.

Figure 2. Outline of Krippendorff's (2004) methodological framework.

In this directed content analysis, the body of text has already been selected and described in the previous section, namely the formal curricula of ten bachelor programmes.

Selecting generic descriptions of PBL may result in coding excerpts where PBL is somewhat decontextualised and removed from the professional domain. This poses certain challenges of a directed content analysis, in particular since we anticipate that exemplary and authentic problems closely ties PBL to a professional practice, stressing the importance of supervisors continuously making students aware of transversal competences obtained through the project work, a process that can prove difficult for some students (Kolmos et al., 2008). However, since knowledge transfer between courses and projects cannot be expected for all students, formulations of LOs relating to a specific professional domain are omitted for the purpose of this particular content analysis.

The context in which the documents are analysed follows the rationales of LOs, mainly the student-centred argument and change in locus of control (Bologna Working Group on Qualifications Frameworks, 2005; González & Wageneer, 2003). This situates the documents as 'actors' in a formal educational setting. At AAU, the practice of PBL is both one of canonical knowledge and theory and project-oriented group work. Students engage in group work for half of their study (Kjersdam & Enemark, 1994), meaning that many learning activities are constructed by students and thus hidden and not easily captured in a formal curriculum. How students interpret, translate and enact a formal curriculum during their study is unknown, thus the authority attributed to the documents by students is undetermined.

According to Krippendorff (2004) analytical constructs '*take the form of more or less complex "if-then" statements*' (p. 35). Practically this means that in this directed content analysis, *if* an LO addresses the development of one of the four PBL competences, *then* the LO is coded in NVivo in the corresponding category as illustrated in figure 3 visualising the coding tree. In some cases, more than one LO is stated in one string:

'*to design and reflect on problem-based project work*' (Communication and Digital Media (CDM), authors' translation).

The LO above contains both design and reflection. The student must be able to design project-based work, but it is not stated if the design addresses processes or content. Similarly, it is not clear whether 'reflection on project-based' work entails the work conducted in its totality or its constituting parts, or with what intention. For the sake of simplicity, an LO like the one presented above was coded as a structural and a meta-cognitive competence (reflection).

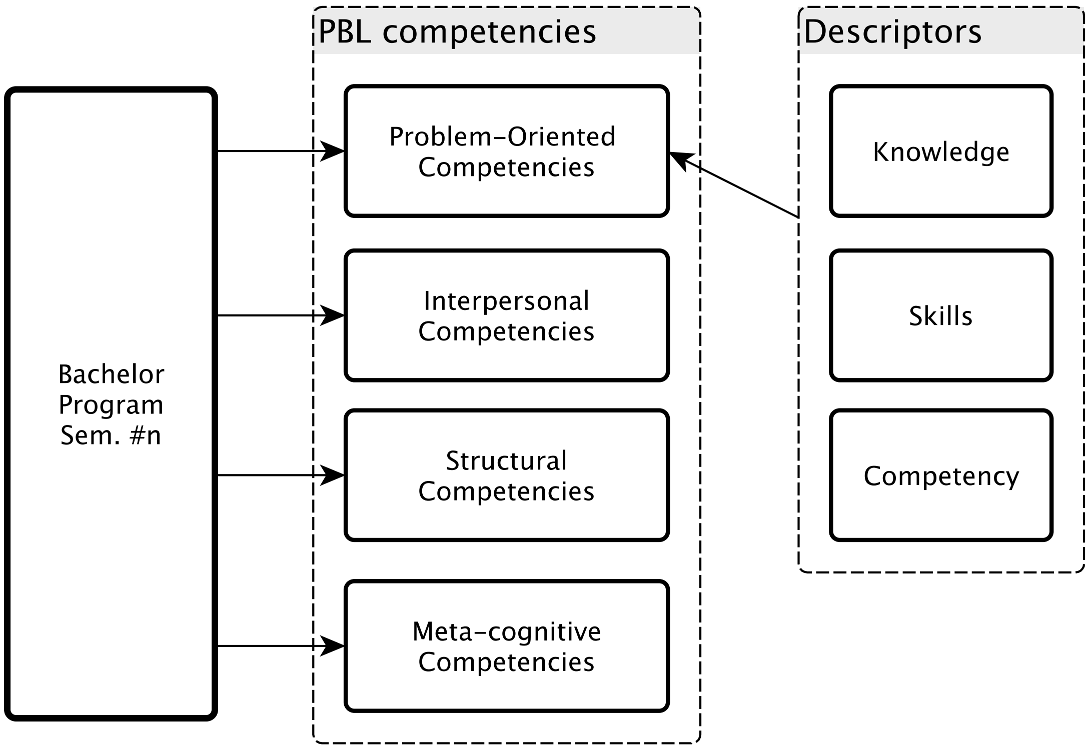

Figure 3. The coding tree for the coding and categorisation of LOs in NVivo informed by the 4 PBL competence domains and their descriptor knowledge, skills or competences.

Practically, if an LO is stated under the descriptor 'Skills' in the formal curriculum, it is coded in the competence domain related to the:

'*Explain problem-based study and the AAU model of PO PBL*' MED (2017)

The LO is stated under the descriptor 'Knowledge' and coded in 'Knowledge' (child node) ← 'Problem-Oriented Competences' (child node) ← '1. Semester' (parent node). This process has been repeated for all nodes.

FINDINGS

The content analysis of the formal curricula shows that the total presence of LOs addressing the development of PBL competences is present primarily in the first semester. This includes all four competence domains of PBL competences and descriptors. Consequently, the dialectic relation of theoretical knowledge and practice constituting PBL competences ends rather abruptly. While projects still account for roughly half of the time spent studying, students are dependent on researching on their own initiative or inputs from supervisors or other teaching staff to supply the theoretical dimensions of PBL to the more practice-oriented group work (Kolmos et al., 2008).

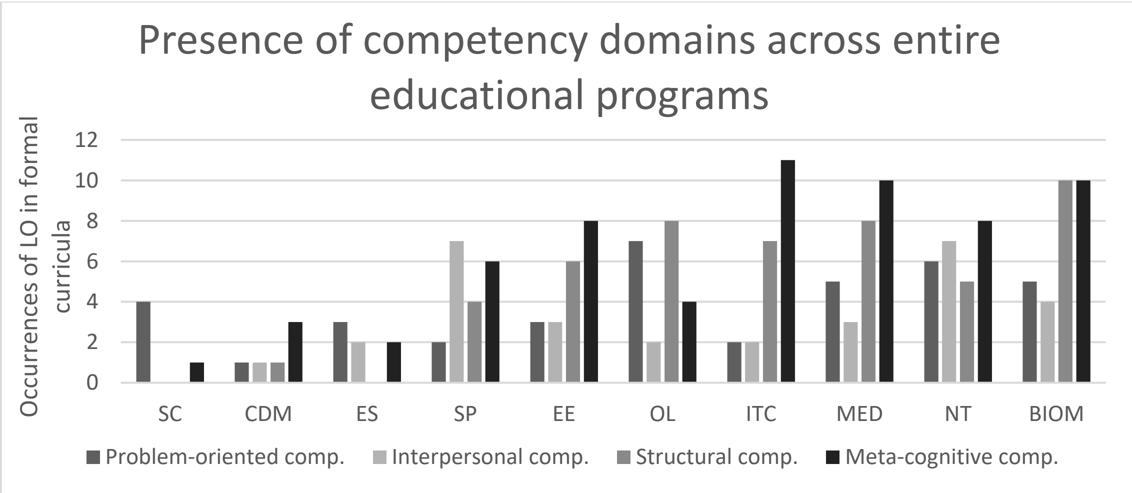

Figure 4. Presence of LOs supporting the development of PBL competences through entire educational programmes.

Figure 4 illustrates the frequency with which the four competence domains (problem-oriented, interpersonal, structural, and meta-cognitive competence) are included in the formal curricula through the entire programme of each selected case. This initial analysis shows great variations in prevalence of PBL competence-related LOs both across programmes and in between competence domains. The rationales behind this variation or the emphasis on one competence domain as opposed to others within individual programmes is not apparent from the formal curricula. There is great variation between educational programmes. Meta-cognitive competences are but one example of this, where they are mentioned two times in English Studies (ES) but eleven in Internet Technology and Computer Engineering (ITC). Another example is the problem-oriented competences, where ITC only mentions these twice in the curriculum, but seven times in the curriculum of Organisational Learning (OL).

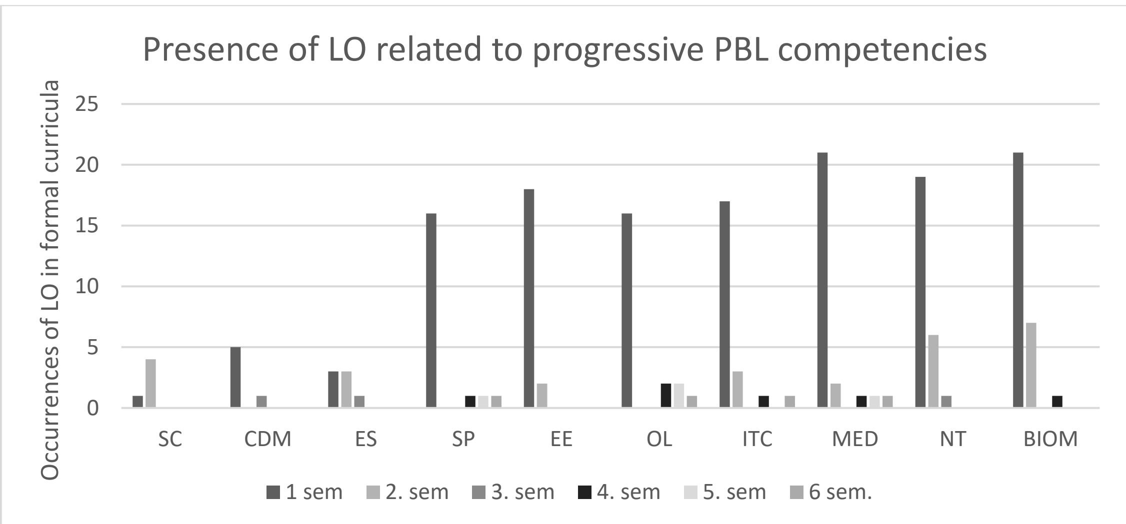

Figure 5. Presence of total LOs supporting the development of PBL competences through the semesters.

The chart presented in Figure 5 shows a rapid decrease in LOs supporting the development of PBL competences after the first semester. It also shows variation between some of the educational programmes, especially Sociology (SC), Communication and Digital Media (CDM), and ES (English Studies), compared to the rest. A possible explanation could be that in some programmes the introduction to PBL is part of introductory subjects of the particular academic discipline, meaning that the expected generic outcomes can be intertwined in existing courses in later semesters. Other educational programmes have a stand-alone subject introducing PBL to new students. These are also the programmes with the highest presence of LOs. However, Figure 4 shows little evidence of progression of the relevant LOs in any of the curricula.

Competence Domain	Descriptor	Themes of LO's from Formal Curricula
Problem-Oriented Competences	Knowledge	*Outline different approaches to problem-based learning, including the AAU PBL model and problem-oriented methodology (*BIOM, CDM, EE, ES, ITC, MED, NT, OL, SP)
	Skills	*Conduct a problem-analysis and compose a problem formulation* (BIOM, EE, MED, OL) *Define the goal of project work and develop a strategy for problem-solving* (NT, OL)
	Competence	*Formulate a problem formulation within a theme* (OL)
Interpersonal Competences	Skills	*Organise short term group work and collaboration with supervisor* (BIOM, MED, SP) *Analyse and reflect on causes and potential solutions to potential conflicts within the group* (BIOM, ITC, MED, NT, SP)
	Competence	*Participate in group-based project work* (BIOM, CDM, EE, ES, MED, NT, OL, SP)
Structural Competences	Knowledge	*Knowledge of work processes in problem-based project work* (BIOM, EE, ITC, MED, NT, OL, SP) *Explain techniques for planning and managing project work* (BIOM, EE, ITC, MED, NT, OL, SP)
	Skills	*Can organise group work* (BIOM, EE, MED, OL, SP) *Apply concrete tools and principles for management of problem-based project work* (SP) *Reflect over causes and solutions to potential conflicts within the group* (EE)

	Competence	*Design and manage problem-based and project-oriented work* (BIOM, CDM, NT, OL)
Meta-cognitive Competences	Knowledge	*Explain basic individual and organisational learning processes* (BIOM, MED, OL)
	Skills	*Analyse individual learning process* (BIOM, EE, ITC, MED, NT, SP) *Analyse and identify the strengths and weaknesses of the project group's collaboration and suggest potential improvements* (BIOM, EE, MED) *Apply theories and methods supporting learning processes in problem-based project work* (SP)
	Competence	*Participation and optimisation of collaborative learning processes* (BIOM, CDM, EE, ITC, MED, NT, SP) *Can consciously reflect on individual learning* (BIOM, EE, ITC, MED, NT) *Analyse and reflect on individual learning process and learning 'needs'* (BIOM, CDM, EE, ITC, MED, NT, SP) *Reflect and evaluate individual experience of group work* (BIOM, CDM, EE, ITC, NT, SP) *Use PBL as a methodology for individual and others' learning* (OL)

Table 1. LOs supporting development of PBL competences in first semester.

In all of the competence domains, the three descriptors shown in table 1 depict a relation between knowledge, skills, and competence; however, when focusing on a particular education, some variation in the dialectic relation of theory and knowledge, skills, and competence emerges.

For instance, in the meta-cognitive domain, only Biomechanical Engineering and Informatics (BIOM) and Medialogy (MED) have LOs in all three descriptors, e.g. in *knowledge*, the students must be able to 'explain basic individual and organisational learning processes' implying students must have been introduced to theoretical knowledge of basic learning theory. In *skills*, the students must demonstrate the skills to apply the knowledge to analyse individual learning processes and the group's collaborative processes. Furthermore, in *competences,* the students are expected to participate in group work competently and reflect on individual and collective learning processes. The same is the case for the structural domain, where students in Biomechanical Engineering and Informatics (BIOM), Organisational Learning (OL), and Nanotechnology (NT) are expected to demonstrate knowledge of work processes and techniques for conducting group work, have the skills to organise group work, and the competences to design and manage problem-based project work.

Competence Domain	Descriptor	Themes of LOs from Formal Curricula
Problem-Oriented Competences	Skills	*Be able to critically evaluate knowledge, models, and theories used to analyse a problem* (EE, NT, SC) *Be able to break a problem in smaller constituents* (ITC)
	Competence	*Analyse the problem domain* (BIOM, MED) *Assess the relevance of collected information in relation to project* (BIOM)
Interpersonal Competences	Competence	*Be able to participate in collaborative group work* (ES, NT)
Structural Competences	Skills	*Plan and manage project work* (BIOM, NT) *Apply a method to organise the project work* (NT)
	Competence	*Independently manage lengthy project work* (BIOM) *Analyse the organisation of group work* (BIOM) *Plan, manage, and reflect on project work for future course of study* (EE, MED)
Meta-cognitive Competences	Skills	*Analyse individual learning process* (NT) *Analyse individual learning process using relevant analytical models and experiences from P0 and P1* (ITC)
	Competence	*Analyse individual learning process* (BIOM) *Independently develop competences* (ES) *Reflect on cause and potential solutions for problems in the project group* (BIOM) *Reflect on experiences of project work and problem-solving* (NT) *Generalise and reflect on experiences of project management and collaboration for future course of study* (ITC)

Table 2. LOs supporting development of PBL competences on the second semester.

Table 2 shows macro level LO for the second semester, and most notably the descriptor ‘knowledge’ is absent. This implies that students have not been presented with new theoretical knowledge on the four competence domains on this particular semester. The dialectic relation between theory and practice has thus become somewhat one-sided and completely dependent on the students’ own research into this area or the supervisor’s suggestion of resources in these domains. This is also seen in ‘Skills’ of the meta-cognitive domain where LOs e.g. from Internet Technology and Computer Engineering

(ITC) refers back to the project of the previous semester. However, ITC is also expecting the students to be able to use reflection of experience as a mean to anticipate possible directions for future project work.

Competence Domain	Descriptor	Themes of LOs from Formal Curricula
Interpersonal Competences	Competence	*Be able to participate in collaborative group work* (ES, NT)
Meta-cognitive Competences	Competence	*Independently develop competences* (ES)

Table 3. LOs supporting development of PBL competences on the third semester.

In table 3 summarising the third semester, only two categories were coded, both within a competence descriptor indicating that students are now expected to independently participate in group work and develop competences within a professional and disciplinary context, and, as with second semester, the knowledge descriptor remains absent.

Competence Domain	Descriptor	Themes of LOs from Formal Curricula
Interpersonal Competences	Competence	*Collaborate with others to develop and optimise situations for learning on an individual, group and organisational level* (BIOM, SP)
Structural Competences	Skills	*Apply methods for process- and project management* (OL) *Apply methods to transfer and implement knowledge* (OL)
Meta-cognitive Competences	Competence	*Recognise need and provide knowledge* (ITC)

Table 4. LOs supporting development of PBL competences on the fourth semester.

For the fourth semester, table 4 shows four educational programmes which have LOs relating to PBL competences, focusing particularly on the competence descriptor. Similar to the second and third semester, the dialectic relationship between knowledge and practice remains absent, with the risk that both knowledge, skills, and competences related to PBL become tacit and a-critical and might not be easily expressed and scrutinized potentially resulting in a-critical or habitual practice (Polanyi, 1972; Schön, 1983).

Similar patterns are observed for both the fifth (Table 5) and sixth (Table 6) semesters with fairly few explicated PBL-related LOs across the cases and although all four competence domains (problem-oriented, interpersonal, structural, and meta-cognitive) are represented by the competence descriptor, no new knowledge or skills are assessed in this final year of the bachelor programmes.

Competence Domain	Descriptor	Themes of LOs from Formal Curricula
Problem-Oriented Competences	Competence	*Reflect on the relation between research question and research design* (SP)
Interpersonal Competences	Competence	*Apply PBL as an approach for individual and others' learning* (OL)
Structural Competences	Competence	*Apply PBL as a method for planning and completion of scientific work* (OL)
Meta-cognitive Competences	Competence	*Independently continuously develop competences* (ES)

Table 5. LOs supporting development of PBL competences on the fifth semester.

Competence Domain	Descriptor	Themes of LOs from Formal Curricula
Problem-Oriented Competences	Competence	*Application of knowledge to real problems* (NT)
Interpersonal Competences	Competence	*Plan, structure, and manage a project* (ITC, MED)
Structural Competences	Competence	*Apply PBL as a method for planning and completion of scientific work* (OL)
Meta-cognitive Competences	Competence	*Identify individual learning gaps and structure learning in different learning environments* (OL)

Table 6. LOs supporting development of PBL competences on the sixth semester.

It is clear that the bulk of LOs addressing PBL competences are present in the first semester, limiting the temporal aspect in the descriptions of PBL competences and thus the possibilities of assessing progression throughout the educational stay at AAU. Furthermore, the knowledge dimension supporting particularly reflection on competence development quickly decreases after the first semester, with the risk that PBL practices and associated knowledge, skills, and competences become tacit. Based on this, Holgaard et al. (2019) suggest changing the traditional, standardised semester structure (15 ECTS project and three 5 ECTS courses) prevalent in most bachelor programmes and instead introduce variation with different types of problems, types of projects, and levels of complexity, supporting reflection through a greater diversity in the PBL learning experience (p. 7).

IMPLICATIONS AND FUTURE WORK

This paper presents findings from a cross-case curriculum study showing great variation in how and to which extent PBL competences are explicated in the formal curricula at AAU. The majority of learning objectives specifically addressing the development of

PBL competences are present in the first (and occasionally second) semester with only a few in the following semesters. This points to challenges and potentials for future curriculum development particularly with attention to domains and progression of ‘generic’ PBL competences throughout the educational stay at AAU. This article forms a baseline from which revised formal curricula can be compared to earlier renditions. Future research is needed to evaluate how the framework potentially can assist in integrating generic competences in formal PBL curricula.

The results showcase an issue in the dialectic relationship between theory and practice where the theoretical aspects of PBL are partly missing after the first semester. If the semester projects also follow a similar standard and structure throughout their educational stay, students may experience a stable practice without much variation. A consequence of this could be that PBL related knowledge, skills, and competences become un-reflected professional knowledge-in-action, where students are unable to describe and reflect upon the knowledge their actions reveal (Schön 1983). Following Polanyi (Polanyi, 1972, 1974), inarticulated knowledge is challenging to view from more than one perspective simultaneously, resulting in trial and error. Articulation allows us to assess, reflect and make inferences critically about what has come to as an 'external object' (1972, p. 16).

From a formal level, this means that the project supervisors are the primary resource for facilitating the theoretical reflection on variations in project work and group collaboration (Kolmos et al., 2008), unless group members initiate such a process on their own. With the lack of reciprocal exchange of theory and practice follows the risk that the PBL practice and obtained knowledge, skills, and competences become tacit, in which case experience alone determines actions during project work. Consequently, students are unable to explicitly communicate their PBL and project related competences. This is further buttressed by the traditional approach to projects supporting a stable practice for students with little variation in the semester projects, particularly at bachelor level. Based on this we argue that revision of the formal curricula must consider the practical turn after the first semester, supporting students with theoretical knowledge on PBL, project management, and group collaboration throughout the study to accommodate a greater variety in types of problems, projects, and complexity. This calls for further elaboration of the concept of progression in relation to problem-based learning and generic competence frameworks to ensure that progression is in fact integrated into the programme and not a mere matter of sprinkling learning outcomes scattered over the educational programme.

Furthermore, whereas a formal curriculum analysis at the programmatic level can inform the translation of a public policy nexus at an institutional level, the authoritative status of the curriculum remains uncertain, and research needs to be conducted on how students interpret and include PBL-related learning outcomes in their everyday PBL practice. If faculty and teachers ascribe more authority to the documents than students, revisions may not bring about the change needed. This notion aligns with Brooman, Darwent, and Pimor (2015), who invited students to participate in focus group interviews during the redesigning of a curriculum, helping to clarify and challenge researchers' approaches to curriculum development. In learning environments such as PBL, an invitation to student participation in the development of a curriculum would reignite the participatory and emancipatory components central to student-centeredness rather than only by learning outcomes.

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How Does an Industry-aligned Technology-rich Problem-based Learning (PBL) Model Influence Low-income and Native Hawaiian Student's STEM Career Interest?

Nahid Nariman *

ABSTRACT

The need to increase students interested in pursuing careers in science, technology, engineering, and mathematics (STEM) is growing. The current study delivers results of an Upward Bound program focused on advancing students' interest toward STEM fields and careers. Project STEMulate, funded by the National Science Foundation's ITEST program, used Problem-Based Learning (PBL) in challenging students to engage in solving hands-on, real-world authentic problems in their communities. Project STEMulate takes structured PBL one step further by collaborating with local STEM Industry Partners for contextual learning and STEM pipeline development. The results revealed a raised interest in STEM, and a correlation between: 1) students' career interest and their science ability and motivation, and 2) their Science Self-Efficacy and PBL ratings associated with their interest in STEM careers. These results highlight the significant potential of PBL instructional strategies to increase students' attitudes toward and interest in future STEM careers.

Keywords: Problem-Based Learning, STEM, Underrepresented Minority High School, Native Hawaiian Students, Science Self-Efficacy, Science Education, STEM Camps, Youth

INTRODUCTION

The goal of this three-year ITEST project (2017-2020), Project STEMulate, was to motivate and advance the interest, knowledge, and skills of underrepresented Native Hawaiians and low-income, first-generation college-bound students in STEM by providing technology-rich STEM curricula that actively engages them in real-world

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problem solving and learning. To achieve this next practice of PBL, the project focused on five key components: (1) adaptation, implementation, and testing of a technology-rich, problem-based high school STEM curriculum; (2) professional development and training of 27 teachers; (3) extension of learning through academic-year internships adhering to the PBL model; (4) formative and summative evaluation to refine curriculum; and (5) development of a STEM workforce pipeline. This paper reports on the second year of project's impact on its college-bound first generation Upward Bound students.

REVIEW OF LITERATURE

Whether or not the United States is still globally competitive in STEM fields has been a major concern. With the ever-growing concern for the future of the U.S. economy and workforce, and the short supply of STEM graduates (Johnson, 2018), attention is focused on increasing the number of K-12 students to complete their education with degrees in STEM fields and pursue a STEM career. Many researchers have found that fewer minorities entering STEM fields. In exploring the causes and searching for targeted interventions helpful in escalating student interest in STEM – particularly for minorities – many researchers have begun to examine the STEM pipeline. For the near future, increasing the number of students interested in STEM fields and retaining that interest until they have completed a STEM degree is the key. This exploration has encompassed the examination of an educational pathway that starts in early education, extends into college graduation with a STEM degree, and leads to a career in STEM. However, because of the progressive loss and dropout of capable students from STEM disciplines, many refer to this as a "leaky pipeline" (Dasgupta & Stout, 2014; Resmini, 2016; Van den Hurk, Meelissen, & Van Lagen, 2019).

The Significance of STEM Proficiency

After the Soviet Union launched Sputnik, the world's first space satellite, STEM became a major concern in the United States (Herman, 2019). Thus, during that time, the proposition of STEM education reform arose in response to the mounting risk for national security (Bybee, 2013). The decline in STEM proficiency had been reflected in U.S. students' math and science test scores since the 1980s in comparison to other industrialized countries, and in students' decreased desire for STEM subjects. The National Science Foundation (NSF, 2010) revealed that many academically capable students were not pursuing STEM majors. For example, from 1985-2009, although the number of college students doubled, the number of students graduating with a math or science degree increased by only 3%. According to the Programme for International Student Assessment (PISA), a global benchmark for measuring STEM proficiency in the world, U.S. 8th graders ranked 36th in math and 19th in science, out of 79 in 2018 (OECD, 2019). Many such concerns, and the overall low performance of U.S. students led to the conception and founding of many programs, policies, and grants offered by the National Science Foundation or the America Compete Act of 2007. Identifying and implementing effective educational interventions that enhance K-12 STEM education may be a way to increase the number of students interested in STEM majors and careers. All students should have opportunities to participate in formal and informal STEM learning that prepares them for post-secondary success. One recent survey of college students disclosed that 78% decided to pursue STEM-related majors and careers in high school, whereas only 21% indicated having made that decision earlier (Microsoft Corporation, 2011).

Underrepresentation of Minorities in STEM Fields

Women and minorities (such as African American, Hispanic American, Hawaiian and Pacific Islanders, low income, etc.) have been clearly underrepresented in STEM fields and careers (Conklin, 2015; Morrison, Roth-McDuffie & French, 2015). This setback has endured and created more difficulties given the current national needs. Research confirms there was a time when STEM careers were considered "nontraditional" for women and minorities, creating many barriers and a lack of support for these individuals in their pursuit of STEM careers (Betz & Hackett, 2006; Stout, Dasgupta, Hunsinger, & McManus, 2011; Walton & Cohen, 2007). Various concerns about the decline of U.S. students' interest in STEM have increased the level of national funding for schools and universities to explore best practices for increasing recruitment and retention of women, minorities, and low-income participants in STEM fields.

The Need for Increasing Interest in STEM

Research on the pipeline to STEM fields and careers indicates that early exposure to inquiry, reasoning, and problem-solving skills in STEM stimulates student learning and interest in pursuing an eventual STEM-related degree (Dejarnette, 2012). In search of an explanation for what ignites and retains students' interest in STEM, a number of varied programs have been envisioned and developed from K-12 to college and at the graduate level, and several have explored strategies for attracting students to STEM. Some programs (such as Project STEMulate) have been implemented through funding from federal agencies or corporate entities. Goals have been varied, covering a wide range of purposes such as assessing how to retain college students in their STEM field, how to motivate and encourage middle or high school students to enroll in STEM programs, or how to provide K-12 teachers with STEM education and professional development. Meanwhile, other researches (Mathers, Goktogen, Rankin, & Anderson, 2012) emphasized the hands-on experiences that will engage and inspire students toward STEM careers. Although some researchers emphasized an earlier start on the educational pathways toward STEM fields and have identified elementary school students as the best targets mainly because they have more time to build a superior competence in STEM

(Alumbaugh, 2015; Cantu, 2011; Isabelle & Valle, 2016), others have concentrated on middle and high school students (Tai, Liu, Maltese, & Fan, 2006). High school is a critical time for providing positive experiences that engage students in STEM activities since it is the time when they are beginning to consider possible career pathways (Hansen, 2011).

Toward STEM Literacy
STEM literacy is also seen as critical for personal decision making and living a productive and engaged life (NRC, 2011, p. 5). To become a productive and contributing members of today's society, all students must succeed in STEM (Ceballos, 2014; Lacey & Wright, 2009). Thus, to foster STEM interests in high school students, Beier and Rittmayer (2009) offered several recommendations in their review of motivational factors in STEM. The main recommendation was to create an open learning environment where: (1) students are in charge of and creating their own learning; (2) there are opportunities for hands-on learning in STEM for students to build their self-confidence; (3) students' achievement is recognized and valued; (4) influential others including students' parents and role models are involved to boost their perceptions; (5) the materials used are targeted to increase achievement, self-concept, and interest in STEM of both girls and boys; and (6) students are divided into small groups based on their STEM capability. These recommendations match with recommendations suggested for PBL. Some of the paths for motivating and encouraging more minorities and women into STEM include providing curricular and extra-curricular STEM-related opportunities to students in the form of after-school clubs, STEM schools, STEM Days or STEM Summer Camps.

PBL and STEM
Problem-Based Learning (PBL) is an instructional strategy that enhances student learning by integrating well with other disciplinary subjects, teaching students how to dig deeper, think analytically, and probe and solve problems (Hallermann, 2013). PBL encourages collaboration and working in teams. It involves "real-world tasks, builds 21st century 4 C's competencies, and has an open-ended question while emphasizing student independence and inquiry to create a product" (Larmer, 2013, p. 3). PBL, although developed in the medical field, is well suited for STEM learning with its emphasis on self-directed and student-centered learning, making it an appropriate instructional approach for the present project. The key components of PBL according to Barrows (1996) are: (1) learning is student centered; (2) learning occurs in small groups; (3) teachers are facilitators or guides; (4) problems form the original focus and stimulus for learning; (5) problems are a vehicle for development of problem-solving skills; and (6) new information is acquired through self-directed learning.

PBL engages students in research and inquiry, communication, collaboration, creativity, critical thinking, and team-work (Ertmer & Simons, 2006; Hmelo-Silver, 2004). It is a student-centered approach that supports the instructional demands for STEM education.

It is depicted as an instructional strategy consistent with the principles of constructivism, driven by stimulating, open-ended questions and collaborative learning (Nariman & Chrispeels, 2016). Learning in a PBL environment happens in small student groups where meaning is negotiated in a collaborative team setting (Barrows, 1996). In such an environment, the problem acts as an impetus for learning, and knowledge acquisition happens through self- and team-directed quests and questioning. The teacher's role is that of a facilitator, enabler, or activator, scaffolding learning instead of directing it (Fullan, 2013; Hattie, 2009). Active learners are engaged in authentic tasks and real-world problem-solving activities (Savery & Duffy, 1995). Students in a PBL environment retain information better and longer mainly because they are actively engaged in their learning.

PBL Effectiveness

PBL effects have been reviewed extensively. For example, PBL positively impacts self-efficacy and the confidence a person feels in STEM fields (Baran & Maskan, 2010); it activates students' intrinsic motivation, self-efficacy, and conceptual knowledge (Massa, Dischino, Donnelly, & Hanes, 2009); it enhances at-risk female middle school students' self-efficacy (Cerezo, 2015); it increases students' engagement and satisfaction in STEM subjects and makes students more interested in pursuing STEM careers (Baran & Maskan, 2010; Berk et al., 2014; Mergendoller, Maxwell, & Bellisimo, 2006); it encourages students to continue their coursework instead of dropping it (Dominguez & Jamie, 2010); and it enhances learning for socioeconomically disadvantaged and ethnically diverse students (Cuevas, Lee, Hart, & Deaktor, 2005; Lynch, Kuipers, Pyke, & Szesze, 2005). The latter is particularly relevant to the goals of Project STEMulate.

Meta-analyses findings indicate that PBL excels over traditional learning methods in teaching critical thinking, communication, collaboration, and applying knowledge to real-world situations (Darling-Hammond et al., 2009; Strobel & van Barneveld, 2009; Walker & Leary, 2009). Although PBL can be used with students of any age and skill level (Lockhart & Le Doux, 2005), results of several high school PBL studies indicate that PBL is equally or more effective than traditional instructional approaches (Mergendoller, Maxwell, & Bellisimo, 2006; Savery, 2006), especially for low-income students (Cuevas, Lee, Hart, & Deaktor, 2005; Gallagher & Gallagher, 2013). STEM-focused PBL summer programs also have been shown to increase STEM career aspirations (Zhe et al., 2010; Lam et al., 2005). The University of Akron Upward Bound Math-science (UBMS) program (a 6-week residential program with classes in math, science, and composition, similar to the UHMC UBMS program), changed from a lecture-based to inquiry-based approach (Lam et al., 2005). Over the following 5-year period, results showed significant increases in GPA, decreased anxiety towards math and science, and increased STEM self-efficacy. A majority of participants entered a STEM degree program following high school graduation.

STEM for Hawaiian Students

The National Science Foundation (2017) revealed that although the number of students in community college is on the rise in Hawai`i, students registered in STEM fields are still very low. Levine (2015) offers 10 hypotheses exploring causes for the lack of Pacific Islanders in STEM careers. However, he emphasizes that the problems begin long before students reach the college admittance level because roughly 40% of school children do not complete primary school, and only 20% graduate from high-school. Further complicating matters, students with Hawaiian ancestry have more economic barriers to education as presented in Hawai`i Papa O Ke Ao, a 2012 report to the University of Hawai`i Board of Regents (2012) and by Tran et al. (2010).

With the goal of raising Hawaiian students' interest in STEM, project STEMulate sets to create, implement, and evaluate an innovative and industry-aligned STEM curriculum explicitly designed for Native Hawaiian and other underrepresented, low-income, potential first- generation-to-college high school students. Prior researchers have pointed to the positive effects PBL summer camps have on raising students' interest in science and mathematics, and the likelihood they will pursue STEM-related college majors and careers (Han, Capraro, & Capraro, 2015; Han, Rosli, Capraro, & Capraro, 2014; Lou, Liu, Shih, & Tseng, 2011; Lou, Shih, Diez, & Tseng, 2011; Robinson, Dailey, Hughes, & Cotabish, 2014). Project STEMulate was adapted, implemented, and tested a PBL setting based on the successful Pacific Institute for the Mathematical Sciences Industrial Problem-Solving (PIMS) Workshop's postsecondary model.

This model provides for the basis of the 'next-practice' of PBL by creating an opportunity for students to learn about scientific methods and how to research and find solutions to genuine real-world problems that are relevant in their local community, and by fashioning a value for the PBL rating for each student that later will be correlated with the students' science ability and motivation, etc. through a regression analysis.

THEORETICAL FRAMEWORK

This research draws upon constructivism, a learning theory rooted in the work of John Dewey (1933/1998), Jean Piaget (1972), and Lev Vygotsky (1978, 1986). Constructivism advocates for learning to be an active process of knowledge construction, and not a passive memorization process. PBL is an instructional strategy that stimulates students by activating their prior knowledge. Students are then provided with opportunities to build new knowledge and to elaborate on their own knowledge (Schmidt, 1983). In PBL, a real-world, relevant problem starts the learning. Teamwork drives problem-solving, and in small groups, students brainstorm various solutions and decide which one will best help them solve the problem. Later, students engage in critical thinking and problem-solving to explain the phenomena at the root of the given problem (Schmidt & Moust, 1998). It is through group discussion and exploration of the problem that a link is created between previous and new knowledge. Therefore, the quality and relevance of problems presented to students and their lives is the key. The success of PBL relies on providing a problem that scientists and engineers might face in the real world (Lockhart & Le Doux, 2005). Larmer (2013) argues that the most powerful, engaging, and effective problems for students are those with the most real-world impacts. King, Newmann, and Carmichael (2009) also agree that PBL must have a real-world context and impact outside the classroom.

Another theory guiding this research is social cognitive career theory (SCCT) as articulated by Lent, Brown, & Hackett (1994), and driven from Bandura (1986). SCCT suggests that self-efficacy and interest play unique roles in career choice (Armstrong & Vogel, 2009; Betz & Borgen, 2010; Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010; Donnay & Borgen, 1999; Lent et al, 2010; Silvia, 2003; Tracey, 2010; Tracey & Hopkins, 2001). Individuals, according to SCCT, develop interest in activities in which they believe they can perform well. Furthermore, previous research has shown that self-efficacy is positively related to student academic performance, and self-efficacy in science impacts student selection of science-related activities that will both help them succeed in and maintain interest in science (Britner & Pajares 2006; Parker et al. 2014; Richardson et al. 2012). As a result, the personal, academic, and career goals which individuals set for themselves are consistent with their interest, their self-efficacy, and the outcomes they expect to achieve (Sheu et al., 2010). In other words, individuals develop interests primarily on the basis of their beliefs about their self-efficacy and their outcome expectations. If they believe that they can do something well, it encourages them to further partake in that activity. Thus, SCCT hypothesizes that career interests and personal goals involve a process that includes performance, self-efficacy, and outcome expectations.

METHOD

This study draws on a subset of data collected as part of a larger three-year project (NSF ITEST # 1657625). The impact of the project on students' career interests, attitudes, and motivation was assessed via a multi-method evaluation of various sources of data including: (1) the Career Interest Questionnaire (CIQ) (Tyler-Wood, Knezek, & Christensen, 2010); (2) surveys of all participants regarding science self-efficacy, and science motivation; and (3) a survey of students' reactions to and reflection about the PBL environment.

Context of the study

This study focused on high school students who participated in the five-week Upward Bound (UB) summer academy on three islands: Maui, Oahu, and the Big Island (Hilo) with 52% identifying as Native Hawaiian or Pacific Islander. UB program directors on each site identified students to participate in Project STEMulate with the goal of establishing a comparison group comprised of students who had a similar summer experience with traditional courses in math, science, and technical writing.

The aim of project STEMulate, following the PIMS model, is to create an alignment and mutually valuable link with the STEM-industry in Hawai`i. Each year, local STEM industry partners are invited to present one of their current real-world problems for students' teams to explore and resolve, and to present the results of their research back to the STEM industry partner at the end of the program. The problem presented to students in this study came from Hawai`i's EPSCoR (the Established Program to Stimulate Competitive Research) namely, its 'Ike Wai Project (from the Hawaiian words for knowledge and water)[1]. With the reduced rainfall in Hawai`i (18% over a 30-year period from 1978 to 2007); increased drought (75% of Hawai`i's land area was "Abnormally Dry" in 2013); the change in land use (for example half of Hawai`i's original watershed forests being destroyed), and increased global warming, Hawai`i is recognized to have entered a period of increased insecurity regarding its long-term water security (Hawai`i Community Foundation, 2019). Considering the issue of diminishing fresh water supply facing every island in Hawai`i, the 'Ike Wai mission is to ensure Hawai`i's future water security. Students were presented with recent concerns on the limits of Hawai`i long-term fresh water supply, and the need for understanding Hawaiian water sources. Students were encouraged to explore the topic, through research, offer solutions and present their solution to the STEM industry partners, UB administrator and instructors, and the project STEMulate team.

Procedure

For this mixed method study, multiple data sources were used to enhance data credibility (Creswell, Hanson, Plano Clark, & Morales, 2007; Yin, 2009, 2012). Survey data was collected, converted into Microsoft Excel files, then coded for input into SPSS 26.0 for further analysis such as correlation, confirmatory factor analysis, linear regression, multivariate regression, etc. To ensure confidentiality, each student was assigned a numerical ID.

Participants

In total, 116 students participated in the study. Fifty-eight students participated in Project STEMulate (the STEMulate group), and 58 students served as the comparison group. All students consented to participation in this study. Of STEMulate group, 65% were females and 20 35% males.

Interestingly, the majority of the student population (55%) considered themselves a mix of two or more races. Of those who only selected one race to identify themselves, 29% selected Asian and 9% considered themselves Native Hawaiian/Hawaiian/Pacific Islander, with a small percentage selecting African American (1%), Caucasian (2%), or Hispanic (4%).

		Ethnicity
	Asian	29%
	Native Hawaiian/Pacific Islander	9%
	Hispanic	4%
	Caucasian	2%
	Black/African	1%
	2 or more races	55%
Total		100%

Table 1. Participants' Ethnicity.

The participants ranged in age from 13-19 where 26% of them were 15 years old. The UB program is offered to students from rising 9th to rising 12th grade. Thirty-seven percent of the participants were in rising 9th and 12th grade.

Research Questions

The project's goals were to: (1) determine if an industry-aligned, technology-rich STEM PBL curriculum model that is adapted for diverse and underrepresented populations can effectively stimulate STEM interest and learning for today's high school students, and lead to productive participation in the STEM-related workforce of the future; (2) advance knowledge into the experiences that engage and prepare students for the 21st century; and (3) develop a STEM workforce pipeline. Specific research questions were as follows:

RQ1. Could an industry-aligned, technology-rich STEM PBL curriculum model raise STEM interest in high school students?

RQ2: Is there any correlation between students' perception of PBL and their Science Self-Efficacy (SSE), and Science Motivation (SM) ratings?

RQ3: Is there any correlation between Career Interest (SCI) and their Science Self-Efficacy and motivation?

RQ4: Is there a relationship between students' PBL rating and their desire for STEM careers (SD)?

Measures and Instruments

Five different measures were used in this study. This included surveys on science self-efficacy, science motivation, STEM career interest, STEM career desire, and perceptions of PBL. The selection of these measures was based on earlier reviews of the effects and impacts of these measures. All the measures used are listed in Table 2.

	T1	T2
Science Self-Efficacy (SSE)	Yes	Yes
Science Motivation (SM)	Yes	Yes
STEM Career Interest (SCI) Perceptions of PBL (PPBL)	Yes	Yes
STEM Desire (SD)	Yes	Yes

Table 2. Common and Unique Scales Used at Time 1 (T1) and Time 2 (T2).

Science Self-Efficacy (SSE). The overall scales average is derived from a 7-item scale defining students' self-confidence in their science abilities and skills. Science efficacy items were partially adapted from the STEM Career Interest Survey, Science Section (Kier, Blanchard, Osborne, & Albert, 2013). Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree." The science efficacy scale achieved high internal consistency in both pre and post (Pre $\propto = 0.74$; Post $\propto = 0.81$). This scale consisted of items such as "I like my science classes," and "I complete my science homework."

Science Motivation (SM). The overall scales average is derived from a 4-item scale defining students' motivation toward learning science. Science motivation items were adapted from the ROSE Questionnaire (Schreiner & Sjøberg, 2004). Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree" and achieved high internal consistency in both pre and post (Pre $\propto = 0.81$; Post $\propto = 0.83$). This scale consisted of items such as "learning science in a real-life context is stimulating," and "learning science has made me more critical."

STEM Career Interest (SCI). The overall scales average is derived from a 12-item scale defining students' career interest. For this scale, the Career Interest Questionnaire (CIQ) (Tyler-Wood, Knezek, & Christensen, 2010) was adopted. Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree" and achieved high internal consistency in both pre and post (Pre $\propto = 0.91$; Post $\propto = 0.94$). This scale consisted of items such as "I would enjoy a career in science," and "I will make it into a good college and major in an area needed for a career in science."

Desire for STEM Career (SD). An SD score was created to capture students' desire and willingness on attaining STEM careers. Students were presented with 11 items related to STEM careers. Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree" and achieved high internal consistency in both pre and post (Pre ∝= 0.84; Post ∝= 0.90). This scale consisted of items such as "school science has improved my decision-making," and "I would like to get a job in technology."

Perceptions of PBL (PPBL). This scale was adapted from the LaForce, Noble, and Blackwell (2017) scale. This was a 9-item scale that was only asked of the STEMulate group at the end of the summer program. Each item was measured on a 5-point Likert scale anchored by "never" and "always." It achieved a high internal consistency (∝= 0.996), and consisted of the items such as "the STEMulate course made us do research to look for background information," and "it was relevant to our daily lives."

Data Analysis

Rios-Aguilar (2014) framework for the critical quantitative scholarship provided the expanded structure for this study. The proposed framework is based on the premise principles that interact between research questions, theory, method/research practices, and policy/advocacy. In other words, Rios-Aguilar (2014) emphasized to go beyond developing research questions and pay closer attention to factors influencing research practices such as considering intentions about the uses of the study to advocate for equal opportunities for all students. For this study, selecting the multi-method evaluation to calculate and report the effect of this program on students, particularly underserved and underrepresented Hawaiian students provided outline for the implementation, data collection and analysis that could be used in the similar program implementation.

FINDINGS

In this section, the primary measures are taken to calculate, compare, and contrast students' STEM dispositions, science abilities and motivations. Descriptive statistics and general group mean trends were graphically represented when possible. In addition, linear regression and a few series of multivariate regression analysis were conducted to examine the association between student's perception of PBL, their STEM career aspiration, and their science ability and motivation. The results revealed that student ratings of PBL were associated with interest in pursuing a career in STEM. Results also highlighted the significant potential of PBL for increasing students' STEM attitudes and interest in future STEM careers. To determine the regression analysis, the first task was to calculate various scales used in this study and show their distributions.

Student Desire for STEM Career (SD)

Students' desire for STEM was measured after the intervention. On a scale of (1) Strongly disagree to (5) Strongly agree, those with low aspiration scale totals (0 through 3) were assigned an SD score of 0, and those with high aspiration scale totals (4 and 5) were assigned a SD score of 1. Figure 1, showing SD distribution, indicates that over 91% of the STEMulate group had a high aspiration for STEM careers compared to 78% of the comparison group (see Figure 1).

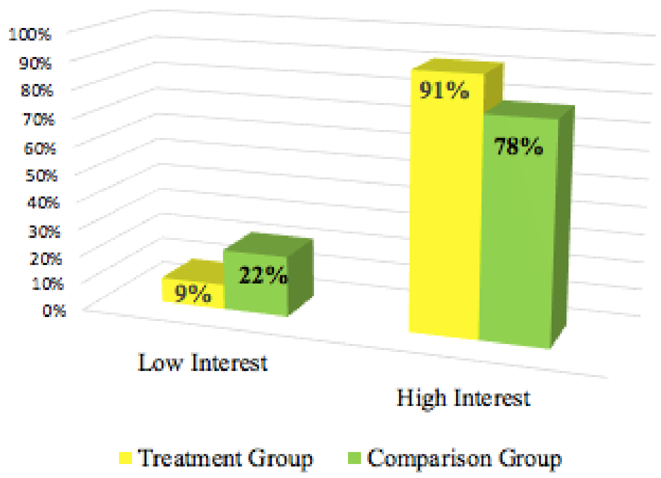

Figure 1. SD Distribution.

Student Science Self-Efficacy (SSE)

Students SSE was measured at the beginning and the end of the summer academy. On a scale of (1) Strongly disagree to (5) Strongly agree, those with low SSE scale totals (0 through 3) were assigned an SSE score of 1, and those with high SSE scale totals (4 and 5) were assigned an SD score of 5. Fig. 2 shows that the SSE scale ranged from Low to High. A confirmatory factor analysis of the measures in the SSE scale indicated that it was bidimensional and reliable, and the factor analysis was statistically significant (KMO = .780, $p < .001$). These results suggest that after the STEMulate, 38% of the STEMulate group had a relatively high SSE compared to only 21% of the comparison group.

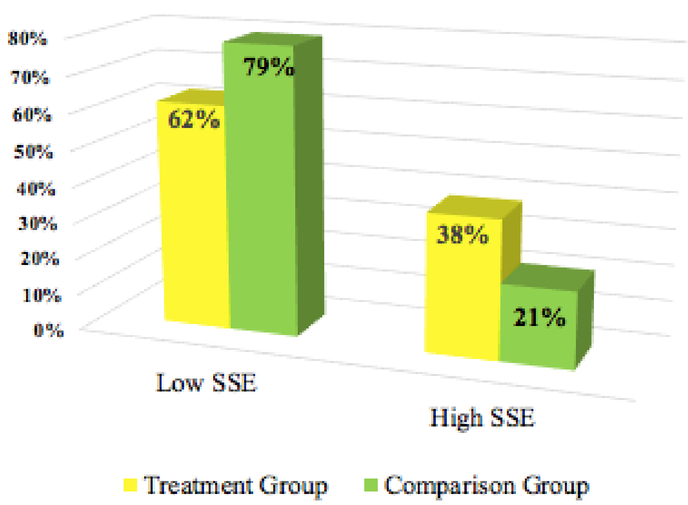

Figure 2. SSE Scale Distribution.

Student Science Motivation (SM)

Students SM was measured at the beginning and end of the summer academy. On a scale of (1) Strongly disagree to (5) Strongly agree, those with low SSE scale totals (0 through 3) were assigned an SSE score of 1, and those with high SSE scale totals (4 and 5) were assigned a SD score of 5. The distribution of the range of SM scale (Low to High) is shown in Fig. 3. A confirmatory factor analysis of the measures in the SM scale indicated that it was statistically significant (KMO = .808, $p < .001$). These results suggest that after the STEMulate, 45% of the STEMulate group had a relatively high SM compared to only 23% of the comparison group.

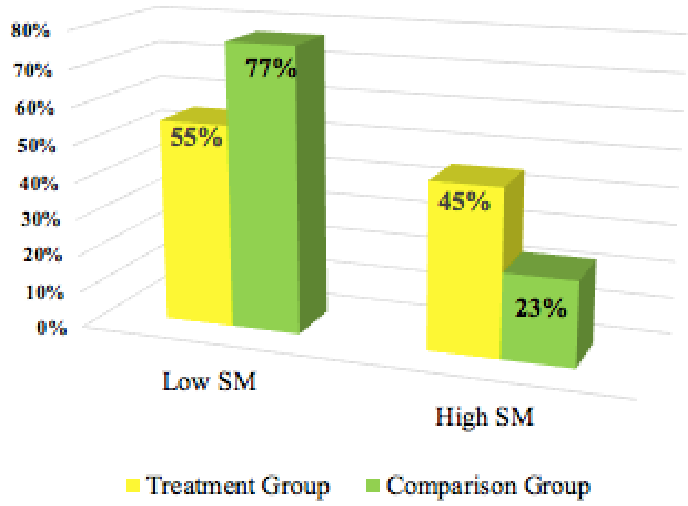

Figure 3. SM Scale Distribution.

The Perception of PBL (PPBL)

The 8 items of the perceptions of PBL were subjected to principal components analysis (PCA) using SPSS Version 26. Upon the completion of exploratory factor analyses (principal components analysis) with all 9 items loading at 0.4 or above, the results revealed this factor to account for 98% of the variance. The parallel analysis (O'Connor, 2000) also supported a one-factor solution. Thus, a one-factor scale ($\propto$= 0.996) average for the PBL rating was used in all analyses.

STEM Career Interest (SCI)

STEM Career Interest (SCI) has three subscales that measure student perception of a supportive environment for pursuing a career in science (Interest), their desire in pursuing educational opportunities that would lead to a career in science (Intent), and their perceived importance of a science career overall (Importance). A number of parallel analyses were conducted to determine the extent to which the SCI documents the effects of Project STEMulate on students' career attitudes. First, the internal consistency of the

SCI for the pre- and post-survey was calculated (see Table 3). The Cronbach's alpha for the pre- and post-surveys was reported for both STEMulate and comparison groups. The range of the Cronbach's alpha for this study was very high, .91 to .94 for both pre- and the post-survey data, compared to the Cronbach's alpha levels reported in the literature that ranged from .70 to .93. Nevertheless, although the internal consistency of the SCI subscales was higher than what was reported in the literature for the support and education subscale, it was very low for the career (Importance) at both pre and post.

		STEMulate Group	Comparison Group
Support (Interest) 3 Items	Pre	.88	.83
	Post	.89	.89
Education (Intent) 5 Items	Pre	.91	.93
	Post	.94	.94
Career (Importance) 4 Items	Pre	.53	.55
	Post	.92	.70
Total (12 Items)	Pre	.92	.91
	Post	.94	.94

Table 3. Internal Consistency Reliabilities for STEM Career Interest Subscales at both Pre and Post Time.

The mean of the subscales (see Table 4) ranged from 2.94 to 4.18 across the subscales. Importance ratings were the highest of the three subscales for each group. Although the comparison group showed a higher mean at all the subscales for the pre-data, their average dropped on the post-data. For both groups, higher Intent is provided compared to Interest ratings. Although the comparison group provided slightly higher ratings than the STEMulate group in all the subscales of the pre-survey, the STEMulate group had a higher rating in all the post subscales.

		STEMulate Group		Comparison Group	
		M	SD	M	SD
Support (Interest)	Pre	3.09	1.14	3.19	1.06
	Post	3.13	1.19	2.94	1.13
Education (Intent)	Pre	3.14	1.10	3.29	1.14
	Post	3.25	1.19	3.05	1.15
Career (Importance)	Pre	4.05	0.63	4.11	0.65
	Post	4.18	0.66	3.96	0.80

Table 4. Means and Standard Deviations for Pre-Post SCI subscale scores by Groups.

Second, was a traditional pre-post analysis to document whether students' career attitudes improved as a result of Project STEMulate. Repeated-measures ANOVAs were conducted to determine the impact of the program on STEM career attitudes. The within-subjects factor was average SCI score at two levels (pre and post). The repeated-measures ANOVA for the STEMulate group was not significant (Wilks K = .970, $F(1, 42) = 1.288$, p = .26, partial η^2 = .03). The repeated- measures ANOVA was also not significant for the comparison group (Wilks K = .977, F (1, 36) = .855, p = .361, partial η^2 = .023). SCI was a useful tool to provide empirical evidence in documenting the impact of the technology-enhanced program of Project STEMulate program, particularly with regard to intent to pursue a STEM career.

RESULTS

The first research question (RQ1) explored the correlation between the perception of PBL, Science Self-Efficacy (SSE), and Science Motivation (SM). As Table 5 displays, there is a high positive statistical correlation between SSE and SM, *r* (116) = .77, p <.001. There is a positive and significant correlation between SD and SSE, *r* (162) = .69, p <.001. Findings showed a positive and significant correlation between SD and SM, *r* (112) = .73, p <.001, and another positive and significant correlation between SD and SCI, *r* (112) = .71, p <.001. Furthermore, PPBL shows minor significant correlation with SSE and SCI.

	SM	SSE	SCI	PPBL	SD
SM	1				
SSE	.77**	1			
SCI	.79**	.79**	1		
PPBL	-.20*	-.16	-.19*	1	
SD	.73**	.69**	.71**	-.20*	1

*p < .05. **p < .01 (2-tailed)

Table 5. Students Science Self-Efficacy, Science Motivation, STEM Career Interest, Perceptions of PBL, and STEM Career Desire: Correlations and Descriptive Statistics (N = 116).

The results of the above analysis support RQ2, indicating that an industry-aligned, technology-rich STEM PBL model raised students' career interests. To determine whether SSE and SM were correlated with career interest (SCI) (RQ3) a simple linear regression was calculated.

Science Self-Efficacy. A simple linear regression was calculated to predict SCI based on SSE. The results, F (1, 114) = 187.04, p <.001, were found to be significant with an adjusted R^2 = .618.

Science Motivation. A simple linear regression between students' SM and SCI. The results, F (1, 114) = 191.36, *p* <.001, were significant with an adjusted R^2 = .623.

These results from initial regression analyses supported RQ3, indicating that students' SSE and SM significantly predicted their interest in pursuing a STEM career (p < .001). The overall saturated model explained 62% of the variance in students' SCI. In other words, industry-aligned, technology-rich STEM PBL curriculum model raised STEM interest in high school students.

Research question (RQ4) explored the relationship between students' perception of PBL rating and their desire for STEM careers (SD).

STEM Career Interest. A simple linear regression was calculated to predict students' career interest based on their perceptions of PBL rating. A significant regression equation was found, F (1, 55) = 6.229, *p* = .016, with an adjusted R^2 = .085.

STEM Desire. A univariate analysis of variance was conducted on students' SD. The STEMulate group scored significantly higher than the comparison group (STEMulate M = 3.72, SD =.76, Comparison M = 3.47, SD = .66), F (1, 147) = 6.87, p = .010, η^2 = .0384. The effect size was small. These findings suggest that STEMulate participants had significantly greater STEM aspiration than the comparison group.

The results from the analysis of variance (ANOVA) on students' SD suggested that STEMulate groups had a significantly greater STEM aspiration and the simple linear regression analyses supported RQ4, indicating that the STEMulate group students' perception of PBL rating significantly predicted their interest in pursuing a STEM career (p = .04). However, this affect was small as the overall saturated model explained only 8.5% of the variance in students' SCI.

Science Self-Efficacy, Career Interest, and STEM Desire

The initial regression analyses results indicated that students' ratings of PBL significantly predicted their aspiration in pursuing a STEM career (p < .001), and the association stayed significant even after controlling for science ability beliefs and intrinsic motivation (p = .007). With a multiple regression analysis, the overall regression model was significant, F (3, 53) = 65.13, p <.001, R^2 = .58. The overall saturated model explained 58% of the variance in students' STEM aspiration.

The Coefficient table shows the amount of unique variance that each variable brings. For example, from the table we can say that the amount of variance that SSE score accounts for, predicts, or explains, the SCI is unique to itself and is significant. i.e., SSE explains something that SM and PBL do not.

DISCUSSION

Learning does not simply happen by listening to the lectures in the classroom, rather by experiences students acquire upon active participation (Montessori, 1946). The results of this study align with constructivism. Promoting student's free exploration, constructivism upholds that students construct new understandings and knowledge, integrating with what they have previously learned, and thus for knowledge acquisition to happen through a process of action, reflection, and construction (Brau, 2020). The course environment and the PBL setting stimulated and activated students' prior knowledge and provided them with opportunities to take an active role in knowledge construction by exploring a real-world problem that was relevant to their lives. Many different criteria are essential for a good PBL problem. Although constructivism is not free of limitation, according to Jonassen (1993) it helps students to gain the highest complexity of knowledge possible.

A special feature of this study was for students to explore an authentic problem suggested by the STEM industry partner. Research shows that at high school, STEM industry involvement has enhanced student's engagement and interest in STEM careers for low-income, first-generation students. The alignment with the STEM industry in Hawai`i further provided opportunities for contextualizing knowledge by providing students with a real-world industry problem. Since the freshwater shortage problem given to students had the most real-world impacts, it was very engaging and geared students into action (Larmer, 2013). The problem was presented in a very simple format to match students' prior knowledge level while at the same time motivating them to further explore it. The PBL problem was suitable for analysis and further discussion and showed a clear connection to potential future professions. These criteria matched with four criteria suggested by Majoor et al. (1990) as vital considerations in constructing a problem. Also, it matched other criteria for clarity of its goal, as well as being open, relevant, and concrete (Schmidt, 1983).

Project STEMulate curriculum also aligned with Kim et al. (2006) who reviewed and synthesized the literature across various disciplines that pinpointed five main attributes of an effective PBL problem: the case should be realistic, instructional, engaging, relevant, and challenging. Additionally, Azer's (2007) criteria for generating trigger images for PBL were evident in the problem presented to students, because the problem was highly authentic, innovative, creative, engaging and was specifically chosen to guide students to STEM careers. These results offer solutions to challenges that the educational system is encountering, particularly in the United States. To deliver for a future STEM workforce, all students must be provided with opportunities that prepare them for the careers of the future.

The present study and its curricula demonstrate that the design for the near-future PBL settings needs to be completely student-centered with problems that are relevant to students' local living environment, realistic to their learning and the impact it can have on their living, while being challenging enough to provoke students to think differently when problem-solving so they can find out-of-the-box solutions. For example, with the value of fresh water for the islands of Hawai`i, it seemed imperative to bring students' focus to a relevant local problem.

> Fresh water is the lifeblood of society. As an island people, we inherently understand that the quantity and quality of available fresh water in our Islands directly impacts our health, our economy, our fisheries, our capacity for food production, the health of our native ecology, Native Hawaiian cultural practices, and other elements of our quality of life. However, recent findings have raised concern among scientists, farmers, and others about the long-term fresh water security of our Islands (Hawai`i Community Foundation, 2019).

It is also important that, at the same time, students are exposed to and learn from the local industry and companies that can inspire them to envision a similar future career for themselves. For a balanced planning of future PBL settings, a comprehensive understanding of the learners' motivation is needed to promote engagement in their learning, to foster the motivation to learn more deeply, and to support the workforce pipeline by informing instructors on guidelines for providing a motivationally supportive learning climate.

The Upward Bound program provided an ideal environment to research the effectiveness of industry-aligned PBL curriculum for low-income first-generation and geographically-isolated students. This program taught students how to be self-directed in their own learning while having access to three teachers who were ready to provide support and guidance. Also, by bringing students to the university campuses, this program exposed students to college student life. These findings align with those of Hutchins and Akos (2013) which indicated that geographically-isolated students face limited exposure to STEM careers. Involvement with STEM industries increased awareness and realistic expectations of local STEM opportunities (Hutson, Cooper, & Talbert, 2011).

Middle and high school students' career knowledge, interest, and intentions vary widely, with many factors influencing them. Some research shows that students start to make decisions about their future careers as early as middle school (Tai et al., 2006). In this study, factors under review were STEM career aspiration, science self-efficacy, and science motivation in a PBL environment. Present findings align with Compeau (2016), Nugent et al. (2015), and Zhang and Barnett (2015) which indicate that science self-efficacy and PBL are significant factors for high school students' aspiration of STEM careers. Research shows that the constructs of science ability beliefs and motivation are highly related to each other, as students who consider their learning outcome to be within their control tend to be more motivated (Bandura, 1997). This study's findings raised the understanding of the development of positive student attitudes toward future STEM careers. Prior research has demonstrated the significant role that motivation and ability beliefs play in student success (Tai et al., 2006; Wang, 2013). The impact has been depicted in many instructional approaches incorporated in educational systems (e.g., problem-based learning, social modeling, cooperative learning, social persuasion, motivational feedback, inquiry-based instruction, differentiation, etc.) and is strengthened by the results from our study.

The unique effect of PBL on STEM aspiration was statistically significant. In this study, PBL's direct effect on STEM career aspiration was observed even after controlling for STEM attitudes. As the findings suggest, higher PBL ratings predict higher aspiration for STEM. This is in alignment with findings from LaForce et al. (2017) regarding the importance of the quality and implementation of PBL.

To support development of a future STEM workforce, all students need to be provided with opportunities that prepare them for the careers of the future. The present study and its curricula demonstrated that the design for the near-future PBL settings highly benefits from being completely student-centered with problems that are relevant to students' local living environment (as supported by the constructivist practices) and realistic to their learning as seen in the results of the pre-post survey collected. Moreover, it can have an impact on their lifestyle and wellbeing through self-efficacy as it has increased and improved their science self-efficacy, and is challenging enough to provoke students to think differently when problem-solving so they can find out-of-the-box solutions.

This research was based on student self-reported data, but further research should collect data from other perspectives such as team members, facilitators, teachers, and mentors to triangulate all input for a more comprehensive understanding. Despite limitations of this study, the results exhibit a connection between student perceptions of PBL and their aspiration for future STEM careers. This result can go beyond the high school and secondary level as the preparation to increase and enhance the future STEM workforce is the main objective. Summer STEM activities are but one channel through which a future STEM workforce can be increased and enhanced. Given the benefits of creating a PBL environment where students can participate in hands-on learning and considering the number of students attending the summer STEM activities and camps, it is important to carefully plan summer activities that support students' self-directed learning and ultimately expand their interest in STEM careers. The findings on the qualities of PBL which support Hawaiian students' interest may be applied in any classroom whether it is during the regular school time or the summer programs.

Educational Importance of this Study

The significance of this study is how engagement in the PBL industry-aligned Project STEMulate helped underrepresented Native Hawaiian and/or socio-economically disadvantaged first-generation college-bound students to develop skills needed for success at the university and higher education. According to social cognitive career theory, self-efficacy and interest play unique roles in career choice. Students' science self-efficacy is positively related to their career interest. Students with higher self-efficacy showed a higher interest in STEM careers. The focus on a local-community problem presented by the STEM industry partner was the key. Hawaiian students pondered the problem of the limited supply of fresh water, an issue hitting home with many students, and they came up with real solutions that could actually help solve the problem. Those with a higher self-efficacy developed the belief that they could do something meaningful with a learned skill and this made their participation in the activity more profound. In other words, the SCCT hypothesis was confirmed. Students with higher self-efficacy performed better and saw STEM as a career option for them, where they would be able to succeed in setting goals and reaching for outcomes.

Practical significance of Project STEMulate surfaced in Year 1 when the UB directors utilized findings to introduce changes in their program. One major modification was to make Project STEMulate available to all UB students and not just for UB math and science students. The introduction and implementation of PBL, for example, has prompted UB directors to look beyond the scope of the 5-week summer camp. Therefore, now that Year 3 is also completed, the UB directors are considering ways to provide the PBL professional development to their future instructors and to keep that as part of their programs. In other words, Project STEMulate has provoked future exploration of innovative change in the UB program. This paper contributes to research on improving instructional practices and integration from a model of PBL like Project STEMulate as a way to facilitate deeper learning for students. It contributes to understanding classroom and instructional changes needed if students are to construct new knowledge.

Concluding Remarks

Prior research has clearly demonstrated the important role that motivation and ability beliefs play in student success. As supported by the literature, a PBL environment engages students in a process that supports their learning through enhanced critical thinking and the use of multiple modes of instruction (Loyens & Rikers, 2011). Project STEMulate set out to identify a coherent set of experiences that effectively and efficiently support student competency, motivation, and persistence to enter the STEM-related workforce. Findings suggest that industry-aligned technology-rich STEM PBL curricula can successfully build interest, motivation, and capacity for underrepresented high school, low-income, and geographically isolated students. By having students explore solutions to an industry-aligned problem, by going on field-trips that helped them understand the severity of the problem in their local area, and by presenting their solutions to the STEM industry partner, students developed an idea of productive participation in the STEM workforce and learned about the significance of various STEM careers. The outcomes establish a pipeline between underrepresented high school students, postsecondary education, and STEM employers. Also, more specifically, Project STEMulate created a team of university instructors, UB administrators and staff, local STEM industry partners, trained instructors and mentors, and the dynamics of this team contributed to the program effectiveness.

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[1] For more information on this industry STEM partner, please visit http://www.hawaii.edu/epscor/

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Fiddlers Green College: Looking for Equitable Workforce Pathways in Silicon Valley

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ABSTRACT

Often, research on the efficacy of postsecondary workforce programs does not convey their impact on true social mobility. The purpose of this study is to investigate project-based Career and Technical Education (CTE) workforce pathways in Silicon Valley.[1] *This study takes a step towards better understanding what constitutes the metrics that explain functioning pathways. In contributing to Project-Based Learning (PBL) theory, Amaral et al. (2015) found that seven PBL essentials form good learning outcomes; Creghan and Adair-Creghan (2015) then showed a measurable outcome of PBL is higher attendance, to which Plasman and Gottfried (2020), using a case of Applied STEM CTE (AS-CTE), framed attendance as a predictor of the efficacy of a workforce pathway. Recommendation: Through ethnography, the investigators observed that when social mobility was added as a metric of high quality PBL with AS-CTE in a predictive ontology framework of education success, an improved level of attendance was observed. The authors conclude that using the seven essentials and social mobility as a metric of PBL helps explain the observation of PBL's improved efficacy. Hence, social mobility should be a metric of PBL AS-CTE program outcomes.*

Keywords: Social mobility, Career technical education, Workforce pathways, Equity, Virtual design and construction

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Although Silicon Valley, California is one of the most technologically advanced regions in the world, entire groups of people are pushed to the margins and prevented from partaking in the fruits of this prosperity. Just as tech draws the best and brightest from all over the world, so too do technical trades taught in the workforce postsecondary Career Technical Education (CTE).[2] There is a call for highly skilled workers in the San José region to construct the many massive mixed-use development projects.

Through ethnographies as postsecondary Applied STEM CTE (AS-CTE) instructors teaching those highly skilled workers – using Project-Based Learning (PBL) – the investigators observed that many students fall short of their goal of social mobility to high-skill, high-wage jobs. These findings necessitate further inquiry and a social mobility metric to address a lack of student matriculation into the highly skilled workforce and further problematize the use of innovative PBL pedagogies as the sole means of fostering social mobility. Our ethnographies have found that efficient PBL pedagogy alone will not provide equitable social mobility and that in order to move our PBL pedagogies to the future, theorists must first acknowledge the larger systems that need to be interrogated and redefine success through more precise metrics such as our proposed social-mobility metric. This paper is a distress call reminding our colleagues that in order to move forward and into the future, PBL practitioners and theorists must acknowledge large systemic barriers in order to ensure efficacy and to include historically marginalized groups who have largely been left out of the fruits of these pedagogical practices to join us in a future created in part through a PBL driven equitable education.

Traditionally, technical trades were taught through apprentice programs, which often have trade-union-mentored, on-the-job project-based learning formats. Workforce education has taken many forms, and this research is attuned to the past exploitation and pain caused by non-union vocational education programs that targeted Black, Indigenous, and People of Color (BIPOC). These programs perpetuated social inequities through the economic surplus created from the exploited labor of marginalized people. These are examples of programs that do not provide social mobility. The investigators are not advocating for this form of vocational education, nor are the investigators advocating for a discounted ‘cheap’ labor force.

Problem statement: Current research on PBL and the efficacy of postsecondary workforce programs does not convey their impact on true social mobility. Although highly skilled workers are required to build Silicon Valley, that highly skilled workforce is now scarce. The investigators posit that a lack of observed social mobility is not due to low attendance or inferior pedagogy, but could be due to leaks in the education system. Research goal: The purpose of this study is to investigate the postsecondary PBL AS-CTE workforce pathways in Silicon Valley to understand what additional metrics help to explain the functioning pathways. This study is guided by two research questions: (a) What current metrics in literature explain functioning CTE education pathways; (b) What additional observable metric improves on explaining functioning CTE education pathways. In our ethnography, we uncover two very different postsecondary PBL pathways and propose a new metric of social mobility to be added to the framework of efficient PBL programs.

REVIEW OF POSTSECONDARY CTE SUCCESS METRICS

Applied STEM Career and Technical Education (AS-CTE) research often frames predictors of vocational education success through metrics like motivation (Lee & Stankov, 2018) and measures success in administrative qualities like leadership (Bartlett et al., 2018). Amaral et al. (2015) found that seven PBL essentials form good learning outcomes. Creghan and Adair-Creghan (2015) found that PBL resulted in higher attendance – a predictor of program completion as shown by Plasman and Gottfried (2020). To contribute to PBL theory, the investigators pull from underpinning concepts in AS-CTE as guides in the formalization of a framework that demonstrates an improvement in predictive performance for academic success – keeping the attendance contribution metric by Plasman and Gottfried in mind – over that last contributed by Creghan and Adair-Creghan.

Project-based Learning Strategies That Increase Program Completion and Attendance:

Creghan and Adair-Creghan (2015) found that school attendance rates of economically disadvantaged students increased when PBL strategies were used in the classroom. The demographics of the students in these findings were similar to those of the feeder schools and postsecondary schools in Silicon Valley. Both Creghan and Adair-Creghan (2015) and Plasman and Gottfried (2020) found that project-based education resulted in higher attendance (PBL and AS-CTE, respectively). They found that correlation with improved attendance was, therefore, a better predictor of academic success than previous frameworks using metrics such as motivation (Lee & Stankov, 2018). The investigators take the Plasman and Gottfried (2020) attendance framework as their point of departure.

Underpinning Concepts in AS-CTE Formalizations

In formalization development, the investigators pull from the following concepts: project-based learning, critique of workforce education, and historical views of certification in CTE.

Project-based Learning in Workforce Education: Silicon Valley CTE courses have undergone a paradigm shift, adopting progressive pedagogies which include PBL strategies. The feeder secondary school referenced later in this paper (under the 'Participants' header) is classified as an engineering education pathway, however, its classes differ from traditional secondary engineering courses in which students are often "singularly focused on a solution and not an iterative design process" (Hughes & Denson, 2021 p. 6). This pathway's engineering curricula leverage core concepts of Project Based Learning (Amaral et al., 2015; Guerra et al., 2017; Larmer & Mergendoller, 2010). Students chose an 'ill-structured problem'(Savery, 2015) and followed the seven PBL essentials originally laid out by Larmer and Mergendoller (2010) and were utilized by Amaral et al. (2015). These seven essentials state that the problem should have: (1) a need to know, (2) a driving question, (3) student voice and choice, (4) 21st-century skills, (5) inquiry and innovation, (6) undergo critique and revision, and (7) a public presentation. The authors come from a tradition of a workforce virtual design and construction courses where PBL projects are presented publicly to an expert panel (Frank & Fruchter, 2014; Fruchter & Courtier, 2011; Tarantino et al., 2016).

Critique of Workforce Education: Highly skilled labor and its pathways, commonly referred to as CTE or vocational education, are being rebranded to attract more students, especially women and students of color. The truth is that these pathways need rebranding because of their toxic history. Vocational institutions have exploited people in the United States (U.S.) for many years. The exploitation of indigenous youth is just one of many examples of this victimization (Lomawaima, 1996; Williams & Tracz, 2016). If, as a community, our goal is truly to fix the issues within workforce pathways, then there must be an acknowledgment of the historical tracking and exploitation of marginalized groups at the hands of these institutions. Many of these schools were created as a means for proletarization. In vocational education, proletarization and external labor are personified in high-tech manufacturing industries where exploited workers labor on or with commodities that are beyond their financial reach. With the rebranding of high-tech CTE in fields such as cybersecurity, software, and coding, a new vocational education era begins: one that is looking to exploit high-tech workers. Furthermore, there is a new inclusion of exploited affective labor careers (Hardt, 1999) where there is a discontinuity in the wage and the labor produced, such as teaching and nursing, in CTE (Vora, 2015). With the 2020 global COVID-19 pandemic, the affective toll that nurses and other caregivers face is a result of a mismatch in the fungibility of wage and labor prices. These mismatches exist by design and are felt more severely by marginalized workers.

Historical Views of CTE Certifications: The mission of the workforce education system is to develop human capital. In the U.S., this mission falls to the community college system: 40 percent of U.S. undergraduates are educated at a community college (Budd, 2018). Those colleges focus on certifications that categorize workers into different classifications of value. Groeger (2017) saw that craft employers view education as a metric of human capital value. The investigators are acutely aware of the origins of vocational education and the role of certifications rooted in human capital. While the authors are aware of this framing, we do not aim to view this study through the lens of human capital theory. Groeger (2021) further problematized human capital theory with her critique of credentialism, where she questions the actualization of human capital benefits. Informed by the underpinning concepts of human capital and credentialism, we look for a path forward which we posit will more accurately measure success through social mobility and reentry to the academy of higher education and the workforce.

Using a critical lens to view our CTE history, the investigators entered ethnographies of the Silicon Valley postsecondary AS-CTE education centers to develop and teach a PBL AS-CTE course. Through these ethnographies, the authors propose adding social mobility as a success metric of postsecondary AS-CTE pathways.

RESEARCH METHODOLOGY

Experiment Setting

The investigators studied social mobility through ethnography (Hartmann et al., 2009) and case study examples gained through a community-based participatory research approach (CBPR) (Amaral et al., 2018; Minkler & Wallerstein, 2011). In our methodological approach, we do not try to fit an objective ideal of an imagined perfect reality into our observations (Kliewer et al., 2004; Montoya et al., 2020). Rather, we seek to understand a pragmatic reality, and then to explain that reality and apply the explanation in a useful way (Bernstein, 2013). The ethnography was taken via the investigators' roles as classroom instructors in several postsecondary educational settings using project-based learning (PBL) in college, apprenticeship, and adult education settings: a situation in which PBL is suited for data collection (Fruchter & Townsend, 2003).

The investigators are further informed by their in-situ ethnography prior to attaining a university education, holding roles in the proletariat class of unskilled laborers. During years-long experience in those roles, each has been recognized by their fellow workers with a rank of 'lead' laborer in which they became responsible for mentoring new laborers. This lead role is required to help new laborers quickly learn to work safely and skillfully, as well as to pass on a tradition of knowledge in the class struggle for human rights.

The theory development is based on an ontology. In ontological theory development, the project follows a formalization of the framework, an application of that framework in a beneficial process, and finally an example of a practical implication of that process. This paper is focused on the formalization of the metric and framework.

Research-Practice Partnership

This study is part of a larger project (Montoya et al., 2020, 2018; Tarantino et al., 2016) which relies on the same Northern California Silicon Valley–based Research-Practice Partnership (RPP). Our RPP included educators and other community participants (i.e., union leadership, policymakers, business partners). Figure 1 depicts the numerous organizations which make up our RPP and together are known as the Santa Clara County Construction Careers Association (S4CA).[3] Our larger partnership includes four high schools, three community colleges (i.e., 2-year colleges), eight apprenticeship programs, an adult education program, and two universities (i.e., graduate and bachelor's degree–granting institutions). This paper focuses on postsecondary education institutions.

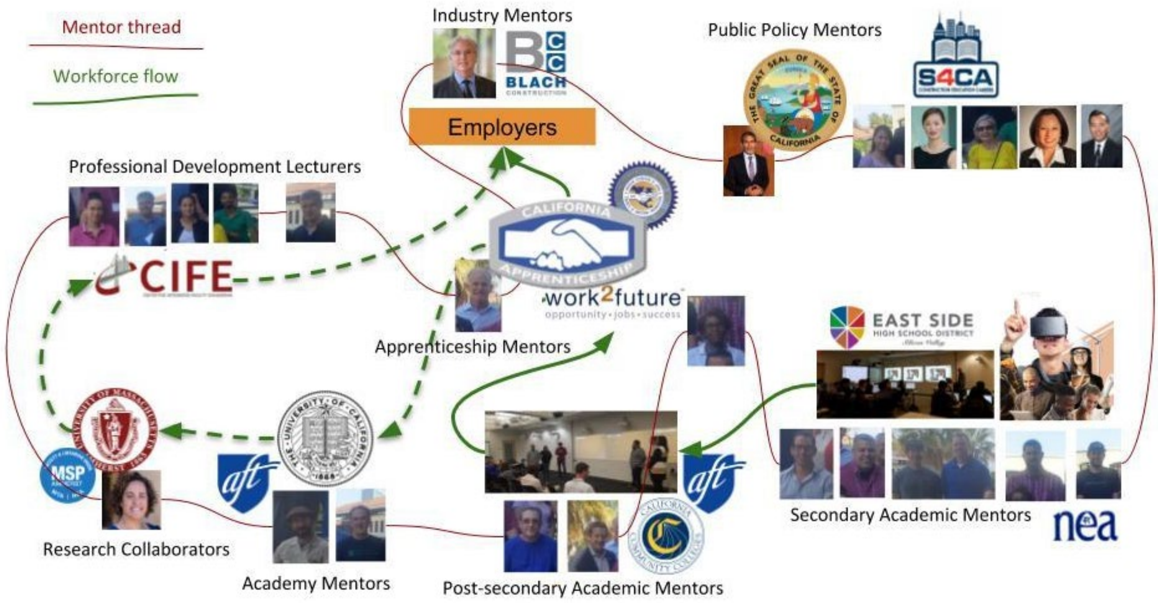

Figure 1. Research-Practice Partnership Network.

Note: An evolving network of community participants, researchers, and practitioners (adapted from Montoya et al., 2020; Tarantino et al., 2016). The participants represent each stop in the workforce pathway from education, to employment, to public policy, to labor standards oversight.

Participants

The study draws on data from students, instructors, and mentors. These participants come from two community colleges that we have collectively given the pseudonym Fiddlers Green College and an adult education center we call the Pipe Trades Education Center. The participants are from the tenth-largest city in the United States. This region's demographics are evenly divided between Latinx, Asian, and white: half of the homes in this city speak English as a second language.

The students reside in a lower-income working-class community whose feeder secondary schools are composed of 50 percent students who qualify for free and reduced-price meals. The region is industrial and its working communities suffer from a legacy of contaminants from industrial sites (Montoya et al., 2018; Pimentel, 2004; Schlanger, 2017; Stewart et al., 2014). Despite the racialized socially and environmentally unjust reality, the students are a high-performing and distinctly working-class demographic.

Sources of Data

This paper focuses on the researchers' roles as instructors in postsecondary classes, but is also informed by their dual-enrollment[4] course observations, informal interviews with interlocutors, and various meetings with the greater RPP to collect and analyze data for this study. Each of these individual categories is described in detail below, but see Table 1 for an overview of the data collected in this study.

Data Source	Overall
Observation/fieldnotes	182 days of practitioner fieldnotes
Postsecondary classroom observations	100 hours
Dual-enrollment course hours	50 hours
Informal interviews	20 interviews
Researcher meetings	40
S4CA meeting notes	4
Apprenticeship coordinators meeting notes	4

Table 1. Sources of Data.

Using an ethnographic action research method (Hartmann, et al., 2009), the authors leveraged their roles as instructors and researchers to gather various sources of data. The course takes a project-based learning format to teach virtual design and construction as an implementation of the PBL lab's Architecture Engineering and Construction (AEC) Global Teamwork course (Fruchter & Courtier, 2011; Fruchter & Townsend, 2003). The authors collected data using fieldnotes, student artifacts, and narrative ethnographic notes. Data were collected in the following settings: the postsecondary classroom, informal interviews, and formal meetings.

Postsecondary classroom observations were recorded through daily fieldnotes and ethnographic narratives by the two lead authors, who worked as instructors of two individual postsecondary courses. Fieldnotes were taken directly after courses were taught. The authors utilized an ethnographic narrative style often weaving in personal experience and observations of other courses. All of the quotes for this paper are from the first author's fieldnotes.

The investigators conducted informal interviews (Figure 2) with dozens of students, colleague researchers, and practitioners who are all part of the broader RPP and ethnography. The researchers also used these informal meetings to discuss the curriculum and do member checks and logic checks for interpretation of data analyses.

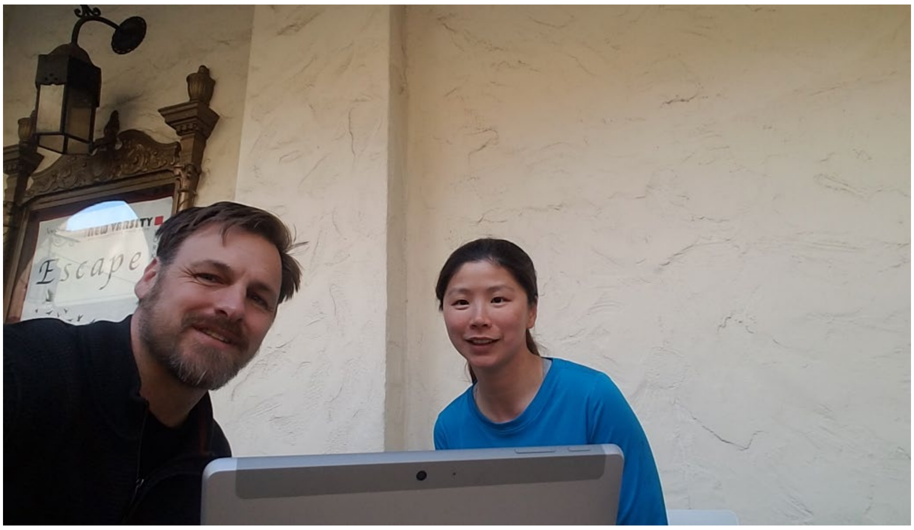

Figure 2. Researcher Meets with Journeywoman Pipefitter Aster for Interview.

Data Analysis

Through ethnographic participatory roles (i.e., as instructors), the authors analyzed and used inductive coding to identify key themes of social mobility and perceptions of social mobility. The lead authors met weekly throughout the course to discuss emerging themes.

Ethnographic Access

To gain access to ethnographic situations, the investigators relied on community-based participants. These participants come from an existing long-term and close collaboration with the Santa Clara County Construction Careers Association (S4CA). S4CA includes educators from community colleges and trade education centers as well as leaders from the academy, labor, industry, and public policy. Many of the S4CA participants overlap with two California Workforce Development Boards which are active in the study region: the North Valley Job Training Consortium (NOVA) and the San José–Silicon Valley Work2Future. The S4CA participants and the investigators of this study have collaborated on workforce education since 2012 and began publishing their findings in 2016.

ETHNOGRAPHY-INFORMED ADDITION OF A NEW METRIC

To address the forks and blocks in workforce pathways, the investigators explored the social mobility of these pathways through roles they took as associate faculty instructors at two local community colleges (Willis, 1977). The investigators define social mobility as students' perceptions that their workforce pathway can give them a career with a living wage and act as a pathway to a career or to higher education (Montoya et al., 2018). The AS-CTE course was an implementation of virtual design and construction curriculum with a social and environmental justice focus (Barg et al., 2020; Bick et al., 2021; Brosque et al., 2021; Fischer, 2006; Garcia-Lopez & Fischer, 2014; Montoya et al., 2018; Peng et al., 2021; Peterson et al., 2011; Song & Fischer, 2020; Tarantino et al., 2016; Tayag et al., 2021) taught through Project-based Learning (PBL), following the PBL Lab AEC course format (Fruchter & Courtier, 2011). The investigators experienced the AS-CTE programs from the inside. The fact that the investigators themselves had, years before, been students in these very same programs added a layer of depth. Further, the investigators worked as instructors and mentors in the secondary schools which act as feeders to these AS-CTE programs. This personal familiarity provides a layer of depth and perspective that allows investigators to connect with interlocutors in a unique way that allows for comfortable and authentic sharing. Thus, this study may not be replicable nor generalizable to other sites and populations. The investigators themselves are products of the investigated community. This experience allowed the investigators to interact with students at several stages of their school and career trajectories. To begin to explore the issues of social mobility, the following narrative will explore a case example of one student who is representative of many.

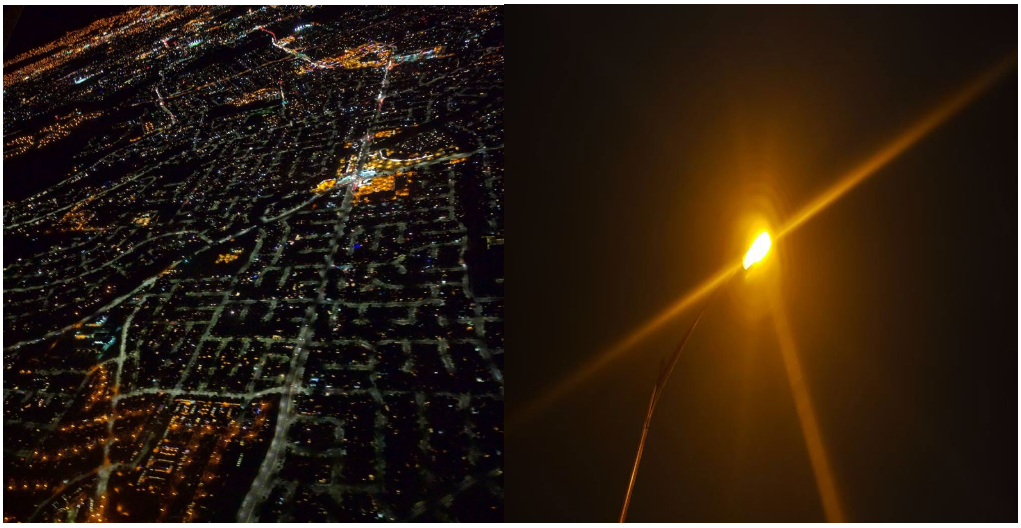

Figure 3. The Setting. Photos courtesy of Jason Brown. May he rest in peace.

Note: The setting of the ethnography often carried through the before- and after-class discussions in the early winter mornings under sodium lights pictured on the right. The *aerial view on the left shows the city's slow change to LEDs with pockets of sodium lights still in use. These lights will soon be phased out, reminding us of the fleeting temporality of this ethnography.*

The following is a first-person narrative account of the investigator's first encounter with a student at the postsecondary institution:

"The subtle orange glow of sodium lights greeted me as I walked onto campus for my first postsecondary faculty position. I arrived nearly an hour early, which, according to my grandfather, would be right on time. The only time he stood on a college campus was to work as a laborer. All of his technical skills were learned on the job.

Standing under those antiquated lights, I considered the differences between how my grandfather learned his trade and how my students are learning theirs. A dark figure approached, with every step revealing more of their face illuminated orange. In the youth's eyes, I saw myself, my grandfather, and my community. As we stood face-to-face, I recognized the figure as a former student from my secondary classroom years earlier. Having myself both worked as a laborer and studied at this institution, looking at the student was like looking into a mirror and a time capsule simultaneously. They smiled awkwardly and hesitated, wondering if I recognized them. I did then and have always been able to truly see my students."

This student was well into their twenties and would be categorized as high-performing, with near-flawless attendance in their secondary and postsecondary classrooms. Furthermore, they were a product of that secondary school's feeder CTE program, which in theory should be a functioning pathway for social mobility to both college and career.

Below, the instructor listened to the same student sharing their motivation and background to attend their postsecondary CTE class:

"We got to talking, and although they did well in high school (secondary) and had completed a CTE education program, they could not find a job. In their opinion, the college's residential construction framing course would give them an opportunity to secure a 'good job.' I asked if they ever considered an apprenticeship. They said no. The student preferred community college because they could work during the day."

Although this student had checked all the boxes to transition to a postsecondary education and career pathway, they were still in community college well into their twenties. They were also working an unrelated low-wage job to supplement their career education. This is a result of many factors, including a lack of articulation and lack of dual-enrollment, that hinder social mobility into the high-skill, high-wage workforce.

> **Arriving early allowed the instructor to speak with many students and hear their individual and collective stories, which were very similar to this student**. **The instructor discusses waiting outside the classroom:**
> *"As an expendable associate faculty instructor, I was not given a key to the classroom. Waiting for the senior instructor to open the door 15 minutes late, I was able to meet nearly all of the forty men and women who were hoping to take my class. Many of these students had similar stories, and already put in a 10+ hour day of work in low-wage non-technical jobs like retail and foodservice."*

This student's situation was not unique, and the more the investigators interacted with students in these pathways, the more stories they heard that were similar to this case study student. Furthermore, the investigators are seeing one of our first clear barriers to these students' social mobility. With 40 people showing up to an 18-student-capacity classroom, over half of these eager students will be turned away.

> **The instructor discusses the issue with limited enrollment capacity:**
> *"With enthusiasm, students asked if they would be able to add the class. The senior instructor replied that they were not sure how many could add and to show up next week. They then released the group and proceeded to explain to me that we needed to cap the class at 18 students."*

Impacted CTE programs are common in public institutions. Through this interaction, another potential block to the students' actualization of their social mobility is clear: the lead instructor was not transparent with the students. Many would show up for the next class only to be turned away. Clearly, these students' time was seen as less valuable than the instructor's time.

> **The new associate faculty instructor and ethnographer describes their concern for these students' opportunity costs below:**
> *"There were some legitimate safety and logistical concerns for capping at 18, but I was mostly confused that they would not share this with the students. Because the senior instructor was the key master, I kept my questions to a minimum. However, I did comment that we should at least email the students, many of whom commute, rush from work, have*

> *babysitters, etc... At the end of the day, these are people with real opportunity costs. I thought it was important to let them know there would be no additions and not to waste their time. The senior instructor's response: just tell them next week."*[5]

This dismissive attitude toward students' time permeated much of the postsecondary CTE program. Often, instructors were not invested in the program and scheduled classes in service to senior faculty members instead of considering students' needs first. Furthermore, they were not transparent about program expectations and policies. This was a recipe for inequitable programs where students found themselves in limbo, often remaining consistently a few classes away from certificates and the completion of programs that would theoretically get them into the high-skill high-wage job market. These experiences reveal that the pathway to work and career has many forks and blocks, and often the results are not fair. Every step forward in research that explains the workforce education pathway is a step towards creating equitable workforce pathways and social mobility for our most marginalized populations.

> **Intervention Ethnography: A New Awakening Through a Case Study**
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> *"Again, I walk to the classroom in the yellow glow of those San José parking lot lights, only now it is the Pipe Trades Education Center that I am approaching. I imagine the same student in the same scenario, with the same excellent attendance, only now, I no longer have the same apprehension for my student's social mobility."*

As an apprenticed pipe trades journeyperson, this student will soon make over 130 percent of the regional mean income.[6] In addition to this income, they will have pension-protected benefits, hiring hall, union-negotiated labor standards and job protections, and an opportunity for continued skills development. This program stands out from the previous ones beyond the measurement afforded by metrics of AS-CTE and attendance.

At the Pipe Trades Education Center, my role is that of a guest to observe an often-unseen reality in CTE education. The Center is administered by a trade union and without a specific reason to be on that site, you would not know it exists. A complex of clean, low-rise education buildings is tucked away adjacent to a commercial zone, with a solidly constructed iron fence protecting the site.

> **The investigators participated in the apprenticeship education system as guests – one describes the social mobility the students enjoy:**
>
> *"It started as a simple call and a request to grab a coffee and talk about apprenticeship education. From collaboration with and numerous visits to*

> *the Pipe Trades Education Center, I was familiar with this apprentice. They had already given guest lectures in courses I taught as an associate faculty. "Just meet me at my worksite, there is a coffee shop across the street!" The contrast between the student in their 'street clothes' and the student in their 'work clothes' was one that as a concrete laborer I understood – that feeling that says, "see, I am a person." As we sat in an upscale coffee shop in the heart of the Silicon Valley venture capital financial district, surrounded by startup teams, we were as socially mobile as everyone around us. We could have pitched a startup just as easily as talked through the human rights this student learned about in their labor course. That this student was employed full-time in a high-skill high-wage occupation seemed secondary, given all the other opportunities we discussed."*

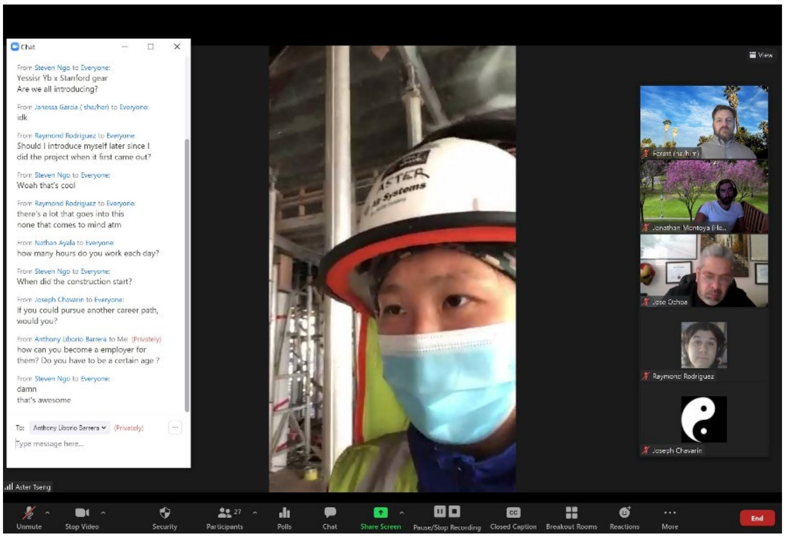

Figure 4. The 'Classroom.'

Note: An investigator visiting the 'classroom' of an apprentice pipe trades student: the student leads their PBL AS-CTE class through a jobsite walkthrough.

CONTRIBUTION TO THE FIELD

Building on Plasman and Gottfried's (2020) success metrics of attendance as a measure of program efficacy as a point of departure, and the authors claim that social mobility is a necessary metric of measuring CTE pathway success. The results of ethnographies reveal differing degrees of social mobility in traditional postsecondary AS-CTE pathways (community college) and union-led apprenticeship pathways (pipefitters). This study centered the stories of traditionally marginalized students who would have been considered successful using the seven PBL essentials to predict pathway success (Amaral et al., 2015) and success metrics using attendance as a measure of program efficacy (Creghan & Adair-Creghan, 2015; Plasman & Gottfried, 2020). However, their personal stories and struggles described in this ethnography reveal a different narrative. Through their roles as postsecondary PBL AS-CTE instructors, the investigators observed a lack of both social mobility and perceived social mobility for students who would be considered successful. Given this discrepancy, social mobility should be added to the postsecondary PBL AS-CTE ontology as a metric of success (used for example in program evaluations).

IMPLICATIONS

This ethnography left a bleak vision of how the workforce has been sold versus the reality of historically marginalized students. However, there is a glimmer of hope in the counter-narrative of the pipe trades. The authors identified that social mobility is a metric of success for the pipetrades, and suggest that trade programs strive for this metric which improves on attendance alone as a predictor of success. While the authors observed many other interesting metrics, as researchers the authors identified a concise contribution in social mobility which itself encompasses many program-specific metrics which may detract from the greater PBL AS-CTE contribution. To move toward an equitable future for those in the workforce and education system we need work to problematize the historical roots of workforce pathways. While looking to the future of Silicon Valley PBL AS-CTE education, we must be cautious to avoid superficial amelioration of past harms caused by these pathways. Let us first take the palimpsest of the workforce education recipe and scrape away the prescribed instructions, analyzing each layer to avoid rewriting historical injustices. This recipe must be critically examined in order to be more justly rewritten. By observing the pipetrades' potential for social mobility, we propose the implementation of an improved predictive measure: that social mobility be added as a metric to a predictive ontology framework of education success. Through the counter-narrative, this study envisages a socially mobile workforce – one where classes are articulated to postsecondary institutions, students earn a living wage, and their health and safety are protected. This is not a pipe dream: it already exists in our region in trade education such as the Pipe Trades Education Center.

This study forces us to acknowledge past harms caused by CTE programs in marginalized communities such as San José. Al Garza and Herman Gallegos have shared details of these toxic pathways and their impacts on marginalized communities in Silicon Valley (Martinez, 2014). Project-based learning curricula such as workforce VDC have shown promise in helping to mitigate such harms. However, the implementation of Workforce VDC may simply postpone the inevitable reality that these programs must either be radically reimagined or dissolved entirely.

SIGNIFICANCE OF IMPACT

This study lends insight into the ways that postsecondary Career Technical Education institutions struggle to fulfill their mission to increase employment and social mobility for students from marginalized communities. Historically, access to education is not enough. Groeger (2017) reminds us that, “increased access to education, so often hailed as a road to opportunity, gave rise to a new form of social inequality in the modern United States.” Groger’s critique highlights ‘credentialism,’ where unequal access to education credentials perpetuates an elite ruling class (Groeger, 2021). This inequality is mirrored in neighborhoods in Silicon Valley. Recent research from Montoya et al. (2018) found poor environmental factors as students completed a safety survey of the routes to their school. The students were then transported to an affluent community where they did another survey and for the first time had a comparative lens to see inequities in both their schools and their environments. This study examines whether inequities reach further than the built environment and extend to their postsecondary CTE facilities.

Not all communities are created equal, and knowing to what degree each postsecondary institution generates social mobility allows for recommendations towards best practice. The investigators are motivated by service to their community and aim to inform community stakeholders which institutions are functioning to facilitate their workforce mobility. Too often, underrepresented minorities and/or low-income individuals carry the burden of social and environmental injustices that impacts their livelihood and lack of mobility. In the high-tech region, neighbors are exposed to environmental stresses and contaminants that measurably impact community health (Montoya et al., 2018). Furthermore, many live with neurotoxins like lead paint, carcinogens like asbestos, or in close proximity to brownfields and manufacturing facilities of unknown and mixed pollutants (Montoya et al., 2018).

As one of the wealthiest regions in the country, the Silicon Valley has impacted communities – composed mainly of minority individuals – that are nine times more likely to reside near toxic facilities and sites (Massey, 2004). Efficient postsecondary PBL AS-CTE pathways help to ameliorate these environmental and structural inequities by providing true pathways to job skills that will result in higher wages.

Uncovering and creating these functioning pathways through PBL AS-CTE helps to increase a homegrown skilled workforce. Job skills and prosperity allow community members to improve the environmental impacts of buildings around them and to join a growing and prosperous workforce (Fischer, 2006; Peterson et al., 2011). These studies have the potential to help bridge these gaps to postsecondary AS-CTE for a community with a historically underrepresented population that has struggled to enter the college–career pipeline and construction management field.

RECOMMENDATION

In conclusion, the authors recommend that researchers, administrators, and policy makers add social mobility as a metric to a predictive ontology framework of education success.

LIMITATIONS AND SUGGESTED RESEARCH

Union apprenticeship programs, like the Pipe Trades Education Center featured, are currently the most apparent pathway to the university. Important concepts, such as social justice, are derived through academic equivalency which creates social mobility. The apprentice described in this paper would never be allowed to teach even a CTE community college course whereas the investigators, due to their advanced degrees, would be able to even if they knew nothing specifically of the topic they were teaching.

Researchers should further explore pathways from the apprenticeship to regional university undergraduate programs, bargained agreements of recognized academic equivalency by industry companies, and potentially across industry sectors if that option becomes available in the United States. As best as we can tell, the pipe trades program had a lower overall cost per student, however, we did not look at the budgets which undoubtedly are public information. Following the example of The European Credit Transfer and Accumulation System (ECTS), the investigators recommend exploring academic credit for knowledge gained through experience, including experience in elected executive-type roles within labor organizations. Last, workforce education centers should be administered by those who have participated in the relevant workforce. Looking ahead, a legislated direction may be necessary to move these recommendations forward to implement social mobility as a metric of predicting PBL AS-CTE program success.

The investigators are aware that, given the nature of their positionality and particular lens, these ethnographies cannot and should not be generalized beyond our unique setting. These analyses are specific to the investigators, and although the investigators have made every effort to avoid blind spots and misinterpretations to accurately describe these students, their experiences, and their pathways, these analyses could not be replicated because they are unique individuals during a unique time.

This study did not explore the pathway of academic equivalency as thoroughly as intended. As ethnographers, much of the pace of research is dependent on real developments by a community of participants that the ethnographers do not and should not have an influence on. This study was conducted during a pandemic and accompanying economic collapse and political upheaval. That said, the investigators present a PBL path forward for AS-CTE students through academic equivalency and reentry to the academy of higher education.

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[1] The authors use the now discontinued term 'vocational' as a term that is recognizable to a wider audience across languages where the term Vocational Education and Training (VET) is commonly used in translations.
[2] CTE courses in Silicon Valley are taught through project-based learning.
[3] For additional information on the organization of the community partnership structure see (Montoya et al., 2018).
[4] Dual-enrollment is an enrollment designation wherein a student is enrolled in both a secondary and postsecondary institution simultaneously, and receives credit from both institutions.
[5] The investigators, as CTE students years prior, had experienced returning week after week requesting to add a course needed to complete their certification or degree. Several times, after weeks had passed, a 'lottery' was held to select a few extra students that would be allowed into the course and the rest were turned away to try again the next academic term.
[6] Occupational Employment and Wages: San Jose, U.S. BLS, www.bls.gov/regions/west/news-release/occupationalemploymentandwages_sanjose.htm

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Emerging PBL Futures: Exploring Normative Scenario Development as an approach to support Transformation in Problem-based Learning and Higher Education

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ABSTRACT

Problem-based learning has a long history of transforming higher education institutions at course-, curriculum- and even systemic levels, and has shown to enhance student-centered learning and core pedagogical values such as facilitating collaboration, complex problem-solving skills and critical thinking. However, rapid digitalisation in higher education and emerging trends such as personalised life-long learning through micro-credentials and flexible curriculum models challenges existing, traditional onsite PBL practices and require new frameworks for envisioning future practice in higher education based on an understanding of its local context and the inclusion of multiple relevant stakeholders and practitioners, not only to co-create potential scenarios suitable for a particular educational institution but also in pointing to directions for initiating and maintaining this change process on a systemic level. In this paper, we propose normative scenario thinking as a method for educational development, and present the first steps and initial findings from a process of normative scenario development within a PBL university. The aim of this process has been to identify and explore key trends and core values that inform the development of future scenarios for the conceptualisation and implementation of PBL at the university, in a digital age. Through the analysis of a specific scenario related to project variation and reflection, we exemplify how a value-based and problem-oriented approach to exploring emerging PBL futures can facilitate systemic change in higher education.

Keywords: PBL, scenario development, systemic change, higher education

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INTRODUCTION

There is a call for change in higher education to address and respond to rapid digitalisation as well as increasingly complex current and coming societal challenges e.g. related to the Sustainable Development Goals and technological innovation. Thus, education and access to education is a strategic priority both in Europe and globally with student-centered and life-long learning approaches to skills and competency development increasingly emerging as trends in existing and emerging educational models and practice. The question is, how should universities respond to these challenges without risking an even more overloaded curriculum? What should be the long-term goals and the short-term actions? Student-centered learning as one of the overarching responses from higher education in the EU (Klemenčič, Pupinis & Kirdulytė, 2020) points to forms of active learning methodologies such as problem- and project-based learning (PBL) as the most dominant trend particularly within engineering education (Graham, 2018).

For traditional universities transforming along that change track, existing examples of PBL at course-, curriculum and institutional level has served as a platform for inspiration, research documentation and as living labs for visitors to learn about and experience alternatives to traditional teaching. However, PBL universities are already embodying student-centered learning and active learning methodology at a system level, and the question thus is, where do they look for practice to inspire for further development? How can they ensure continuous development and incorporate emerging trends such as digital transformation into their pedagogical vision and values?

In this paper, we discuss the application of value-based scenario development specifically within PBL institutions and present the first steps and initial findings from a process of normative scenario development as part of the research project PBL Future at Aalborg University. The paper presents the different phases in scenario development and demonstrate how a problem-oriented approach to identifying and exploring key trends and core values can inform and facilitate the development of future scenarios for PBL that are in line with its pedagogical vision while also facilitating systemic change in higher education.

EXPLORING THE FUTURE: SCENARIO METHODS AND METHODOLOGIES

A scenario can be defined as a description of a possible future situation, including the path of development leading to it. The term was introduced in military and strategic studies by Herman Kahn in the 1950s, and was later used by corporations as a more sophisticated planning tool to analyse and understand key competitive decisions and to develop business strategies (Schwarz, 1991). Scenarios are not intended to represent a full description of the future, but rather to highlight central elements of possible future(s) and to draw attention to the key factors likely driving the development (Bishop, Hines & Collins, 2007). Thus, scenarios are not predictions about the future but rather simulations of possible futures used to explore potentials and support decision-making, to highlight the discontinuities from the present and reveal choices available and their potential consequences (Kosow & Gaßner, 2008). A chosen scenario methodology describes the basic assumptions and process model, how the future is to be captured in the scenarios, and the methods through which the scenarios are formed, including the recommended support systems, modeling techniques, and data sources (Kosow & Gaßner, 2008). In this process, scenario methodologies apply a variety of methods depending on the scope, e.g. most 'probable'/'preferable' scenario. Although techniques vary, the scenario process tends to unfold in a similar manner across approaches (Kosow & Gaßner, 2008):

- In the first phase, the first step is to *determine the scenario field* by establishing the scope of the study and relevant questions to ask.
- In the second phase, researchers *identify key factors* that might influence how the future will unfold for further discussion with stakeholders and practitioners.
- The third phase analyses the range of outcomes these key factors could produce. This phase can be highly participatory and collaborative, informed by both research and practice.
- A following *fourth* phase involves condensing the list of central factors in order to generate a relatively small number of distinguishable scenarios.
- Finally, a *fifth* phase which then 'transfers' these scenarios to strategy and implementation

One of the purposes and uses of scenarios is to help decision-makers acquire knowledge and understanding to anticipate the context in which they have to act. However, for scenarios to be used effectively, the participants must be convinced of the soundness, relevance and value of the process. This is essential as the foundations on which scenarios are built, the structures that they use, and the reasoning they employ, must stand up to highly critical examination for it to contribute to decisions and actions (European Foresight Platform, 2020).

Scenario Development and policy making in higher education

In higher education, scenario planning as a tool has mostly been used in relation to policy studies (Amer, Daim & Jetter, 2013; Dator, 2002). On an international level, organisations such as OECD, UNESCO and national governments apply scenario methodologies for creating awareness and pointing out different possible future directions, focusing on the functions and societal role of the university as an institution.

For instance, in 2008 an OECD study pointed out four scenarios for higher education related to two dimensions: *national* versus *international* and *administrative supply driven* versus *market demand driven* (OECD, 2008). In this study, OECD identifies key drivers of change for each of the four future scenarios for higher education;

1) *Open networking* (based on partnerships and global higher education systems)
2) *Serving local communities* (focused on national/regional issues and publicly funded)
3) *New public responsibility* (involving new public management tools/incentives)
4) *Higher education Inc.* (driven by commercial interest and competition)

Today, all these types of universities do exist in glimpses and with tensions. On the one hand, there is a call for more globalisation like the Bologna process in Europe and on the other hand, national governments start to claim the use of national languages excluding international students in the programs. Private universities already exist, however a push for more privatisation such as School 42[1] is seen in recent years, both politically and from industry with the growing need for graduates with specific skills, particularly within computer science. Open networking scenarios are explored within projects such as the ECIU[2], however one could argue that a truly network-based higher education sector should include partners equally from all parts of the world to avoid polarisation.

Similarly to OECD, UNESCO creates policies for higher education and published a report in 2017 on Education for Sustainable Development formulating learning outcomes for each of the 17 Sustainable Development Goals with related interdisciplinary competences such as systems thinking, anticipatory competences, normative, strategic and collaborative competences as well as critical thinking skills (Rieckmann, 2017). These competences all represent a holistic future- and value-oriented approach, in which deconstructing disciplinary boundaries is considered key to facilitate complex problem solving. Another UNESCO study launched in 2015, *Future skills – The Future of Learning and Higher Education* is an ongoing project in which the third phase is based on a Delphi survey on skills and scenarios for future learning (Ehlers and Kellerman, 2019). In this study, four scenarios are built from students' perspectives:

1) the future skill university with increased focus on skills and competences rather than traditional knowledge acquisition
2) the highly digitalised and networked university where students will graduate with curriculum elements from various universities
3) the 'my university scenario' – or personalised curriculum – where students follow their interests and build a personal path
4) the life-long learning scenario for learners from workplaces where the universities offer micro-credentials.

The results of the survey point to the realisation of scenario 4 within five years, i.e. in 2020, and the realisation of the first three scenarios within a span of 10 years. A timeline that seems to have been further escalated by the sudden need for rapid digitalisation of teaching as a result of the covid-19 pandemic (Dhawan, 2020).

Whereas the two studies approach the question of developing future scenarios for education from different perspectives and apply different methods, they still point to common directions towards more flexible higher education system with a focus on skills and competency development, digitalisation allowing for new roles and types of industry-university collaboration, personalised curricula and life-long learning. However, at the same time they also highlight a potential tension within the education system itself, i.e. in the contradiction between a market-driven focus on skills and employability, and academic strategies of response to society's grand challenges which include a large focus on identity formation (Bildung) and critical thinking skills, pointing to the need for scenario development that combine both perspectives (Jamison et al., 2014).

Value-based scenario development at institutional level

Whereas scenario development within policy making in higher education will likely continue to rely heavily on trend extrapolation and quantitative data, scenario development particularly at an institutional level can benefit from a more normative-narrative or value-based approach. One example is the 'Near Future Teaching' project that applied scenario methodology to develop a shared value-based vision for the future of digital education at the University of Edinburgh (Bayne & Gallagher, 2020). As such, this project has served as an initiative to discover and create institution-wide awareness of the shared values and future directions for teaching and learning which is community focused, post digital, data fluent, assessment oriented, playful and experimental, and boundary challenging.[3] Thus, the application of participatory and value-based scenario methods is a creative and flexible approach to consider uncertainties and serve as a transdisciplinary tool for mutual learning, facilitating a sense of ownership and motivation for change among academic staff and students, and through this not only co-creating possible and preferable scenarios suitable for a particular educational institution, but also point to directions and processes for initiating and maintaining this change on a systemic level. Similar methods have been applied when developing new programs and new educational institutions, as is the case with e.g. Charles Sturt University[4] (Graham, 2018) and London Interdisciplinary School[5]. Here, new scenarios and even new digitally supported approaches to higher education is co-created with the involvement of academic staff, experts and stakeholders in response to an increasingly complex society and the need for new, interdisciplinary competences, student-centered learning environments and the development of life-long learning trajectories.

PROBLEM-BASED AND INTERDISCIPLINARY PBL SCENARIO DEVELOPMENT AT AALBORG UNIVERSITY

Since its establishment in 1974, Aalborg University (AAU) has applied a problem- and project-based pedagogical approach combining traditional course formats such as lecturing, labs and exercises, online and blended courses with extensive team-based project work (50% of students' time) assessed by oral, group-based defenses (Kolmos & de Graaff, 2014). Research has documented the effects of PBL on areas such as motivation, retention, competence development, sustainability and employability (Dochy, Segers, Van den Bossche, & Gijbels, 2003; Strobel & van Barneveld, 2009). However, in the early 2000s a need for the development of shared visions and values for PBL was identified at AAU, as the local PBL practice had evolved with great variety across faculties and programs with little interaction and knowledge-sharing (Bertel et al., 2021). Thus, a process was initiated to further conceptualise the AAU PBL model and based on existing research and interviews with staff and students a shared set of guiding PBL principles for all study programs at AAU was developed (Aalborg University, 2015):

- The problem is the starting point of the learning process
- Project organisation creates the framework for problem-based learning
- Courses support project work
- Cooperation is a driving force in problem-based project work
- The problem-based project work of the groups must be exemplary
- The students are responsible for their own learning achievements

These PBL principles created a joint vision and a shared language of PBL throughout the organisation. However, to further support the development of a shared PBL practice, AAU allocated funding for a number of PBL initiatives as part of the university's strategy, including a significant number of local PBL development projects as well as a large cross-faculty research project on the future of PBL[6] (Bertel et al., 2021). One of the strengths of PBL is its inherent adaptability in the project-based approach to address complex and emerging problems in diverse contexts, with the combination of project collaboration and discipline specific knowledge to mirror the societal need for adaptable and transferable skills. However, though the AAU PBL model continues to receive international acclaim as a radical pedagogical innovation (Graham, 2018), PBL models also face an increasing number of complex challenges in the post-digital age. Emerging technologies and increasing demands from students, staff and external stakeholders to focus e.g. on employability, sustainability and life-long learning, require continuous revision and adaption of PBL practices on a systemic level. Thus, in 2017 AAU initiated *PBL Future*, an institution-wide research project, to facilitate a problem-oriented approach to the transition to digitally supported PBL and to the development of research-based directions and value-based scenarios for PBL in a digital age (Aalborg University, 2017).

The PBL Future project: Determining the scenario field (phase 1)

In a scenario development perspective, the PBL Future project construction in of itself constituted the first phase, i.e. identifying the *scenario field* consisting of a problem-identification process, in which a consortium of senior PBL researchers across the five faculties developed the project proposal, and an international expert advisory board was established, defining the scenario field and the purpose of the project, which is to:

> *"(...) re-conceptualise how PBL could operate in new formats, based on the core principles of PBL, while exploring and developing new digital approaches that operate in and open up for new hybrid PBL learning models." (PBL Future, 2021)*

Identification of key factors (phase 2)

In the second phase, the consortium identified preliminary *key factors* to influence the development of future scenarios based on the principles or core values of PBL at AAU. In this problem analysis process, these preliminary factors and values and their context were categorised divided into five subprojects; four subprojects (including four PhD projects) each addressing particular issues identified through the problem analysis, and a baseline study mapping out existing practices and understandings of PBL at AAU from student, staff and curriculum perspectives, and identifying key trends pointing to future directions (subproject 0). See figure 1 for an overview of the subprojects, key factors and core values (i.e. their relation to PBL principles).

Subproject	Key factors	Values/PBL Principles
(1) Student-centered problem design	Student-centered learning Increasing complexity Sustainability	•The problem is the starting point of the learning process
(2) Emerging PBL collaboration skills for a digital age	Digital transformation Global pandemic accelerating digitalisation	•Project organisation creates the framework for problem-based learning •Cooperation is a driving force in problem-based project work
(3) Strengthening reflection and PBL competence development of individual students	Student-centered learning Competency-based curricula Life-long learning	•The problem-based project work of the groups must be exemplary •The students are responsible for their own learning achievements
(4) Towards a PBL flipped semester approach	Digital transformation Flexible curriculum Life-long learning	•Courses support project work •The students are responsible for their own learning achievements
(0) PBL competences – Baseline study and future directions	Digital transformation Competency-based curricula Student-centered learning	•PBL at systemic level •Research-based teaching and PBL practice

Figure 1. Overview of PBL Future subprojects and related key factors and core values.

Analysis of the factors (phase 3)

In the third phase of scenario development, *the range of outcomes* that the key factors could produce are examined. This phase can be highly participatory and collaborative, informed by both research and practice. In the PBL Future project, the approaches and methods applied in the individual subprojects all contribute to the exploration of key factors and core values related to that particular subproject for further elaboration in the consortium. In subproject 1 and 2, different forms of ethnography (video and digital) and situational analysis were applied as methods for exploring student-centered problem design and collaboration processes through the duration of a semester project (Thorndahl et al., 2018 and Ryberg et al., 2018). Subproject 3 and 4 applied participatory methods and co-creation workshops to develop new approaches to course design and methods for supporting student reflection and individual competency development (Lolle & Scholkmann, 2021 and Kofoed et al., 2019). Subject 0 applied surveys, quantitative content analysis and statistical instruments to investigate PBL competences from student- staff- and curriculum perspectives. As the PBL Future project addresses questions specifically related to researching PBL as an institutional phenomenon, measures were taken to include and capture the complexity of PBL through case studies in multifaceted (physical and blended) learning spaces as well as to ensure that data from all faculties and research units were represented.

In this third phase, the consortium explored data and findings from phase 3 to further expand each key factor and core value through workshops, resulting in a visualisation of the variations within each of the existing PBL principles (figure 2) serving as a tool for developing and choosing distinguishable scenarios for further exploration.

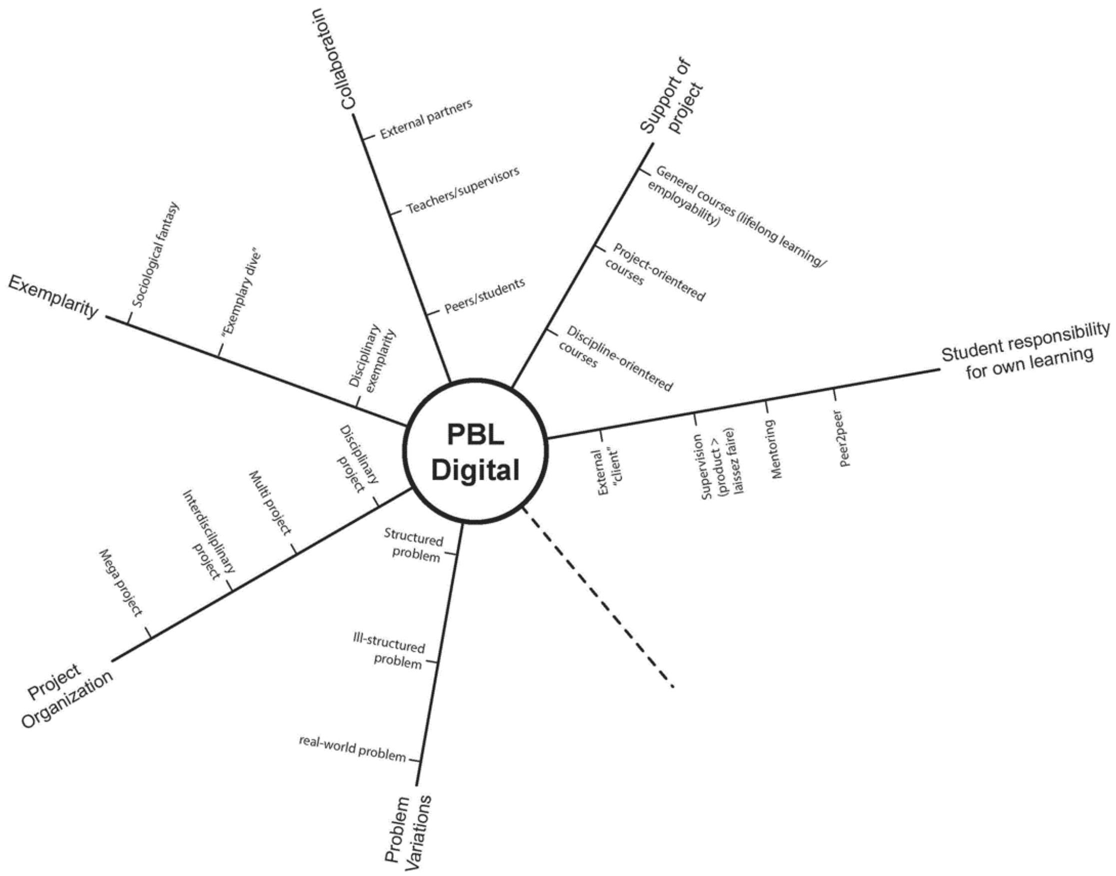

Figure 2. Analysing variations within the value-based scenario field of PBL at AAU.

In this process, each PBL principle was projected through 'factor funnels' (Kosow & Gaßner, 2008), a funnel-shaped span of possible developments of this particular principle, together forming the joint space of possible, plausible and preferable (PBL) futures for these factors in the scenario field. Upon deconstructing and expanding each of the existing principles into dimensions of PBL, eight new guiding principles with for the PBL Future scenarios emerged (figure 3) with *variation* (between these scenarios) as an emerging core value connecting them:

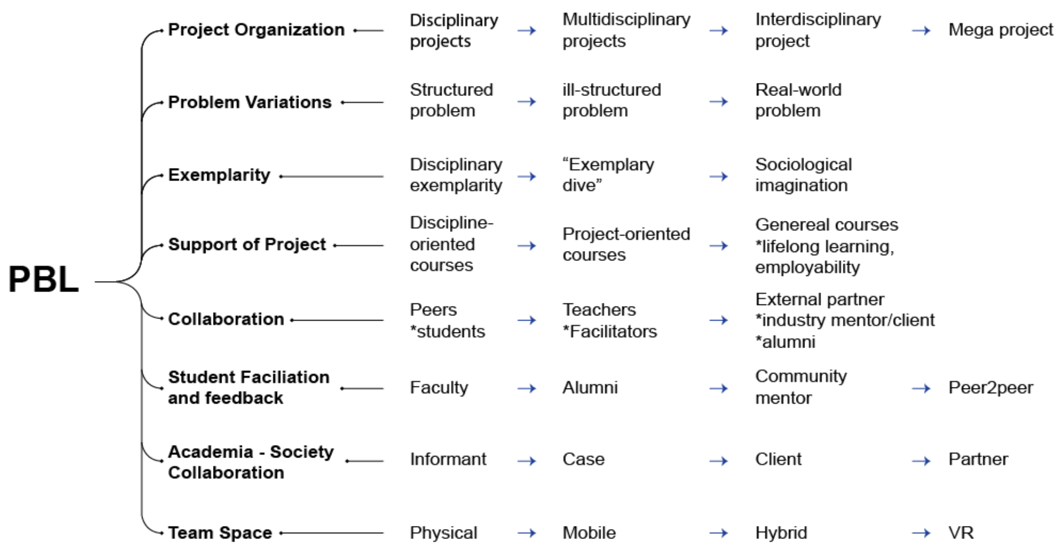

Figure 3. Overview of emerging principles and related scenarios after initial analysis. Scenario generation (phase 4.)

The PBL Future project is currently in its fourth phase, where the condensed list of key factors and core values has been further conceptualised into 'general' and 'specific' principles for PBL in order to generate a relatively small number of distinguishable scenarios for practical experimentation and potential implementation. In the following, we will exemplify this process by diving into the condensed principle of project variation and describe distinguishable scenarios developed for this particular key factor and discuss this scenario in relation to the aforementioned future scenarios for higher education described by OEDC and UNESCO.

PROJECT TYPES AND CRITICAL THINKING SKILLS: VARIATION IN THE PBL EXPERIENCE AS A CORE VALUE

Whereas project-organisation is has been a guiding principle for PBL at AAU across all faculties and programs for many years, the key factor analysis in phase 3 showed local variations, i.e. in the ways in which students work with problem identification (Velmurugan, 2019); the way they organise themselves and their collaboration processes online and onsite (Ryberg, Sørensen & Davidsen, 2018); their experiences with competency development in the projects (Scholkmann, 2017); and the ways in which courses support project work (Kofoed et al., 2019). Results from the baseline surveys support this, with both students and staff emphasising project group work, and particularly digitally supported interdisciplinary group work, as important for the future of PBL at AAU (Clausen & Kolmos, 2019). However, the baseline curriculum content analysis also show, that the standard discipline-specific semester project is still most common at AAU, with little variation in project-size or timespan (Boelt, Clausen & Bertel, 2019).

A similar trend is seen in the PBL literature with an increasing prevalence of project activities, however often characterised by problems given by teachers, projects that run for a semester or a throughout the duration of a course, and with smaller teams of mostly three to eight students (Chen, Kolmos & Du, 2020). However, if students experience repeating patterns of project work throughout their education without reflection on differences and similarities, there is a risk of it becoming routine and the knowledge, skills and competences associated with it, tacit. Thus, facilitating reflection on the experiences of variation e.g. in type of problems and projects, can support students in articulating contrasts, similarities and differences and thus make explicit their PBL competences, including critical thinking skills. We propose this can be done in two ways; by implementing a more systematic practice of reflection regarding project work and competences (Holgaard & Kolmos et al, 2019), and by developing more diverse project types that vary in complexity of scientific scope and (online/onsite) structure (Kolmos et al., 2020).

Developing diversity and variation in scientific complexity can involve scaling up the scientific scope by expanding the range of project types from single disciplines to multi- and interdisciplinary projects, in principle determining choice of discipline and method to match a similar range of narrow discipline specific to complex interdisciplinary problems (Kolmos et al., 2020). Similarly, developing variation in complexity of project structure can involve scaling up the collaboration from a handful of students within a team, to teams of teams collaborating in a networked structure (Routhe et al., 2021). Within the two dimensions; *interdisciplinarity* and *teams in networks*, four basic project scenarios were identified (Kolmos et al., 2020);

- *Single-discipline projects* carried out in single project groups, widely used both at course and curriculum level, where students within the same educational program apply discipline-specific knowledge/methods, skills and competences to a discipline-specific problem
- *Interdisciplinary projects*, which can be carried out in one project group composed of students from different disciplines or as a single discipline group ‘borrowing’ methods and concepts from other disciplines to address an interdisciplinary problem. Initial problem analyses are often interdisciplinary in scope, with students often integrating interdisciplinary methods to identify user needs in otherwise discipline-specific projects
- *Multi-projects*, which occurs in bigger courses or clusters of sub-disciplinary courses, and is characterised by a number of project groups working on the same or complementary elements (work packages) within the same or similar disciplines. These types of projects require (digitally supported) coordination among project teams to ensure the quality and feasibility of a common product and/or problem-solving method

- *Megaprojects*, which covers large, long-term and highly complex interdisciplinary projects (broad or narrow interdisciplinary) e.g. supported by an interdisciplinary team of supervisors, with great collaborative complexity in digitally supported networks of teams responding e.g. to global crises such as the COVID-19 pandemic or grand challenges related to the sustainable development goals.

Whereas this distinction in project scenarios is made for prescriptive purposes with real-life practice providing many more variations, the exploration of the scenario field within project variation also showed that all four categories of projects were already present or emerging in practice, but lacking a systematic practice for reflection on variation in the PBL experience and progression in associated PBL competences.

Emerging AAU Megaproject scenarios: Dissolving disciplinary boundaries through digitalisation?

To explore and further develop the megaproject scenario, students, staff and stakeholders were involved in piloting AAU Megaprojects[7] in 2019-2021, with three megaprojects: *'Simplifying Sustainable Living', 'The Circular Region'* and *'Better Together'* with approximately 80 students total participating in clusters of groups working together through an online platform to solve challenges related to the above themes.

PBL Future followed the process, and found that the concept was indeed addressing specific factors related to student-centered learning and student engagement and provided the opportunity for variation in the PBL experience and complexity of problems (figure 4).

Scenario	Key factors	Values/PBL Principles
AAU Megaprojects	Student-centered learning (flexible curriculum, networked learning) Increased complexity (sustainability/interdisciplinarity) (Digitally supported) collaboration	•Variation in the PBL experience •The problem is the starting point of the learning process •Students are responsible for their own learning

Figure 4. Key factors and core values initially addressed in a Megaproject scenario.

However, we also found that adjustments and improvements of the setting and structures were needed to support other relevant values and principles, e.g. related *to project organisation and team space,* i.e. the interdependency between projects in the network (Routhe et al. 2020) as well as interdisciplinary *facilitation and support* of the project and *progression and assessment* (Bertel et al., 2021), pointing to a need for more feedback and ongoing assessment of both the projects' process and its products, as well as digital tools and methods through which students can articulate and document knowledge, skills and competences developed through the megaproject. This way, empirical findings from the piloting of megaprojects provided insights into potentials and challenges specifically related to variation in the PBL experience as a core value at AAU.

Another key factor that the initial megaproject scenario did not anticipate was the rapid digitalisation of course content and project work that took place in spring 2020 and onwards due to the covid-19 pandemic and the resulting lockdowns. On the one hand, this provided access to more interdisciplinary knowledge, skills and competences and enhanced the principle of courses supporting projects, but on the other hand also escalated the complexity of the collaboration, bringing tensions between the principle of *problems as point of departure for learning* and the discipline-specific learning outcomes in the formal curriculum. In this way the normative scenario development process and the problem-based approach to exploring potentials and challenges in megaprojects continue to mutually inform one another, and a new megaproject concept further emphasising digitally supported reflection, feedback and assessment has been developed through scenario workshops in the fall of 2021 and is expected to launch in 2022.

POTENTIALS AND LIMITATIONS IN NORMATIVE SCENARIO DEVELOPMENT FOR CHANGE IN HIGHER EDUCATION

Whereas the trend extrapolation in scenarios for higher education such as those proposed by OECD and UNESCO are based on somewhat verifiable calculations and thus represent a certain global probability across contexts, a normative scenario development process as shown above has the possibility of incorporating the participation of many different actors with no restrictions in terms of the number of factors to potentially be taken into account. However, at the same time normative scenarios also tend to be particularly selective (and provocative) ‘wish’-scenarios that are not necessarily easily implemented, and the process is resource-intensive.

The scenarios emerging from the normative scenario development process address similar issue as those highlighted in trend extrapolation, i.e. an increased focus on skills rather than knowledge acquisition, a highly digitalised and networked university and personalised curriculum, as well as a multitude of life-long learning trajectories through which industry and academia can collaborate (online and onsite) to solve the global and grand challenges of tomorrow, but the normative approach also attempts to link these to critical thinking skills and PBL competences, thus the added value of this approach is in the integrated and transparent connection between specific scenarios and pedagogic principles, pointing not only to important contextual values but also to paths for scenario transfer and future implementation.

CONCLUSIONS AND FUTURE WORK

In this paper, we presented the first steps and initial findings from a process of normative scenario development in PBL Future – an institution-wide research project to develop PBL for a digital age at Aalborg University. Through the analysis of the scenario field and related key factors and core values, digitally supported project variation was chosen as a distinguishable scenario to exemplify how a problem-oriented approach can be used to explore emerging and digitalised PBL futures. The initial results show, that normative scenario development can connect significant emerging trends to current and emerging practice, pointing not only to contextual and core values but also to paths for scenario transfer and future implementation. In future work, other scenarios developed through the PBL Future project will be piloted and further analysed for applicability and implementation in relation to the current strategy for PBL at Aalborg University as a mission-driven university, and normative scenario development further explored as an institutional approach to develop and transform current and emerging practices in PBL and higher education on a systemic level.

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