PBL in a Digital Age

Kolmos, Anette; Ryberg, Thomas

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Anette Kolmos & Thomas Ryberg, Eds.

PBL in a Digital Age

AALBORG UNIVERSITY PRESS

PBL in a Digital Age

AALBORG UNIVERSITY PRESS

PBL in a Digital Age
Edited by Anette Kolmos & Thomas Ryberg

1st Open Access Edition, 2023

No. 3 in the series: Studies into Problem Based Learning in Higher Education.

Layout: Toptryk Grafisk Aps / Tina Nielsen
Cover Illustration: Colourbox.dk
ISBN: 978-87-7210-790-5
ISSN: 2246-5804

Published by Aalborg University Press | www.forlag.aau.dk

The publication is financially supported by Department of Planning, Aalborg University

Contents

PBL in a Digital Age

Kolmos, Anette; Ryberg, Thomas; Andreasen, Lars Birch; Kofoed, Lise Busk; Clausen, Nicolaj Riise; Bertel, Lykke Brogaard; Velmurugan, Giajenthiran (Kalle); Sørensen, Mia Thyrre; Boelt, Anders Melbye; Bruun-Pedersen, Jon Ram; Kristensen, Nanna Svarre; Scholkmann, Antonia; Lolle, & Elisabeth Lauridsen

In 2017, the PBL Future research project was initiated at Aalborg University, bringing together PBL researchers from all faculties in a common research project exploring the future direction of problem-based learning. The overall goal for this research project was to develop research-based directions for problem- and project-based learning (PBL) in a digital age. The project set out to re-conceptualise how PBL could operate in new formats, based on the core principles of PBL, while exploring and developing new approaches that operate in and open for new hybrid PBL learning models.

The PBL Future project was split into 5 subprojects, focusing on both the current practice and how PBL can be transformed to fit a learning landscape which is increasingly becoming more digital.

The book *PBL in a Digital Age* seeks to summarise the findings of the PBL Future research project and to provide an answer to the overall questions *how can the Aalborg PBL model adapt to contemporary challenges and is PBL still the answer*?

Prelude

Four years ago, the research project PBL future was inaugurated as a strategic research project across the five faculties of Aalborg University (AAU). Since the 90s, this was the first time PBL researchers from Aalborg University were united in a common research project. The overall goals of the PBL Future project were:

> to develop research-based directions for problem- and project-based learning (PBL) in a Digital Age. This is an important enterprise to ensure: that the AAU model for PBL remains a world acclaimed, radical pedagogical innovation; that AAU remains at the international forefront in developing PBL; and that students develop PBL competences that are relevant in a digital age. This project will 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. An important goal of the project is to have a high degree of global and local impact. This will be achieved by setting a research agenda for PBL in a digital age that will attract international attention as new directions for more student-centred learning is a global need (PBL-future, 2017)

Following these goals, five subprojects were established based on five selected challenges for the existing practice:

1. The role of the problems as drivers for learning
2. The learning of PBL competences
3. Integrations of digital technologies and collaboration skills
4. The impact of digital technologies on the interplay between courses and projects

Furthermore, a baseline study was added with the purpose of creating a reference point before any changes might be implemented. The baseline study focused on the triangle of academic staff and student perceptions of the experienced and practised PBL curriculum and an analysis of the formal PBL curriculum.

For each of the subprojects, theoretical and empirical research was conducted, and each of the subprojects was then intended to point out the directions of future PBL practices. The five subprojects all feed into a common framework for the future directions of PBL at AAU.

During the last three years, AAU PBL practices have gone through a rapid development process – and the intended outcome of the PBL Future research project has partly been implemented. We sought to address how PBL could be applied to the transformation to digital learning, and we must realise that the digitalisation agenda has emerged much faster than anyone had expected. This has been driven and accelerated by the COVID-19 pandemic. Digitalisation is a must in education today – and nearly three years ago, AAU established a cross-faculty PBL-digital initiative: the institutional unit for digitally supported learning (CDUL), which was established to support the digital transformation, and which bears witness to the institutional priority of the PBL principles. However, suddenly the global learning landscape changed overnight due to the COVID-19 crisis, and both teachers and students needed to adapt to online learning. This has not only created challenges, but also an urgent need to learn how to scaffold and unfold learning based on the experiences from the first phase of the COVID-19 pandemic. We are still in the process of figuring out what we have learnt from this period, and how we can build upon these experiences. There is no doubt that the digitalisation of teaching might be founded in the face-2-face culture, and that we now need to rethink the existing digital practice in order to apply the advantages from digital possibilities.

In our research application, we have argued that the value of PBL competences is underestimated in the AAU curriculum – and PBL future intended to raise arguments for a more explicit implementation of PBL competences. Two years ago, the implementation of PBL progressive learning outcomes was introduced, and these are now explicitly formulated in all formal curricula descriptions and have been so since the beginning of 2020. This has brought about an increased need for knowledge on how students reflect and learn these practice competences and contribute to an understanding of the uniqueness of PBL competences compared to more generic competences.

Finally, multi- and interdisciplinarity have been addressed by AAU. Recently, AAU's megaprojects were introduced to students across the five different faculties. The AAU megaprojects embrace the integration of the UN sustainable development goals (SDGs) and constitute a fantastic invention which will bring AAU to the forefront of educational inventions as the megaprojects all integrate the disciplines in analysing and solving the SDG challenges. The megaprojects are still new and will need to be developed much further.

Regardless of the rapid implementation of digital learning, PBL competences, SDGs or multidisciplinary megaprojects, the PBL future project has contributed to and navigated these changing conditions and has been agile in relation to the research questions and methods. We have interacted and collaborated with other smaller research projects in order to capture the changing reality. Therefore, the platform for pointing at future PBL directions has been based on a broader research base than that of the PBL future research project and also includes the work of the Aalborg UNESCO PBL Centre on megaprojects and variation in learning.

June 2021
Anette Kolmos & Thomas Ryberg

New Realities and PBL Futures

Anette Kolmos & Thomas Ryberg

The higher education landscape has changed over the last 30 years, and there are identifiable tensions in three university modes that saturate curriculum development and teaching approaches in higher education. The first is the academic mode, which emphasises disciplines and theoretical knowledge. The second is the market-driven mode, with a greater focus on employability and competences. Finally, the community-driven mode focuses on civic society and sustainability (Jamison et al., 2014). All the modes are to be found embedded in the culture even at the programme level, although some programmes and institutions are more dominated by one of the modes, such as the academic theoretical mode, or the integration of work-related activities in the curriculum (Magnell et al., 2017).

All modes are important in the curriculum, as, for example, it is important that students learn to relate and apply theoretical knowledge to problems and understand the various societal and sustainable challenges. Academic knowledge is at the core of teaching and learning at university, no matter what, but the way academic knowledge has traditionally been taught – emphasising theoretical learning without relating it to society or the practical world after university – has increasingly been challenged.

Since the 1990s, the Bologna process has pointed towards a more student-centred and competence-based curriculum in Europe, and international accreditation boards such as ABET and the Washington Accord have adopted competences in their accreditation criteria (ABET, 1995, 2014). The competence and skills agenda of the more market-driven mode has dominated the development of higher education all over the world, and it has been brought into education in various ways, ranging from an add-on strategy to an integrated curriculum strategy. The tensions between the academic and the market-driven modes involve the discussion of university approaches and the risk of taking a short-sighted competence perspective versus a theoretically sound academic approach (Maassen & Stensaker, 2011; Trowler, 2002).

The community mode is dominated by the sustainability agenda, which is a major issue in the future development of higher education for finding solutions to climate change, the north/south relationship, and the UN Sustainability Goals. The community mode calls for new types of interdisciplinary collaborations across disciplines, programmes, and universities, with embedded social and civic values such as the ecological university (Barnett, 2010; Sterling, 2004). This mode might enable the emergence of new directions for the universities, as these challenges will be very difficult to solve. Both theoretical knowledge and competences to act and change practice will be needed, and the universities will need to look into interdisciplinary approaches at both the knowledge level and also at the competence level, as graduates will have to work together efficiently across boundaries.

Over the last 30 years, pedagogical trends in higher education have been moving from teacher-driven to much more student-driven learning environments, and new student-centred learning methods have been applied. For example, active learning, design-based learning, enquiry-based learning, flipped classrooms, case-based problem-based learning, and project-based learning have become prominent approaches (Kolmos et al., 2021). Problem-based learning (PBL) has indeed been one of the answers to these challenges and has turned out to be a success with regard to the competence, employability, and sustainability agenda, where students are working on more complex problems (Guerra, 2015; Kolmos, 2021).

The question is, however, how PBL can continue to be a response to the emerging new societal challenges such as sustainability, digital learning, personalised learning and flexibility. Will it be possible to renew and rethink PBL for contemporary challenges, and in which ways?

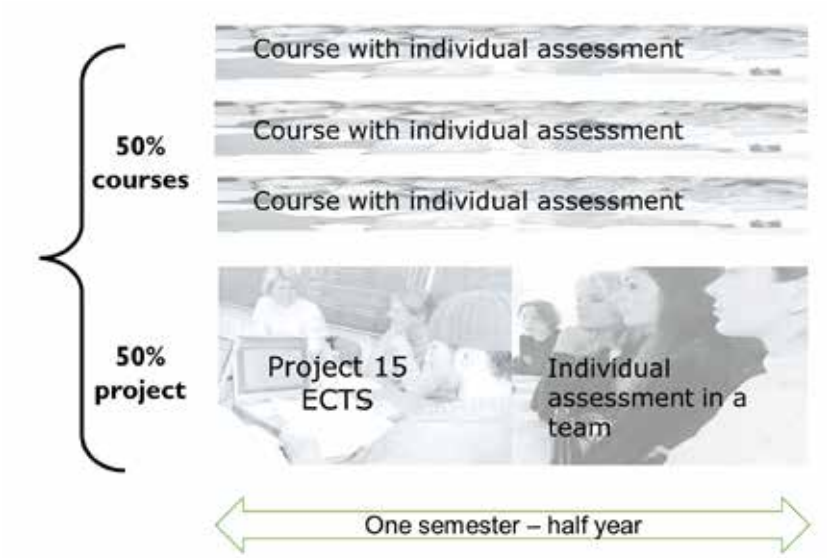
Where we come from

Aalborg University has been a pioneer in problem-oriented project work in higher education –even if it took some years for the university itself to realise that what it had created was something to be proud of. This means, however, that it may be even harder for academic staff at AAU to change, as they have created and defended the Aalborg PBL model which they trust and believe in.

The current AAU PBL model is to a large extent based on the models used when the university was founded in 1974. The essential challenge for AAU is that the PBL model uses a semester approach. The curricular design of the project work, typically awarding students 15 ECTS (European Credit Transfer and

Accumulation System), is larger than that in other international universities that also use PBL at a systemic level. As a general rule, there are also 3x5 ECTS predefined courses. This is a very different system compared to an education consisting of partly mandatory courses and electives.

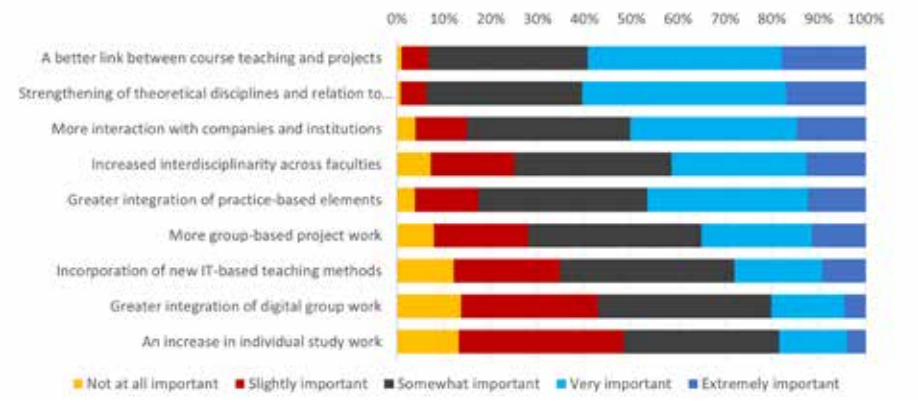
Figure 1.1
The Aalborg PBL Model



In 2010, there was a small change in the relationship between the taught courses and student projects (Kolmos & Holgaard, 2012). During the 1974 - 2006 period there were two types of taught courses: the study courses (7.5 ECTS) and the project courses (7.5 ECTS). The study courses had their own assessment and were often types of basic science courses. The project courses were assessed according to the project and were intended to support the projects. The problem was that students only paid attention to the project courses if they supported and were useful for their projects. As students have always had the freedom to choose which problems to address during project work within the broader learning outcomes, it can be hard to run courses that directly support a single project. The structural change was therefore that all taught courses should have their own assessment (see Figure 1.1). This has created other issues, as the taught courses no longer needed to relate to the project, which is why academic staff felt that there should be better coherence between taught courses and projects.

In the baseline study, we surveyed attitudes and perceptions among academic staff and students. One of the questions concerned the future development of AAU. It is important to note that the data was collected in 2018 before the pandemic started in 2020.

Figure 1.2
Priorities in the Development of the future AAU Model



Note. Answers to the question: Which of the following elements do you think should be important priorities in the development of the AAU model of the future? Cross-faculty departments (N: 135 - 138). (Clausen & Kolmos, 2019)

The academic staff believed that better links between the taught courses, strengthening the theoretical disciplines, and their relationship to the research, followed by more interactions with companies, greater integration of practice-based elements, and increased interdisciplinarity across the faculties were very important. All three university modes are represented in these priorities: the academic mode by emphasising the theoretical content and relationship to research, the market-oriented mode in the company and practice elements, and finally the community-based mode with increased interdisciplinarity. Academic staff, therefore, see a diverse development to address all university modes, but this also means that there are tensions among the academic staff about the direction of the study programmes.

However, the academic staff did not regard an increase in group-based project work and aspects of digitalisation as important priorities. This illustrates the priorities among academic staff before the pandemic when there was a preference for physical learning and less interest in developing the PBL model into

a digital or blended mode. All institutions have issues in creating change, and AAU is no exception. People prefer what they know, and it is hard to create new experiences and trust in systems.

Contemporary challenges for higher education

The question is how the Aalborg model, and even PBL in general, can respond to contemporary challenges. New challenges have emerged over the last 20 years. One of the biggest challenges is to prepare graduates to work on the sustainability challenges formulated in the Sustainability Goals (SDGs). Future graduates need to see themselves as global citizens embracing human and complex challenges. For higher education, this will involve a curriculum that addresses complex problems and systemic and interdisciplinary approaches. No single discipline will be able to solve complex problems, and there is an increasing need for types of interdisciplinary collaboration (Barry et al., 2008). Therefore, there is a challenge for higher education to educate graduates who can contribute to solutions for the SDGs.

Some higher education institutions around the world are responding to these challenges by addressing real-life and complex problems in education. A recent report identified student-centred learning models such as problem- and project-based learning (PBL) as one of the core responses to contemporary challenges (Graham, 2018). A recent review of PBL in engineering education, however, suggests that the most common application of projects is within existing discipline courses rather than across courses, or at the curriculum level (Chen et al., 2020). PBL is rarely applied to address the complexity of current societal challenges, and a change to more interdisciplinary PBL models dealing with complex problems must be facilitated.

The ageing population in the western world, together with ever-faster technological developments has resulted in a renewed and increased need for continuing education or lifelong learning. This need for lifelong learning and education has been acknowledged since the 1990s. Lifelong learning has been included in higher education policies at the European level and is something that becomes more and more urgent (Gordon et al., 2009). During the 1990s and 2000s, universities developed a parallel competence system by offering professional master's degrees as part-time studies and/or via online programmes (Dowling, 2006; Gordon et al., 2009; Hallenga-Brink & Vervoort, 2015).

More recently there has been a change in the discourse around lifelong learning and education, which has become increasingly occupied with questions of

flexibility and personalised learning (Billett, 2018). Lifelong learning has gone from being understood as providing the resources to participate in continuing education to a concept of personal learning trajectories (Nielsen, 2008; Niess, 2015). The understanding of the concept has become more personalised, and the individual learner thus creates their own learning trajectories. It is the responsibility of educational institutions to offer flexible educational offers for lifelong education so that learners can jump in and out of formal education (Ludvigsen et al., 2010).

Personal learning trajectories are based on the concept of personal learning and encompass individual flexibilities in the creation of one's competence development (Lahn, 2010). Learning takes place in many locations, and an individual must be able to advance learning from the wealth of different networks and groups in both formal and informal networks. The individual learner must be able to develop their own professional and organisational competence; that is, both assimilate learning in relation to known frameworks and accumulate and transform learning from one context to another, and from one conceptual understanding to a new one. Accumulating and transforming knowledge and skills is also about being able to choose strategies, methods and techniques for specific situations, and first of all, having the competence to read and analyse the needs in new situations. There is an important distinction between the transfer and transformation of learning. Transfer of learning is possible between similar contexts; however, differing contexts require a transformation of learning (Carlile, 2004).

This development calls for much more flexibility in higher education, to become lifelong education. Minor offers – such as the concept of micro-credentials or MOOCs – can be elements in a learner's construction of their lifelong learning trajectory. It is difficult for universities to offer types of continuing education in terms of short courses. A master's degree fits well into the university structure, but it takes time to obtain a master's degree. There is thus a need to find ways to offer more just-in-time education for lifelong learners and companies which want to upgrade groups of employees systematically. An example is upgrading in AI, where it is necessary not only to integrate the learning of AI into the educational system but indeed to find ways in which universities and companies can educate and re-educate the workforce.

Another trend is the privatisation and corporatisation of higher education, as well as increased demands to respond to business needs. This is associated with the market-driven view of universities. Firstly, this involves the emerging trend wherein companies are liaising with universities to develop specific

courses or programmes to cater to their immediate needs for highly skilled workers in particular areas (e.g., artificial intelligence or machine learning) (Gordon et al., 2009). Secondly, it involves companies or entrepreneurs setting up their own schools and education, thus bypassing "traditional" itineraries through education and challenging universities' existing monopoly on education. One such example involves the 42 schools founded and funded by tech-entrepreneur Xavier Niel. These schools are tuition-free educational opportunities particularly focusing on computer programming or coding. Their motto is "born2code" and the 42 schools advertise "zero tuition, zero teachers, zero classes, 100% coding" and supposedly build on peer-learning and project-based learning (i.e., students work individually or in teams on their own development projects). The programme is described as rigid yet flexible, with projects of varying lengths and a 100% personalised curriculum. The initiative emphasises that its programmes are tightly aligned with industry needs and lifelong learning skills. The schools and campuses have now spread beyond France, there are campuses in Silicon Valley and Armenia, and a flurry of similar initiatives have been (or are being developed) across the globe.

Similarly, the popularisation of MOOCs in 2012 resulted in a massive number of online courses, programmes and forms of certification (Baturay, 2015). These are made available by universities and companies (or various types of collaborations between the two). They build on a variety of different business models and are hosted on different platforms (edX, Coursera, FutureLearn etc.). While some MOOCs are built on more traditional examples of distance education, the MOOC wave also resulted in several pedagogically innovative and experimental designs; for example, featuring problem- or project-based learning, or various types of designs for collaborative or cooperative learning.

The proliferation of MOOCs and similar initiatives to develop new types of online education together, or in competition, with higher education, have also tied in with the political reforms of making higher education more flexible or personalised: that students should have better opportunities to stitch together their own education unencumbered by institutional or geographical borders – their personal learning trajectories. For example, the European Credit Transfer System (ECTS) was/is a political initiative to allow students to traverse geographical and institutional borders within Europa. Equally, the Bologna process of modularising and harmonising educational provision is an attempt to transcend such borders. In more recent times, ideas of international credit transfer, micro-credentials, and the ability for students to freely orchestrate their own education and create their own learning paths, trajectories, or

itineraries have thus emerged and solidified the move towards lifelong learning and education, understood as building on flexibility and the ability to create personal learning trajectories.

Following on from this, one of the new requirements is that learners are able to handle the individual creation of learning trajectories and to be able to navigate among a series of offers from both public and private providers and universities. This is a more recent concept or vision of lifelong learning and education.

Is PBL still the answer?

PBL is a concept covering many practices and has been an answer to the variation in the requirements for the three modes: the academic, the market, and community-driven modes. The type of problems can vary and the interaction with a range of different actors in society can vary. There might also, however, be issues in the degree of flexibility and personalised learning trajectories.

Several new universities were established during the 1960s and 1970s with new pedagogies which included the learners' experiences, social interaction, and real-life problems in the curriculum. Compared to traditional academic learning, which was theoretically oriented without attending much to the relevance of practice, the PBL pedagogies were a revolution. Two types of PBL were established: case-based PBL (mostly applied in the health area) and project-based PBL (mostly applied in the humanistic, social science, and engineering fields). An analysis of the learning principles saturating the original versions of problem-based learning, project-based learning, and even enquiry-based learning shows that they share the same fundamental learning philosophy based on social constructivism. At the level of learning principles, it might be very hard to distinguish one pedagogical model from the other (Marra et al., 2014). The different models aim to stimulate a student's curiosity for learning by identifying problems (authentic and academic) and analysing the problems in a broader societal context. They feature self-directed or participant-directed learning in teams or group work and include new roles for the teachers as facilitators. The models promote interdisciplinary approaches and an exemplary reflection of student learning outcomes in the projects or cases (Algreen-Ussing & Fruensgaard, 1992; Barrows, 1986; Barrows & Tamblyn, 1980; Kolmos, 1996).

The case-based and project-based PBL models are distinguished in that the curriculum and the practices are different. In case-based PBL, the learning

process is organised around cases describing authentic problems. For example, students work in groups of 10–12 persons analysing and identifying their learning objectives. They identify relevant methodologies and solutions for the problems, and in the end, the examination will be individual (Barrows, 1986; Servant, 2016; Servant & Schmidt, 2016). The cases around which the learning process is organised are designed by the academic staff, and a tutorial will accompany the cases, developed for tutors facilitating the students in their groups.

Project-based PBL has other origins, although it started in the same period as case-based PBL. Its Anglo-Saxon history can be traced back to Kilpatrick (1918), who built on the ideas of Dewey in developing the project method (Kilpatrick, 1918; Levine, 2001; Pecore, 2015). Its European history can be traced to German roots in the 1960s, when the critical theories of Negt and Kluge, who argued for developing the social critical mind and developing social class consciousness, dominated (Illeris, 1974; Servant, 2016). The actual practice varies in terms of types of problems, types of projects, length of activities, the combination of lectures and student work, progression throughout the study, assessment methods, teacher training, and institutional or course implementation, among other things (Felder, et al., 2000; Prince, 2004; Savin Baden & Howell, 2004). In the beginning, students identified a problem guided by a broad thematic framework, but over the years, teachers more often suggested relevant problems for their students to work with.

Both the case-based and the project-based systems separately or in combination run the risk of becoming too standardised as do all other university classes. In the case-based system, a great deal of energy is invested in designing cases and the possible accompanying tutorials. Even though cases and problems are new to the students, the organisation of the PBL processes becomes a new "informal textbook" with known procedures for the academic staff.

There is a risk of repeating project proposals from one year to the other in the project-based PBL model. But the culture can influence the engagement of staff and students in identifying new problems, and it can be an easy solution to re-use earlier project proposals to meet the learning outcomes. Even if students are working on authentic problems, this might include a tendency towards pragmatism and instrumentalism.

Thus, an emerging challenge for PBL curricula is that they become rigid. There is therefore a need to develop the understanding, principles, and practices of PBL even if there are presently very positive research results concerning the effectiveness and outcomes of the PBL models.

Challenges for the AAU PBL model

The traditional way of enabling flexibility for students in universities is to provide an elective course system, where students will have to pass some compulsory courses, but simultaneously have the opportunity to elect courses and specialisations according to their interests.

The essential challenge for AAU is that the PBL model has a semester approach. Flexibility in the AAU PBL model and establishment of the personal learning trajectories lies primarily in the project work, as the provision of courses within a semester is relatively static and determined via the programme's curriculum. The opportunities for flexibility and specialisation are therefore primarily associated with the project work. Consequently, the formation of the project group and their choice of problem to work with becomes a decisive factor. A challenge in this regard is that there are other concerns at stake for an individual student than purely educational and professional considerations. In practice, the problem and project groups are often chosen based on, for example, social dynamics, and groups of students often follow each other through the course of their studies.

Many of the contemporary challenges outlined above, especially the personal learning trajectories and flexibility, fundamentally challenge AAU's pedagogical model. Personal learning trajectories, flexibility, and digitalisation are interconnected as a response to the requirement of educating graduates who can engage with increasing societal complexity in a rapidly changing world. The challenges tomorrow, and the challenges faced by students upon graduation, are unknown when they begin their educational journey. Disruption, newly emerging technologies and the ever-increasing emergency of climate change and sustainability combined with economic and global instability and inequality call for graduates who can adjust to constantly changing conditions.

For the higher education systems, this implies that there is flexibility for the learner and that there will be a series of electives from which the individual learner can choose. An elective system can become even more flexible by adopting digital technologies to provide wider access to educational resources, and to other learners outside the universities.

PBL competences as a response to flexibility and personalised learning trajectories?

Aalborg University has responded to many of the challenges over the last four years. Digitalisation has been rolled out as an integrated part of the institution-

al strategy, and, as it has for many other universities, the Covid 19 pandemic has accelerated the implementation of digital technologies for teaching and learning. There have been initiatives for new types of student projects, such as multidisciplinary megaprojects, and progressive PBL competences have been implemented formally in curricula across AAU.

PBL competences involve reflection on the participation in problem-oriented project processes. During the first year, the students will be introduced to PBL and methodologies that reflect the PBL learning practices. Later in their studies, students will have to re-visit these reflections and reflect further on their progress. The PBL competences are defined according to four domains (Holgaard & Kolmos, 2019):

- problem-oriented competences, including the ability to identify, analyse, formulate, and address authentic problems in an exemplary way
- interpersonal competences, including the ability to communicate and collaborate both in a team and with external partners to address complex problems
- organisational and leadership competences, including the ability to manage problem-based processes, such as in a project organisation.
- meta-cognitive competences, including the ability to develop PBL competences as well as to transform learning from one PBL environment to another.

PBL competences can be one response to flexibility and personalised learning, as these competences are acquired by iterative reflection on the educational experiences and in making these meaningful in the learner's inner universe, as well as in a social context. Meaningfulness embraces an understanding of the actual situation in which the learner creates experiences and an awareness of the impact on behaviour and actions in future situations.

These learning processes are complex by nature, as there will be no textbook with the right answer or recipe for how the individual should learn and reflect. The reflection and learning process will be an intertwined process of cognitive rationale, emotional processing, and personal appropriation of tools and skills. The objectives for this process of acquiring PBL competences are that students can scientifically analyse and solve a diverse range of societal problems by participating in, and contributing to, collaborative and complex learning situations.

PBL competences can be acquired by facilitating the reflection of these competences at the individual and the team level and relating and connecting the reflection of practice experiences to theoretical constructs or models. Conceptual and theoretical understanding is important for the learner to transform skills and competences for future situations. Practice competences are normally learned in a specific situation or context, and it is hard to transfer that learning when a new situation arises. One way of making this transformation process easier is being able to articulate and conceptualise the experiences.

Another way of making a transfer or transformation process easier involves competences and awareness of the situation and adaptation. In many ways, these competences can be defined as a type of "art", as they are highly complicated and rely on tacit cultural understandings. They are based on intuition and experiences. Students who participate in the same project group, semester after semester, will create a high level of tacit team culture, and they may act and do things without discussing or negotiating. This is very efficient for the project viewed as a product, however, this is far from efficient for the project viewed as a process for learning organisational competences, as a new situation will require the construction of a new collaboration pattern, such as ways of sharing the work, setting up efficient project plans, team culture, and so on.

Students need to experience variations in the curriculum. By this we mean variation in types of problems, projects (size, support for the projects (facilitator and relationship to courses), teams (group size, local and international teams, types of collaboration patterns), and space (hybrid, digital, blended, and physical). By experiencing a range of different situations across these parameters, students have a better foundation for comparing, discerning, analysing and conceptualising their varied experiences.

There is an argument that students will improve their learning of PBL competences by experiencing more variation in their learning processes. The assumption goes further than that, as students will improve their scientific knowledge and competences by experiencing a higher degree of variation in the PBL curriculum, as well as in the specific learning processes. Types of problems, project size and the coherence between taught discipline courses and the projects are all connected to the subject-related learning outcomes. At the end of the day, many decisions about variation in PBL are scientific decisions rather than being based on considerations for learning PBL competences. When do students need to learn that knowledge exists and might be relevant – and when is it important for students to gain a deep understanding of certain subjects?

Variation is therefore one of the new fundamental learning principles – not only in a PBL curriculum but indeed for organising any learning process. We are used to repeating successes and situations where we had a gut feeling that things would work out well. We are used to repeating what is known to us. The ways we have been taught are normally the ways people will teach, as this is what we know from a learner's perspective. At universities, we are used to being measured by our research records, and not normally by our teaching experiments. We are "used to" being introduced to cuts in resources that will leave less time for teaching and call for faster decisions regarding teaching methods. Any voluntary change might feel like driving on cobblestoned roads unless there is an emergency such as that of the Covid-19 pandemic, but it does not devalue the fact that student learning will benefit from more variation in the curriculum.

The principles of variation and reflection will be the cornerstones of the next chapter, together with an understanding of development as a process of hybridisation.

References

ABET. (1995, October 12). *A vision for change: A summary of the ABET/ NSF industry workshops*. Baltimore. http://bioinfo.uib.es/~joe/semdoc/ PlansEstudis/ABET_Criteria_PTE/Vision.pdf

ABET. (2014, October 12). *Criteria for accrediting engineering programs*. https://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf

Algreen-Ussing, H., & Fruensgaard, N. O. (1992). *Metode i projektarbejdet: problemorientering og gruppearbejde* (3rd ed.). Aalborg Universitetsforlag.

Kolmos, A., Fink, F. & Krogh, L. (2004). *The Aalborg PBL Model*. Aalborg Universitetsforlag.

Barnett, R. (2010). *Being a university* (1st ed.). Routledge. doi:10.4324/9780203842485

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education, 20*(6), 481-486.

Barrows, H. S., & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education: Springer.

Barry, A., Born, G., & Weszkalnys, G. (2008). Logics of interdisciplinarity. *Economy and society, 37*(1), 20-49.

Baturay, M. H. (2015). An overview of the world of MOOCs. *Procedia-Social and Behavioral Sciences, 174*, 427-433.

Billett, S. (2018). Distinguishing lifelong learning from lifelong education. *Journal of Adult Learning, Knowledge and Innovation, 2(*1), 1-7.

Carlile, P. R. (2004). Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organization Science 15*(5): 555-568.

Chen, J., Kolmos, A., & Du, X. (2020). Forms of implementation and challenges of PBL in engineering education: A review of literature. *European Journal of Engineering Education*, *46*(1), 90-115. doi:10.1080/03043797.2020.1718615

Clausen, N. R., & Kolmos, A. (2019). PBL Future work report 1: Preliminary findings of the staff survey: Presentation of frequencies on faculty level from the staff survey. Aalborg Universitet. https://www.ucpbl.net/digitalAssets/659/659959_staff-rapport-pbl-future-2018-final.pdf

Dowling, D. G. (2006). Designing a competency based program to facilitate the progression of experienced engineering technologists to professional engineer status. *European Journal of Engineering Education, 31*(1), 95-107. doi:10.1080/03043790500429542

Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The future of engineering education II. Teaching methods that work. *Chemical Engineering Education, 34*(1), 26-39.

Gordon, J., Halász, G., Krawczyk, M., Leney, T., Michel, A., Pepper, D., . . . Wiśniewski, J. (2009). Key competences in Europe: Opening doors for lifelong learners across the school curriculum and teacher education. *CASE Network Reports,* 87

Graham, R. (2018). The global state of the art in engineering education. *Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA*

Guerra, A. (2015). *Problem based learning and sustainable engineering education.* [Doctoral dissertation, Aalborg University]

Hallenga-Brink, S., & Vervoort, I. (2015). Higher education institutions as international hubs in community service engineering innovation networks a European Lifelong Learning Program project. Proceedings of the *2015 Conference on Raising Awareness for the Societal and Environmental Role of Engineering and (Re) Training Engineers for Participatory Design (Engineering4Society)* (pp. 34-40). IEEE.

Holgaard, J. E., & Kolmos, A. (2019). Progression in PBL competences. Proceedings SEFI 47th Annual Conference: Varietas Delectal: complexity is the new normality (pp. 1643-1652).

Illeris, K. (1974). Problemorientering og deltagerstyring: oplæg til alternativ didaktik: Munksgaard.

Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education, 103*(2), 253-273. doi:10.1002/jee.20041

Kilpatrick, W. H. (1918). The project method: The use of the purposeful act in the educative process. Teachers College, Columbia University.

Kolmos, A. (1996). Reflections on project work and problem-based learning. *European Journal of Engineering Education, 21*(2), 141-148. doi:10.1080/03043799608923397

Kolmos, A. (2021). Engineering Education for the Future. In UNESCO (Ed.), *Engineering for Sustainable Development* (pp. 121-128). UNESCO.

Kolmos, A., & Holgaard, J. E. (2012). *Evaluering af ændringerne i PBL modellen på TEKNAT AAU.* http://www.ucpbl.net/Reports%2C+Videos+and+Promotion/Working+Papers/

Kolmos, A., Holgaard, J. E., & Clausen, N. R. (2021). Progression of student self-assessed learning outcomes in systemic PBL. *European Journal of Engineering Education, 46*(1), 67-89.

Lahn, L. C. (2010). Professional learning as epistemic trajectories. In Ludvigsen, S. R., Lund, A., Rasmussen, I., & Säljö, R (Eds.), *Learning Across Sites* (pp. 65-80). Routledge.

Levine, D. (2001). The project method and the stubborn grammar of schooling: A Milwaukee story. *The Journal of Educational Foundations, 15*(1), 5.

Ludvigsen, S. R., Lund, A., Rasmussen, I., & Säljö, R. (2010). *Learning across sites: New tools, infrastructures and practices.* Routledge.

Magnell, M., Geschwind, L., & Kolmos, A. (2017). Faculty perspectives on the inclusion of work-related learning in engineering curricula. *European Journal of Engineering Education, 42*(6), 1038-1047. doi:10.1080/03043797.2016.1250067

Marra, R. M., Jonassen, D. H., Palmer, B., & Luft, S. (2014). Why problem-based learning works: Theoretical foundations. *Journal on Excellence in College Teaching, 25*(3&4), 221-238.

Maassen, P., & Stensaker, B. (2011). The knowledge triangle, European higher education policy logics and policy implications. *Higher Education, 61*(6), 757-769.

Nielsen, K. N. (2008). Learning, trajectories of participation and social practice. *Outlines. Critical Practice Studies, 10*(1), 22-36.

Niess, M. L. (2015). Transforming teachers' knowledge: Learning trajectories for advancing teacher education for teaching with technology. In Angeli C., Valanides N. (Eds.), *Technological Pedagogical Content Knowledge* (pp. 19-37). Springer.

Pecore, J. L. (2015). From Kilpatrick's project method to project-based learning. In P. Lang (Ed.), *International Handbook of Progressive Education* (pp. 155-171).

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223-231. doi:10.1002/j.2168-9830.2004.tb00809.x

Savin Baden, M., & Howell, C. (2004). *Foundations of problem-based learning*. McGraw-Hill Education.

Servant, V. (2016). Revolutions & re-iterations: An intellectual history of problem-based learning. Erasmus University Rotterdam (EUC).

Servant, V. F., & Schmidt, H. G. (2016). Revisiting 'Foundations of problem-based learning: Some explanatory notes'. *Medical Education, 50*(7), 698-701.

Sterling, S. (2004). Higher education, sustainability, and the role of systemic learning. In Corcoran P.B., Wals A.E.J. (Eds.), *Higher Education and the Challenge of Sustainability* (pp. 49-70). Springer.

Trowler, P. (2002). Higher education policy and institutional change. Citeseer.

Hybridisation, Variation and Reflection: New PBL Curriculum Principles

Thomas Ryberg & Anette Kolmos

Over the years, the Aalborg PBL model has stabilised and solidified. This has led to the formulation of central principles of the Aalborg PBL model. These principles are described in an official booklet available on Aalborg University's website (Askehave et al., 2015) and presented below in a condensed format:

- The problem as a point of departure
- Projects organised in groups
- The project is supported by courses
- Collaboration – groups, supervisor, external partners
- Exemplarity
- Student responsibility for learning

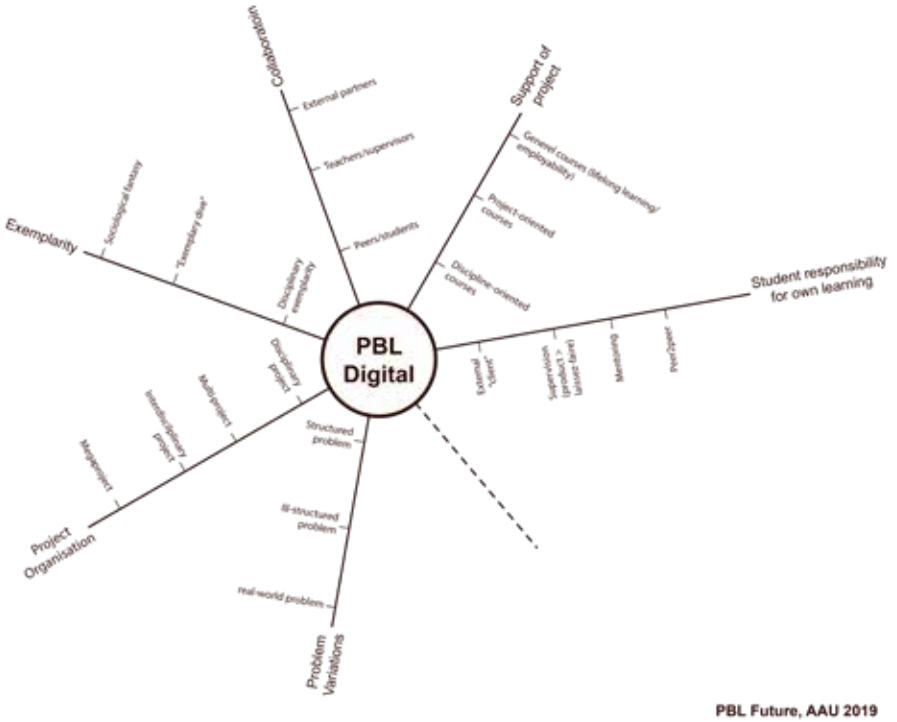
The booklet on the PBL principles also describes the framework (educational vision, curriculum, and assessment), the practice (students, academic staff, external relations), and the role of support functions (resources, student organisation and programme administration, research in PBL).

As described in the previous chapter, and raised in Chapter 5, the principles have led to a solidification of the PBL model with students working in smaller groups throughout the semester on their project (15 ECTS), supposedly supported by disciplinary theoretical, methodological, or practical courses (3*5 ECTS) – to the extent, perhaps, where it is now time to challenge and develop the model, its underlying principles and the ways of organising PBL at Aalborg University.

To address the challenges outlined in the previous chapter, variation in the curriculum can be one of the keys to constructing a more flexible curriculum. During the past four years, new initiatives such as megaprojects, case competitions and hackathons have been pushing the boundaries and understanding of PBL practices. In a study of possible future PBL scenarios, Bertel et al. (2021) suggested incorporating the principles of variation in the creation of the cur-

riculum. For each of the principles, there are different and more varied ways to enact the principles (Figure 1).

Figure 1
Variation in the PBL Principles



Here the authors explore and add varied ways of enacting, for instance, the principle of 'project organisation' or 'problem variations' ranging from narrow to more open-ended approaches. The existing Aalborg PBL model does not exclude changes and the development of new variants of PBL. We could point to examples of innovation such as different types of disciplinary and multidisciplinary megaprojects (student projects consisting of a large number of students working on a common project and organised in subprojects) or ideas of flipped semesters (as explored in Chapter 8). However, the PBL principles have not been discussed from a variation perspective. On the contrary, the principles are being inscribed in the curriculum of all programmes and have resulted in a reification of particular orchestrations of PBL over others.

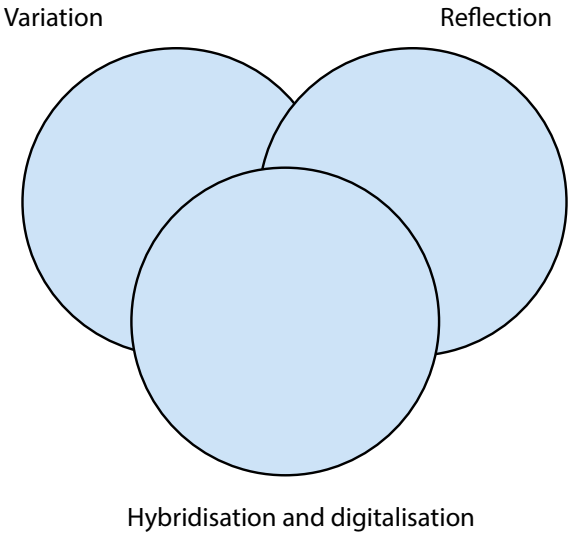
When the PBL principles were formulated, it was the intention to define the core curriculum practice. Since the beginning of AAU, it has been necessary

to define and provide data for the efficiency of the PBL model. Today, with the wide dissemination of PBL all over the world and with implementation at prestigious universities such as UCL and MIT, the question has developed from a question of whether PBL works to a question of which ways to organise PBL most efficiently. As such, it is not a question of applying problems and projects in the learning process, but what types of projects and problems?

Beyond the PBL curriculum principles

Following this, it feels timely to present additional thoughts, theories, and reflections to challenge and revitalise the current PBL thinking. In this chapter, we, therefore, propose some theoretical concepts, which we argue could add an underpinning to the existing model. This will also allow for rethinking and further developing the current PBL principles.
These concepts are hybridisation and digitalisation, variation, and reflection (Figure 2).

Figure 2
Combination of Theoretical Principles



The concepts or themes have emerged over time during the PBL Future research project and the coming together of this book. They saturate, to various degrees, the individual chapters. Some chapters concern variation more than hybridisation and vice versa, but the chapters as a collective revolve around these concepts. Hybridisation and digitalisation have been combined, as digitalisation allows for rethinking the organisation of learning and work. For example, procedures for sharing documents and analysing data have changed and provide new opportunities for collaboration among team members, and therefore the concept of hybridisation is important in the development. In digitalisation processes, it is important to rethink the existing organisation and practice to align with new potential ways of learning and working.

In the following, we will dig deeper into the three concepts and we will return to the concepts more explicitly when discussing the four scenarios in Chapter 9.

Hybridisation and digitalisation

Hybridisation and digitalisation express trends that have shaped and influenced higher education for the past two to three decades and particularly concern the changes brought about by the popularisation of the Internet (or more specifically the World Wide Web). Although online learning via the Internet has been known in the form of computer-mediated communication (CMC) within universities since the late 60s and early 70s (Harasim, 2017), it was with the popularisation of the World Wide Web in the early 90s that online learning became a more widely known and explored mode for higher education – initially through, for instance, bulletin board systems (Weller, 2020), but later in the form of learning management systems (LMSs), such as Blackboard and Moodle. While LMSs were initially devised for fully online courses, the rapid spread in the new millennium of laptops and institutional access to Wi-Fi (later mobile phones and always-on access for students) have made these systems an intrinsic part of higher education. Course and learning management systems have (in some parts of the world) become part and parcel of higher education. Through LMSs, on-campus students have access to various learning materials online (text, slides, videos, etc.), and the student-teacher administration communication around courses has become increasingly mediated. Thus, digital systems have become an important infrastructure for communication and managing the everyday logistics of studying (what to read, schedules, announcements, etc.) (Caviglia et al., 2018).

The increased digitalisation also led to increased interest in blended learning and what has later become known as 'flipped classroom' or 'flipped learning' (Reidsema et al., 2017). At its outset, blended learning concerned primarily pedagogically designed alternations between online and on-site learning and teaching, i.e., having some learning and teaching activities occurring online in a programme or course, while others are carried out on-site. This has led to many different ways of designing blended and flexible programmes – for example, where students only come to class some days during the week, while on other days activities are online and the students can participate from their homes. In a Danish context, this format at the universities is primarily explored in master programmes for professionals (which are often blended or fully/mostly online), whereas the university colleges have more extensively pioneered such formats in their provision for full-time students (Dau, 2020).

Blended Learning, however, has come to mean many things, and as explored and summarised by Hrastinski (2019) it has become a broad umbrella term that can, for example, cover mixing or blending online learning with face-to-face, mixing media, mixing contexts, or mixing theories of learning. In this sense, blended learning has come to mean almost any situation in which digital technologies intermingle with a 'traditional classroom or lecture hall' if there is such a thing anymore.

The latter point, far from being trivial, is that digital technologies (in some parts of the world) are now so interwoven with educational infrastructures that it is hard to imagine untangling digital technologies from education. In saying this, it is instructive to remember that digital technologies are not only the most recent technologies we are currently experimenting with and implementing in education. They are equally the tools we have come to rely on to the extent that we do not refer to them as 'digital educational technologies'. They are the administrative systems for managing students, they are the computers used to produce PowerPoints, research articles, or when coordinating teaching with others through emails. They are the Wi-Fi connections, projectors, etc. that are part of the fabric of education today. In the same vein, some researchers are beginning to speak of the 'post-digital' as a term that better captures the current landscape of how technologies are woven into education, and society more generally:

> The postdigital is hard to define; messy; unpredictable; digital and analogue; technological and non-technological; biological and informational. The postdigital is both a rupture in our existing theories and

> their continuation. However, such messiness seems to be inherent to the contemporary human condition. (Jandrić et al., 2018, p. 895)

Digital and digitalisation are both fundamental conditions but at the same time an ever-looming external pressure and discourse permeating higher education. Digitalisation is a condition, a demand, but also an opportunity for expanding current practice. It is from this perspective that we adopt the terms 'hybridisation' and 'hybrid education'. The digital is already here. It is woven into our educational infrastructures and has already impacted greatly the landscape of higher education.

Hybridisation

Digitalisation and hybridisation are linked and interrelated concepts. In the following, we shall unpack the subtle reasons for adopting the terms 'hybridisation', 'hybridity', and 'hybrid' over terms such as 'blended' or 'flipped'. The terms 'hybrid' and 'blended', as noted by Hrastinski (2019), are often used interchangeably, but we argue that the notion of 'hybridity' has some additional explanatory and analytic capacities.

The idea of hybrids and hybridity has roots in biology and refers to: "cross-fertilization or the fusion of separate parts or species into a new one [...] At its core, hybridity refers to a mixture of different parts into a new breed, form or culture" (Hilli et al., 2019, pp. 68, 69). Thus, hybrids are not merely a mix of two things but are something else in their own right. The notion of hybrids or hybridity we, therefore, see as subtly distinct from a 'blend' of two things, and as a better way to express that the 'fusion' leads to something distinctively new that was not there before, i.e., the whole is greater than the sum of its parts. This is eloquently put by Nørgård (2021): "Unlike blended learning, then, hybridity embraces the qualities of fusing and dissolving difference and works with the blurred lines of today's post-digital world".

Nørgård further explores the distinct meanings of the terms 'hybrid', 'hybridisation', and 'hybridity' (Nørgård, 2021). The *hybrid* itself is the new 'species'. *Hybridisation* is the process or the stages of development in the making of new hybrids, and *hybridity* is a term to describe what makes the hybrid hybrid, i.e., what is its otherness, distinctiveness, or signature trait compared to other species. An important feature of hybridity is that it does not only concern, for example, hybrids that have to do with digital technologies, but an equally pedagogical concept or knowledge domains: "(...) hybrid education and learn-

ing becomes centred around the entanglement and crossbreeding of concepts, formats, domains, etc. that are transfigured into new configurations". Whereas 'hybrid education and learning' and 'hybridity' often concern hybrids emerging from the meeting between online and on-site, the digital and the material, they go beyond 'delivery formats' or the mixing of 'analogue' and 'digital' elements in teaching. For example, Stommel (2012) suggests a longer list of binaries one can view as having potential for hybridisation, including:

- Physical Learning Space / Virtual Learning Space
- Academic Space / Extra-academic Space
- Institutional Education / Informal Education
- Garden-walled Academia / Open Education
- Disciplinarity / Interdisciplinarity
- Individual Teachers, Students and Scholars / Collaborative Communities
- Learning in Schools / Learning in the World
- Machine and Machine-like Interaction / Human Interaction

And Nørgård (2021, p. 8) suggests that we can think of, for example:

- hybrid *roles* (being a learner, a professional, or a citizen),
- hybrid *contexts* (new relations between institution and society, or informal and formal),
- hybrid *practices* (thinking/tinkering and acquisition/performance), and
- hybrid *materials/spaces* (digital/analogue and online/on-site).

Our intention here is not to provide a comprehensive list, typology, or overview of categorisations of potential hybrids. Rather, we aim to highlight the idea that 'hybrid pedagogy and learning' supersedes the immediate connotations of having to do with 'digital' vs 'analogue', online vs on-site, i.e., being primarily concerned with different orchestrations of technology. Thus, we can equally think of hybridity as encompassing new configurations between education and work, the formal and informal, or the fusing of knowledge domains, such as STEM (science, technology, engineering and mathematics) into SSH (social sciences and humanities), or SSH into STEM. The latter is an example of a hybridisation process that is occurring now at AAU (and many other places), and it remains to be seen whether new interesting hybrids will emerge, or whether the transformation process will lead only to two distinct understandings being stapled together without mutually informing each other and transforming into a 'new

third'. This line of thinking, in terms of hybrid education, is also suggested by Jamison et al. (2014) in exploring a new third 'integrative' mode of Engineering Education.

It is worth noting that digital technologies are often an important driver or enabler for new forms of hybrid education – for example, for new ways of bridging education and work, bringing the university into the wider world / bringing the wider world into the university, or as a means to explore new relations between formal and informal learning. In the same vein, we understand and interpret hybridity as a way of actually 'backgrounding' digital technologies and 'foregrounding' instead new hybrids between roles, relations, contexts, spaces, and practices.

Variation

Similarly to hybridisation the concept of variation can also be found within biology. Here it is a core principle in evolution and an important force, as it allows natural selection within specific species. All humans belong to the same species, but we look different because of genetic differences, and we have, for example, different eye and hair colours, and some are taller or shorter, thicker or thinner, etc. We talk about genetic variations, which are the differences in DNA segments or genes between individuals, which is an implicit understanding of development. On rare occasions, we talk about variation in learning except for the different learning style tests, which have been applied to a certain degree for creating awareness of individual preferences.

Variation in learning is a concept that originated from phenomenography, which has given inspiration to both educational models and research on learning methods (Marton & Booth, 1997). The variation theory assumes that individuals understand and reflect on the world from their own perspective and aims to understand the variety in the experience of reality. The main focus of phenomenography is on relation, meaning that it is neither solely focused on what humans experience nor on the object being experienced, but on the relationship between the two dimensions and on the variation of experiencing. Learning takes place when students are "capable of being simultaneously and focally aware of other aspects or more aspects of a phenomenon" (Marton & Booth, 1997, p. 142). Comparing perspectives or experiences can give deeper awareness of what things are or are not, and the understanding of different perspectives might open up creative possible futures.

In variation theory, the object of learning is important, as is the fact that learning is always about something – that there is an object. Learning, then, is the ability to do something with something that relates to the content. Learning is interpreted as a change in the way something is done, seen, experienced, or understood and education is aimed at developing the learners' ability to handle various situations, analyse and solve different problems, and act effectively according to one's purposes and the conditions of the situation. Within the field of science education, variation theory is used for improving scientific understanding, experiencing variation, and articulating contrasts, similarities, and differences as one way to encourage reflection and make tacit knowledge explicit.

Sameness and difference

According to variation theory, there should be sameness and difference in the situations that which learning is transferred to and from. Otherwise, it is not possible to recognise patterns in the contexts or methodologies. The sameness allows experiences and knowledge to be brought from one situation to another; the difference allows for progressing learning. If we stay in the 'sameness', we are not challenged by new perspectives. However, if we stay in the 'difference', we might have difficulty in progressing our understanding and learning. The sameness will identify some kind of constant in the context/situation, or the methods applied. The difference will provide variation and might guide the learner into an accommodative learning process.

Any change in questions, purpose, or context will allow the students to reflect, expect, check, and think. This might lead to significant moments of discussion and learning when expectations are unmet, and students will have to think more deeply.

Variation can lead to learning through reflection on experiences and practice. Through reflection on variation, the learner can become aware of the characteristics of the experiences. The typical illustrative example is that the juxtaposition of colours, where you look at two blue colours side by side, will trigger looking at differences, peculiarities, and possibilities.

The same applies to, for example, project management in a group. If you have only experienced one way of collaborating and managing projects, this is the experience and knowledge you carry forward. However, if you have experienced varied ways of organising work, then you carry experience and knowl-

edge of different ways of doing it, as well as the ability to be flexible and to see which aspects are important in new situations.

For the individual learner, the ability to reflect and create transfer, transformation and progression in learning is a crucial part of creating lifelong learning paths or trajectories. The concept of 'learning trajectory' should be seen as a continuation of lifelong learning, which, 20–30 years ago, focused on creating a framework for lifelong learning through new educational structures. Learning trajectories is a broader concept based on the concept of personal learning and has individual flexibility. Learning occurs in many places and the individual must be able to learn from the wealth of different formal or informal networks and groups they engage with. The individual must be able to develop their own professional and organisational competence, both to assimilate in relation to known frameworks and to accumulate and transform learning from one context to another and move from one conceptual understanding to a new one. Accumulating and transforming knowledge and skills is also about being able to choose strategies, methods, and techniques for specific situations.

Reflection

Embedded in learning is reflection. Reflection is a way for both individual learners and groups of learners to become more aware of learning. It can be a way to reflect on practice experiences and become more aware of tacit knowledge in a practice.

Students' reflection can be enhanced by a variation on their collaborative and structural competences across different types of projects, for example through increased use of virtual platforms and digitally supported project work, as well as through acquiring knowledge of complex project work processes in types of projects in the business world as well as in education. Meta-competences are developed through continuous reflection on the development of the problem, collaboration, and project skills to improve the ability to transfer and transform experiences and methods from completed projects to new ones, as well as lifelong learning, which continues after graduation.

Through reflection in and on practice, there is an increased awareness of the elements of the usually tacit knowledge that is embedded in the collaborative culture that emerges in a project group. The tacit – non-articulated – knowledge, culture, and process make it difficult to transfer and transform knowledge and skills from one project to the next. We discuss reflection in depth in Chapter 6.

Hybridisation and digitalisation, variation, reflection

Bringing the three concepts together is an initial step to start thinking about future curriculum models and the future of the AAU PBL model, which we will pursue in Chapter 9. Variation as a principle is important because it suggests that students should experience various ways of organising for PBL that go beyond small-group project work. This includes new ways of organising and structuring the curriculum, as we return to in Chapter 9. Hybridisation and digitalisation are important in relation to variation as the digital offers new opportunities for teaching, learning, and the organisation of the curriculum. Reflection is what brings variation and hybridisation together. If students (and teachers) do not systematically reflect on their practices, on the variation between different organisations for learning or how different modes (such as on-site vs online) affect collaboration, the result may be disparate and fragmented experiences that do not add up to a greater whole in terms of learning outcomes but remain a disaggregated part. Thus, as we shall return to in Chapter 9, overarching curriculum models are needed to ground and anchor changes.

References

Askehave, I., Prehn, H. L., Pedersen, J., & Pedersen, M. T. (2015). PBL – Problem-based learning. Retrieved from https://www.aau.dk/digitalAssets/148/148025_pbl-aalborg-model_uk.pdf

Bertel, L. B., Askehave, I., Brohus, H., Geil, O., Kolmos, A., Ovesen, N., & Stoustrup, J. (2021). Digital transformation at Aalborg University: Interdisciplinary problem- and project-based learning in a post-digital age. *Advances in Engineering Education, 9*(4).

Caviglia, F., Dalsgaard, C., Davidsen, J., & Ryberg, T. (2018). Studerendes digitale læringsmiljøer: Læringsplatform eller medieøkologi? *Tidsskriftet Læring og Medier (LOM)*, *10*(18). https://doi.org/10.7146/lom.v10i18.96928

Dau, S. (2020). Læring på og i Blended Learning. *Tidsskriftet Læring og Medier (LOM)*, *12*(22), 23–23. https://doi.org/10.7146/lom.v12i22.115955

Harasim, L. (2017). *Learning theory and online technologies*. Routledge. https://doi.org/10.4324/9781315716831

Hilli, C., Nørgaard, R. T., & Aaen, J. H. (2019). Designing hybrid learning spaces in higher education. *Dansk Universitetspædagogisk Tidsskrift*, *15*(27), 66–82.

Hrastinski, S. (2019). What do we mean by blended learning? *TechTrends*, *63*(5), 564–569. https://doi.org/10.1007/s11528-019-00375-5

Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education*, *103*(2), 253–273. https://doi.org/10.1002/jee.20041

Jandrić, P., Knox, J., Besley, T., Ryberg, T., Suoranta, J., & Hayes, S. (2018). Postdigital science and education. *Educational Philosophy and Theory*. https://www.tandfonline.com/doi/abs/10.1080/00131857.2018.1454000

Marton, F., & Booth, S. (1997). *Learning and awareness* (1st ed.). Routledge. https://doi.org/10.4324/9780203053690

Nørgård, R. T. (2021). Theorising hybrid lifelong learning. *British Journal of Educational Technology*, *n/a*(n/a). https://doi.org/10.1111/bjet.13121

Reidsema, C., Kavanagh, L., Hadgraft, R., & Smith, N. (2017). *The flipped classroom: Practice and practices in higher education.* Springer. https://link.springer.com/openurl?genre=book&isbn=978-981-10-3411-4

Stommel, J. (2012). Hybridity, Pt. 2: What is hybrid pedagogy? *Hybrid Pedagogy*. http://hybridpedagogy.org/hybridity-pt-2-what-is-hybrid-pedagogy/

Weller, M. (2020). *25 years of ed tech*. AU Press.

Participant Direction

Anders Melbye Boelt & Nicolaj Riise Clausen

Although various modes of problem-based learning (PBL) are currently being practised within many realms of education, each mode shares the aspiration of bringing students to the forefront and centre of the learning process. The central position proposed in PBL affords substantial opportunities for students to influence the trajectory of scientific inquires, whether these are based on closed or complex problems. In many PBL models and practices, however, problems are defined by the fact that academic staff and students have limited options to influence the direction of their learning. This chapter is intended to re-activate the discussion on participant direction and student-centredness, and to do this, we look at the potential framing of learning processes afforded by various PBL practices.

According to Savin-Baden and Major (2004), there are multiple modes of PBL practices, each with different aspirations and aims, some of which have been addressed in a more systematic manner than we will provide here (see Chen et al., 2020; Savin-Baden, 2014; Scholkmann, 2020). Olsen (2013) provides an example from a Danish context, noting the differences in the interpretation of the pedagogical principle *exemplarity* at Roskilde University and Aalborg University, where the former, in his view, is comparable with Negt's (1971) ideas of sociological imagination, and the latter is more akin to the exemplary platforms described by Wagenschein or even the *exemplar* found in Kuhn's *Structure of Scientific Revolution*. The latter is also noted indirectly by Kjersdam and Enemark (1994), who writes that educational themes and projects must be exemplary for professional practice. This example is exemplary(!) of the diverse field of PBL – even here between two sibling institutions in a small country, where similar traits and concepts are used and shared, albeit with local interpretations resulting in problems of direct commensurability between practising institutions (see for instance Scholkmann, 2020).

A concept closely related to participant direction is self-directed learning (SDL), which is often highlighted as an essential part of PBL, both as a correlat-

ed positive outcome and as an integrated process (Leary et al., 2019). Students in PBL environments are encouraged to take responsibility for and regulate their own learning through case or project work, often through supervisors or teachers who gradually become less involved over time (Dolmans & Schmidt, 2000; Loyens et al., 2008). That the students direct their own learning has often mistakenly been thought of as an individual process, but in doing so, students often apply peer learning and work in groups which motivates them to also keep each other accountable for their collective work. PBL is intended to not just teach students about the subject matter, problem-solving, and disciplinary information, but also to teach students how to navigate the ever-growing reservoir of knowledge within their field through self-direction (Savery, 2006). SDL has also been highlighted as playing such an essential role in PBL because of the large proportion of student time spent engaged in highly specialised work, potentially leading to a more narrow knowledge base and a heightened need for the ability to mitigate this (Kolmos & de Graaff, 2013). SDL originates in adult education theories and describes:

> […] a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, selecting and implementing appropriate learning strategies, and evaluating learning outcomes. (Knowles, 1975, p. 18)

While SDL is often mediated by supervisors or teachers, at least to formulate learning goals, students remain responsible for most elements found in the learning process. The social aspect of PBL precisely addresses this point by allowing participants to activate prior experiences to understand what is new, but subjective interpretations of experience mean that the basis differs and affects individuals in a group differently. Finding an agreeable direction then calls for abilities to de-centre one's beliefs to let others become involved in close collaboration (Hmelo-Silver, 2004).

SDL is the central theoretical and practical component of PBL and the emphasis on student-centredness. This should, however, not be mistaken as complete autonomy, but autonomy within the confines of a selected theme or initiating problem, depending, again, on the local interpretation and enactment of PBL. According to Illeris (1981), participant direction should *always* be considered relative to traditional lecture-based teaching, but external requirements and control mechanisms outside the educational sphere will render absolute

participant direction impossible (p. 105). The direct association between problem orientation and student autonomy is described as follows: a problem is not a problem in a psychological sense unless those who are engaged in working with it experience it as a problem (p. 102). Illeris (1981) writes that the Piagetian notion of accommodative learning only takes place in situations where something personal is at stake, so to speak – and why else bother? Although Dewey is not referenced by Illeris (ibid), Dewey writes in The Child and the Curriculum (1902/2014) that the point of departure for teaching should be based on an "[…] organic assimilation starting from within" (p. 9), and continues: "Literally, we must take our stand with the child and our departure from him [*sic*]. It is he and not the subject-matter which determines both quality and quantity of learning" (p. 9).

According to Deng and Luke (2008), the subject matter for Dewey was not determined only by academic logic or the psychological traits of individuals. Dewey uses geography as an example and writes that in itself it is not only the classification of facts and principles, but also a way of feeling and thinking about the world, and this embodiment presupposes the former. Although we usually meet adult students rather than children as PBL practitioners, we see Dewey's notion of starting from within as a suitable analogy for participant direction, as a means for a student's pre-conditions to indirectly set the scope for exploring unknown territories. For Dewey (1902/2014), such a standpoint is characterised by freedom and initiative and less by the conversations of the past and guidance and control, and perhaps mostly by what Whitehead calls a contagious disease - the imagination: "The justification for a university is that it preserves the connection between knowledge and the zest of life, by uniting the young and the old in the imaginative consideration of learning" (1967, p. 93).

However, Whitehead (1967) remarks, that only fools act on imagination alone, and imagination rather serves as a way to illuminate facts, the only requirement being that students can think freely and wrongly as a part of their empowerment – within a thematic space. The aspect of empowerment brings us to a smaller caveat to our contribution: empowerment brings the educational philosophy of Paulo Freire to the forefront, but as with finer things in life, PBL is a patchwork of theoretical support that according to Servant (2016) is primarily added post-hoc, and some readers may find our text missing authors that from, dare we say, a subjective point of view support a personal interpretation of PBL with an emphasis on one detail instead of another. In our opinion as junior PBL researchers, this hypothesis encapsulates PBL quite well as a methodology; there is no escaping an activation of prior knowledge and experience,

and reflection and bracketing are necessary practices with which to weed out those presuppositions that may obstruct an enquiry while remaining open and responsive to "[…] conditions of subsequent learning" (Dewey, 1938/1997b, p. 37), and as noted by Servant-Miklos (2019), being disgruntled with existing practice can be a legitimate reason for change: "In fact, as far as the founders were concerned, the prime reason for developing PBL was simply a disgruntlement with their own educational experience and a desire to offer future medical students a less boring experience" (p.5).

Framing Interpretations

For this chapter, we draw inspiration from John Hanson's *Learning by Experience* (1961), in which the author presents a variety of interpretations of the phrase, ranging from everyday conceptualisations to highly abstract theories, and ultimately shows how different definitions of learning and experience result in ambiguity and vagueness for each concept. One prudent example is one where learning is defined as changes in response or behaviour caused by experience, for which it then follows that *learning by experience* becomes a tautology. Similar to the variety of interpretations and conundrums found by Hanson (1961), we find that concepts such as participant direction and student-centred approaches to learning can be understood quite literally as the framing of learning activities, but can also be included as metaphors used for political ambitions to change the structure and organisation of "antiquated" institutions (see for instance Adam, 2008 or González & Wageneer, 2005).

We will apply one of Bernstein's (1990, 1996) theoretical concepts, *framing*, to capture interpretations and to peer through a variety of conceptualisations. Bernstein's idea of framing is based on a structuralist approach to the sociology of education (Sadovnik, 1991), and concerns the regulation and control of the pedagogical context: communication, sequence, pacing, criteria, and the social base, and from our perspective, the metaphor, provide ample opportunities to look at how different conceptions of student-centred approaches frame and afford different activities and levels of autonomy. Framing is closely related to another concept, classification (the *what* of education), which Bernstein (1996) uses to depict the perceived boundaries of subject matter, disciplines and, more broadly, categories and discourses. Rather than outline yet more theory, we will briefly summarise progressive pedagogies as being weakly classified, meaning that boundaries between subjects and disciplines are less clear-cut than in traditional teacher-centred pedagogical approaches (see Moore, 2013); the limits

of available discourses are less restricted than in pedagogies with strong classification. This position is not far from the inherent interdisciplinary aspirations found in PBL (Kolmos & De Graaff, 2013).

According to Bernstein (1996), two analytical systems of rules are affected by framing, social order, and discursive order. The first involves the hierarchical relations in the pedagogical relationship, such as expectations of conduct and manners, and the latter refers to "the selection, sequence, pacing and criteria of the knowledge" (p. 28). We find the latter to be of primary interest to us as the pacing and criteria for knowledge construction or transmission differ to some extent between modes of PBL. While Bernstein's theory of pedagogic codes and modalities is much more elaborate, we will limit ourselves to the concept of framing and describe central components. Levels of framing involve *who* controls *what* in a pedagogical realisation: "Strong framing: the transmitter controls the selection, organization, pacing, criteria of communication and the position, posture, and dress of the communicants, together with the arrangement of the physical location" (Bernstein, 1990, p. 37).

When framing is weak, the *acquirer* has more apparent control of the selected elements. While *transmission* and *acquisition* may imply a less active role in knowledge construction than we are used to, we will encourage others to unpack Bernstein's metaphors and move forward. Those who already know of PBL approaches, with tutors and pre-defined problems as the central components of a learning environment, may see differences in the framing of pedagogies compared with more project-organised approaches of PBL using open inquiry as a means of problem identification (see for instance Kolmos and De Graaff, 2013, or for framing PBL educational programmes, Boelt et al., 2020).

Table 1

Elements Found in Framing

Selection of communication: determining what counts as legitimate communication of knowledge.
Sequencing: signifies the order, what comes first, second, etc.
Pacing: rate of expected acquisition of knowledge.
Criteria setting for what counts as acceptable knowledge
Control over the social base which makes transmission possible

Note. Bernstein 1996, pp. 26.

To summarise this brief introduction, strong framing results in a visible pedagogy with explicit rules and regulative discourses. On the other end, weak framing results in an invisible pedagogy, where rules and regulative discourses are implicit to the learner (Bernstein, 1996, p. 28).

Students at the centre

As we briefly mentioned earlier, a student's position in the learning process is a pivotal element in PBL. Still, we believe that each mode of PBL affords different positions and regulators of knowledge construction. For analytical purposes, we have created two distinct categories for the next section, one encompassing the project-organised approaches characterising our institution and Roskilde University (RUC), and another encompassing model found in medicine, which to our knowledge affords other structures and regulations of the learning environment (see for instance Kolmos & De Graaff, 2013).

Table 2

Section contents

Student-Centred Learning	This section's primary concern is the approaches found in medical and health education. Our starting point involves models found at McMaster University and Maastricht University.
Participant Direction	In this section, we apply Illeris' (1985) concept of participant direction through 'student-centred learning' to describe the same processes. Our starting point here is primarily our institution at AAU.

Student-Centred Learning

In the "original" PBL from McMaster (quotation marks found in Scholkmann, 2020), student-centredness is pivotal in shifting the responsibilities of learning. Here teachers provide students with information and material, but it serves as inspiration for students to autonomously identify educational needs and find information to cater for these (Barrows & Tamblyn, 1980). As with other modes of PBL, the starting point for learning is a problem, or as more precisely put by Schmidt et al. (2009), an actualisation of scientific ideas that students must master as part of their education. Barrows and Tamblyn (1980) describe the multiple advantages of student-centredness, such as increased responsibil-

ities resulting in better skills for evaluating learning, and more contemporary aspirations such as learning to learn, which is useful throughout the lifetime to adapt to new knowledge in 'any particular area,' and increased knowledge retention due to self-determined studies and their perceived importance. The latter is supported by Schmidt et al. (2009), mainly in that being able to independently choose sources based on one's judgement is conducive to intrinsic interest in a topic. It is interesting to note the problems highlighted by Barrows and Tamblyn (1980) concern institutional issues such as staff planning and the logistics of providing sufficient materials and changing assessment strategies, while they lightly gloss over personal issues by stating that students ought to learn working this way eventually, so why not now?

Although the starting point and organisation share comparable traits with other modes of PBL, the pedagogical sequencing, on paper at least, seems more formally scheduled. Once a problem is presented to a student in the same way as it would in reality (i.e., the extent of available information presented to a practitioner) (Dolmans et al., 2005), Schmidt et al. (2009) note the numerous steps in an overall sequence of steps and learning activities (p. 229):

Table 3

Process of Problem-based Learning Activities

(1) Problem or description of phenomena needing explanation.	An actualisation of scientific ideas.
(2) First meeting in tutorial groups consisting of 6-10 members.	Discussing problems to construct a speculative theory based only on prior knowledge. During this initiation phase students are allowed to propose inaccurate hypotheses, but these need to be expressed allowing any misconceptions to be remediated when met with accurate conceptions.
(3) Identification and formulation of learning issues.	Learning issues are usually based on questions found in the previous step.
(4) Individual and self-directed learning activities.	Students will engage with the issues found in Step 3 through self-directed learning activities. Suitable resources may be provided by teachers or selected by students. Scaffolding is often more extensive in the early phase of study.

(5) Second meeting returning to the tutorial group.	Students review, share and elaborate on what they have learned. Exploration of student understanding of the problem and addressing potential misconceptions, and further continued discussion of the problem.

Note. Schmidt et al. 2009.

Each activity is supervised by a tutor, who guides a discussion and examination of the problem. According to Schmidt et al. (2009), the process described above is embedded in a curriculum, which involves a series of 150 to 350 problems covering central topics of a professional or academic domain.

The first aspect to consider is communication, and as described above, tutors function as facilitators through the planned activities. According to Dolmans et al. (2005), tutoring should be aimed at stimulating self-directed learning by probing "[…] students' knowledge by encouraging specific kinds of cognitive activities" (p. 734), such as those described above by Schmidt et al. (2009). The facilitation and scaffolding of the learning activities are intended to stimulate the elaboration and integration of knowledge and interaction between students by posing questions, necessary clarifications, and the application of knowledge (Dolmans et al., 2005). At the same time, it must be expected that students hold each other accountable when meeting in a tutorial group, which also co-determines accepted means of communication within a specific domain. The boundary for acceptable communication is then established through different modes, facilitation, and interactions between students and tutors, with an emphasis placed on the latter part. The sequencing and pacing of knowledge construction are also made explicit by using recurring circular patterns of the PBL activities outlined in Table 2, albeit with differing lengths (Schmidt et al., 2009). The criteria for what count as acceptable knowledge is determined by peers and tutor together during tutorials, where any misconceptions are addressed. Lastly, the control of the social base can be characterised as distributed among students and tutors. Interactions between students ought to foster collaboratively constructed explanations of given phenomena (Dolmans et al., 2005).

Overall, we find the framing of this variation of PBL to be both weaker and stronger. It is weaker in activities of self-direction, but as we saw, resources may be provided by teachers which indicate a stronger framing of criteria for acceptable knowledge when students are more autonomous in selecting relevant resources (Dolmans et al., 2006; Schmidt et al., 2009), where framing in such a case is less strong. Nonetheless, the more structured approach and continued

tutoring of all activities suggest a stronger framing than those modes of PBL characterised by the project organisation.

Participant Direction

Participant direction is a different entity than student direction, although there are similarities: the problem is still the starting point for learning. A basic principle for Illeris (1974, 1981) was *modkvalificering* [counter-qualification] and qualification, which is an ability to critically assess societal structures with an aspiration for changing them while at the same time participating in an existing society – a scenario where you *can* have your cake and eat it too. Illeris remarks that *a problem,* serving as a viable point of departure for a learning process, can be understood too narrowly and that a problem must first be accepted by participants as a *problem* and has to transcend *itself* to be placed in relation to greater societal contexts (1981, p. 100).

The societal perspective of Illeris (1981) cascades through the pedagogical ideals toward a more democratic conception of education and active participation (such as that found in Dewey (1916/1997a) – later criticised by Labaree (2012) as being over-ambitious), and consequently, Illeris (p. 104) argues that the control of teaching and learning is placed on students, teachers, and other participants in collaboration. It is interesting to note, however, that the teacher has a central position in facilitating the accommodative learning process for students than what is acknowledged in student-centred learning described by Adam (2008). Furthermore, participant direction is a dialectic of internal and external conditions, the former being student pre-conditions and interest, and the latter being the societal requirements of and for education, which is present in some guise. The biggest challenges found in the mid-1980s were the existing habits of students and teachers (p. 108), but according to Ziehe (1999), progressive pedagogies have been overtaken by the everyday participation experienced by contemporary youth, where notions of autonomy are present in more aspects of their educational life than previously.

While Illeris' early writings echo youth revolts, a contempt for ivory towers and disdain for antiquated elitist concepts such as those found in *Bildung* or liberal education (see Illeris, 2019), we find it a more inclusive conceptualisation than student-centredness - mainly due to the awareness and positions of all actors found in the first iterations of Illeris' suggestion for an alternative pedagogy. As we saw in the previous section concerning student-centred learning,

the tutor also has a central position and provides similar restrained teaching by probing existing knowledge with relevant questions.

Kjersdam and Enemark (1994) write that projects often run for an entire semester taking up roughly half the workload of students, with the rest allocated to more traditional courses. This is still the case in most educational programmes at AAU, and so are the thematic boundaries setting the initial space available for participant direction, and the participants must find exemplary problems for professional practice and transferability: projects ought to "contain" knowledge and methods applicable to a wider context (Barge, 2013). At the same time, students ought to situate content and approaches in real-world contexts (Holgaard et al., 2014).

Although students have room for participation, there are some requirements for "legitimate" participation: direction is confined to a thematic space, and practice must be exemplary. However, within a theme, it appears that most directions are accepted so long the former requirements are met. Framing in this context is then dependent on the type of supervision and scaffolding of PBL activities for each programme. Some programmes provide students with project libraries (Hüttel & Gnaur, 2017) in effect reducing a student's responsibilities in identifying a suitable problem. In another case, discrepancies between the timely sequencing and pacing of lectures and project trajectories showcased a need for increased awareness of participant direction, and the interrelated aspects of courses and projects (Boelt et al., 2021). As in student-centred learning, peers and supervisors co-determine what counts as legitimate knowledge within each discipline. Here, however, the ever-present tutor is replaced by a guiding supervisor, who can perform several roles, ranging from laissez-faire to controlled supervision based on both personal epistemologies and the needs of the group (Kolmos et al., 2008). As noted earlier, this also acts as a failsafe to capture misconceptions. Lastly, the control of the social base is distributed between peers in a group, but also between students and administrators, who must provide the physical space for group work.

We find that some aspects are framed less explicitly in AAU and the conception of participant direction, than within the student-centred approach described above. For both approaches, however, analysis of different levels of curriculum making and enactment would provide a stronger foundation from which to make bold claims of levels of control.

Concluding remarks

We have briefly described two approaches to PBL which share overarching principles for student participation. As both authors are educated and employed at AAU, there is a real risk of becoming too autographic and finding evidence to support our subjective theoretical aspirations to praise or criticise an approach from a perspective of theoretical purism. Instead, we want to explain how we see a fruitful way of combining the two approaches in our institution.

Currently, the usual organising principle, which we can call 15-5-5-5, is a project module and three modules with subjects intended to be integrated into the project. Reflecting on the sheer number of cycles and problems proposed by Schmidt et al. (2009) suggests that PBL is a way of analysing problems rather than solving them and that by being exposed to numerous problems the process of inquiry is expected to become second nature. Although it feels almost blasphemous, we find that shorter PBL cycles may provide opportunities to stimulate participation in exploring problems in closer collaboration with experienced tutors or facilitators. With AAU's recent focus on generic competence development, an examination of existing practices and structures might also shed light on new potentials and practices and avoid succumbing to ritualised and habitual ways of doing things. Educating for an uncertain future might require us to think about structure in a similar manner and prepare for more chaos and uncertainty by allowing greater student participation.

References

Adam, S. (2008). Learning Outcomes Current Developments in Europe: Update on the Issues and Applications of Learning Outcomes Associated with the Bologna Process. In *Bologna Seminar: Learning outcomes based higher education: The Scottish experience 21—22 February 2008, at Heriot-Watt University, Edinburgh, Scotland* (Issue February).

Barge, S. (2013). Principles of problem and project based learning. The Aalborg model for problem and project based learning. In Kjær-Rasmussen, L. K., Jensen, A. A. (Eds.) Visions, challenges and strategies: PBL principles and methodologies in a Danish and global perspective. Aalborg Universitetsforlag (pp. 377–395).

Barrows, H. S., & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education. Springer.

Bernstein, B. B. (1990). The structuring of pedagogic discourse. Routledge.

Bernstein, B. B. (1996). Pedagogy, symbolic control, and identity: Theory, research, critique. Taylor & Francis.

Boelt, A. M., Kristensen, N. S., & Clausen, N. R. (2020). Classification and framing in PBL: A case study. In A. Guerra, A. Kolmos, M. Winther, & J. Chen (Eds.), Educate for the future (pp. 343–353). Aalborg Universitetsforlag. http://www.irspbl2020.aau.dk

Chen, J., Kolmos, A., & Du, X. (2020). Forms of implementation and challenges of PBL in engineering education: A review of literature. European Journal of Engineering Education, 46(4), 1–26. https://doi.org/10.1080/03043797.2020.1718615

Deng, Z., & Luke, A. (2008). Subject matter: Defining and theorizing school subjects. In Connelly, M. F., He, M. F., Phillion, J. The SAGE Handbook of Curriculum and Instruction (pp. 66–88). SAGE Publications. https://doi.org/10.4135/9781412976572.n4

Dewey, J. (1916/1997a). Democracy and education: An introduction to the philosophy of education. Free Press.

Dewey, J. (1938/1997b). Experience and education (1st ed.). Simon & Schuster.

Dewey, J. (1902/2014). The child and the curriculum.

Dolmans, D. H. J. M., De Grave, W., Wolfhagen, I. H. A. P., & van der Vleuten, C. P. M. (2005). Problem-based learning: Future challenges for educational practice and research. Medical Education, 39(7), 732–741. https://doi.org/10.1111/j.1365-2929.2005.02205.x

Dolmans, D. H. J. M., & Schmidt, H. G. (2000). What directs self-directed learning in a problem-based curriculum. *Problem-based learning: A research perspective on learning interactions*, 251-262.

Gonzáles, J., & Wageneer, R. (2003). *Tuning Educational Structure in Europe—Final Report Phase One*. Universidad de Deusto. http://tuningacademy.org/wp-content/uploads/2014/02/TuningEUI_Final-Report_EN.pdf

Hanson, J. (1961). Learning by Experience. In B. O. Smith & R. H. Ennis (Eds.), *Language and Concepts in Education* (pp. 1–23). Rand McNally & Company.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Holgaard, J. E., Ryberg, T., Stegeager, N., Stentoft, D., & Thomassen, A. O. (2014). PBL: Problembaseret læring og projektarbejde ved de videregående uddannelser. Samfundslitteratur.

Hüttel, H., & Gnaur, D. (2017). If PBL is the answer, then what is the problem? Journal of Problem Based Learning in Higher Education, 5(2), 1—21. http://dx.doi.org/10.5278/ojs.jpblhe.v5i2.1491

Illeris, K. (1974). Problemorientering og deltagerstyring—Oplæg til en alternativ didaktik. Munksgaard.

Illeris, K. (1981). Modkvalificeringens pædagogik: Problemorientering, deltagerstyring og eksemplarisk indlæring. Unge Pædagoger.

Illeris, K. (2019). Om dannelse og meningsfuld læring. In Illeris, K. (Ed.), Læring mellem udvikling og tilpasning. Kritiske og afklarende bidrag 2007-2018 (pp. 59–63). Samfundslitteratur.

Kjersdam, F., & Enemark, S. (1994). The Aalborg experiment—Project innovation in university education. Aalborg University Press.

Knowles, M. S. (1975). Self-directed learning: a guide for learners and teachers. Association Press

Kolmos, A., & de Graaff, E. (2013). Problem-based and project-based learning in engineering education. In A. Johri & B. M. Olds (Eds.), Cambridge handbook of engineering education research (pp. 141–160). Cambridge University Press. https://doi.org/10.1017/CBO9781139013451.012

Kolmos, A., Du, X., Holgaard, J., & Jensen, L. P. (2008). *Facilitation in a PBL environment*. UCPBL UNESCO Chair in Problem Based Learning.

Labaree, D. F. (2012). School syndrome: Understanding the USA's magical belief that schooling can somehow improve society, promote access, and preserve advantage. Journal of Curriculum Studies, 44(2), 143–163. https://doi.org/10.1080/00220272.2012.675358

Leary, H., Walker, A., Lefler, M., & Kuo, Y.-C. (2019). Self-directed learning in problem-based learning. In Moallem, M., Hung, W., & Dabbagh, N. (Eds.) The Wiley handbook of problem-based learning (pp. 181–198). John Wiley & Sons. https://doi.org/10.1002/9781119173243.ch8

Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-directed learning in problem-based learning and its relationships with self-regulated learning. *Educational Psychology Review*, *20*(4), 411–427.

Moore, R. (2013). Basil Bernstein: The thinker and the field. Routledge. https://doi.org/10.4324/9780203818251

Negt, O. (1971). Soziologisches Phantasie und exemplarisches Lernen [Sociological imagination and exemplary learning]. Europäische Verlagsanstalt.

Sadovnik, A. R. (1991). Basil Bernstein's theory of pedagogic practice: A structuralist approach. Sociology of Education, 64(1), 48–63. https://doi.org/10.1680/udap.2008.161.2.61

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. Interdisciplinary Journal of Problem-Based Learning, 1(1), 5-15. https://doi.org/10.7771/1541-5015.1002

Savin-Baden, M. (2014). Using problem-based learning: New constellations for the 21st century. Journal on Excellence in College Teaching, 25(3 & 4), 1–24.

Savin-Baden, M., & Major, C. H. (2004). Foundations of problem-based learning (1st ed.). Society for Research into Higher Education & Open University Press.

Schmidt, H. G., van der Molen, H. T., te Winkel, W. W. R., & Wijnen, W. H. F. W. (2009). Constructivist, problem-based learning does work: A meta-analysis of curricular comparisons involving a single medical school. Educational Psychologist, 44(4), 227–249. https://doi.org/10.1080/00461520903213592

Scholkmann, A. (2020). Why don't we all just do the same?: Understanding variation in PBL implementation from the perspective of translation theory. The Interdisciplinary Journal of Problem-Based Learning, 14(2). https://doi.org/10.14434/ijpbl.v14i2.28800

Servant, V. F. C. (2016). Revolutions and re-iterations: An intellectual history of problem-based learning. Erasmus University Rotterdam.

Servant-Miklos, V. F. C. (2019). Fifty years on: A retrospective on the world's first problem-based learning programme at McMaster University Medical School. Health Professions Education, 5(1), 3–12. https://doi.org/10.1016/j.hpe.2018.04.002

Wagenschein, M. (2015). Teaching to Understand: On the Concept of the Exemplary in Teaching. In I. Westbury, S. Hopmann, & K. Riquarts (Eds.), *Teaching as a reflective practice: The German Didaktik tradition* (First issued in paperback, pp. 161–175). Routledge.

Whitehead, A. N. (1967). *The Aims of Education and Other Essays* (Reissue). The Free Press.

Ziehe, T. (1999). Schule und Jugend–Ein Differenzverhältnis. Überlegungen zu einigen blinden Stellen in der gegenwärtigen Reformdiskussion. Neue Sammlung, 39(4), 619–629.

Problems, Complexity and Interdisciplinarity

Patrik K. Telléus, Lykke Brogaard Bertel, Giajenthiran Velmurugan & Lise Busk Kofoed

From problem to complex problem

As Hung (2016) states "it all starts with the problem". The pedagogic form of problem-based learning (PBL) situates the idea of a *problem* as the foundation of its learning process. This idea, concept, thing, or phenomenon called a problem is what triggers the learner to employ their tools and skills as well as their theories and knowledge, in an undeniable quest to resolve or dissolve the epistemic lack that the problem somehow represents and makes present. In the broad spectrum of theorists of epistemology, the *problem* appears in many forms and variations. Notable here is, of course, John Dewey, (1910/1933, 1938) and Thomas Kuhn (1996). Both these thinkers use the idea of a problem to initiate learning processes that deviate from the routine, from the habits we have, and from what we perceive as normal. In this sense, the role of a *problem* is to appear as an anomaly or a disturbance that forces us to reflect. Facing this "abnormal" situation means that we have to acknowledge some form of lack or deficiency in what we know and that there is a simultaneous need to address this issue by engaging in a cognitive process that leads to new insights and revaluations. In Kuhn's case, these insights are either adaptions or revolutions; for Dewey, the endgame is to enable proper and adequate judgment.

Dewey and Kuhn are not PBL theorists as such, but there are two important features in their use of a problem that carry over to the PBL conception. The first is the urgency or demand for acknowledgement and response that the problem creates. This is a kind of mandatory response to initiate reflection when one encounters a problem. It does not leave you alone, so to speak. The second is the problem as opposition or resistance to our habits. These habits can be patterns, prejudices, dogmas, and so on, and they are all challenged by the problem, sometimes disclosing these habits as false or illusionary, sometimes just calling attention to some necessary adjustments or some influential blind spots. It is notable here that the problem is in fact beyond our scope or range; it is not part of our acquired perspective and comprehendible perceptions and

predictions. At the same time, the problem is metaphorically "in our faces". It invades us, and as such becomes very much a part of us.

In the theoretical PBL framework, these ideas are interpreted as propositions about a natural interest or meaningful motivation for committing to the learning process. Focusing on problems, especially those which are intimidating and aggressive, shows that there is an intrinsic desire, as well as a contextual need, to address the issue, and engage in the process of unravelling the problem and regaining control of the situation. In short, the problem is what makes knowledge acquisition make sense to the learner, by directing and confining the process to (re-)solving the learner's particular epistemic lack through their particular ability, acquaintance, and circumstance. An institutionalised PBL curriculum is therefore designed to ensure that students encounter problems that on the one hand disclose their epistemic lack, or false perceptions and fallible comprehensions, and on the other hand appear to the students as meaningful motivators to engage them in their particular learning process. Identifying, constructing and presenting problems that appeal to students as well as fit the established disciplinary learning outcomes and progression, and meet institutional requirements, is, therefore, a key component in applying a PBL pedagogic. We are thus back at the opening statement, "it all starts with the problem".

What the problem is, and what constitutes a problem, however, is not a fixed definition. To sustain the idea of the problem being real and relevant, and therefore also motivating, as well as the problem representing a lack or dark spot in our knowledge and comprehension, the early PBL literature often referred to problems as "social issues" (Servant et al., 2016). In recent years, we have seen a new or alternative conceptualisation around the PBL problem: the idea of complex problems (Jacobs et al., 2003). The complexity refers to problems that are not identified within designated disciplines or particular theoretical paradigms, nor are they related to specific practices, stakeholders, or investigators. Some people talk of "wicked problems", to highlight the blurriness but also the urgency of this kind of problem (Jonassen, 2011). The idea of complex problems is repeatedly related to another growing issue in the PBL literature, and that is the idea of interdisciplinary approaches, training, and competences (Jensen et al., 2019). This leaves us with a discourse promoting learning processes starting with complex problems and applying interdisciplinary strategies, resulting in what might be best described as valuable capabilities.

The driving forces in this PBL discourse are constructivist and pluralistic approaches to the theory of science, as well as public opinion and reactions to severe issues such as climate change, sustainability, migration, health, global-

isation, and so on. Other motivators are the Sustainable Development Goals (SDG), Industry 4.0/5.0 and increasing demands for a focus on employability from both students and stakeholders, and other factors of that kind involving the conditions, frames, and outcomes of institutionalised higher education. This results in intellectual and practical conceptualisation within a mixture of threat and urgency, an impression of the inadequacy of traditional approaches and positions, competition and appeal, anything goes and historical narcissism, autonomy and power relations, and so on. The expanding nature of the challenging issues, as well as rapid change within scientific fields and technological innovation, further adds to the difficulty of predicting and integrating skills and competences in existing and new educational models and practices, both locally and globally as well as across the disciplines and domains. The concepts of complexity and interdisciplinarity emerge from all this as beacons or anchors to which pedagogical thoughts and actions can cling and justify themselves. The PBL discourse neatly capitalises on this movement or atonement, by reformulating or translating "the problem as starting point" as the complex problems of today, and in that light reinterpreting the student-driven learning process as an invitation to an interdisciplinary approach.

Even though it is, at least theoretically, simple for PBL to adopt these (partly) new concepts, one important practical or perhaps sensible question remains: how can complex problems and interdisciplinarity be successfully applied in the PBL-driven institutions of higher education? We need to ask ourselves how PBL, as a pedagogical and intentional practice, can be a sensible response to the increasing requirements of competences related to understanding complex problems, and the interdisciplinary learning process of construction and deconstruction in projects working with such complex problems. We will look more closely at these questions in this chapter and present some of the challenges and opportunities for the PBL-facilitated learning process in a curriculum of complex problems and interdisciplinary presuppositions.

Interdisciplinarity

There are numerous ways to define the term *interdisciplinarity*. The simplest is of course the definition provided by a dictionary, "the involvement of two or more disciplines" with disciplines being either areas or fields of particular knowledge or particular productions and/or processes. Today, theorists juggle many versions or adjacent terms, such as transdisciplinary or multidisciplinary, while keeping a critical distance from the core term of *disciplinary*. In gener-

al, different forms of being interdisciplinary appear in the wake of the twentieth century's now-classic epistemological criticism of the classification and abstraction of disciplines. The different types or versions of alternatives to *disciplinary* are often a question of how much of the traditional product, process, and knowledge of discipline the theorist recognises as valuable and allows to remain as part of the new term. Interdisciplinarity is a form of middle ground between the more pro-disciplinary term of multidisciplinarity, and the more anti-disciplinary term of transdisciplinarity (Telléus, 2019). One way to grasp these versions and alternatives is to look at the interactive perspective: to focus on the way that "two or more disciplines" are involved. Multidisciplinarity uses knowledge from different disciplines but involves little interaction across boundaries. Interdisciplinarity involves interactions across boundaries with the potential to affect perspectives and research output from disciplinary members. Transdisciplinarity involves creative synthesis where members of different disciplines transcend boundaries to form a new integrated and more holistic approach. In that understanding multidisciplinarity is additive, interdisciplinarity is interactive, and transdisciplinarity is holistic (Klein et al., 2001).

Interdisciplinary teaching and learning in higher educational institutions have been identified as key to twenty-first-century education (Brassler & Dettmers, 2017; Khadri, 2014). Students need to gain interdisciplinary competences to deal with the greater complexity of the problems. To be able to understand and act in any given interdisciplinary learning or work situation - students need adequate professional/technical, personal and social skills, which relate to PBL competences. It is also important to have a critical stand on disciplinary limitations and to develop the ability to solve complex problems across disciplines, have successful communication across disciplines, be able to manage interdisciplinary collaboration and teamwork, as well as to identify and use unseen potentials, and create innovations. Part of this also requires the development of a more or less calculated risk-taking, which must always be reflected upon during the learning process. These different traits and competences are easily associated with learning outcomes related to PBL processes, such as inter-relational and social capabilities, tools, and competences within project management, substantial experience with problem-oriented processes, the growth and confidence of self-directed inquiry, and the continuous encouragement of responsible and critical reflection. From this perspective, interdisciplinarity and PBL seem to be a natural fit and a match made in heaven (Jensen et al., 2019).

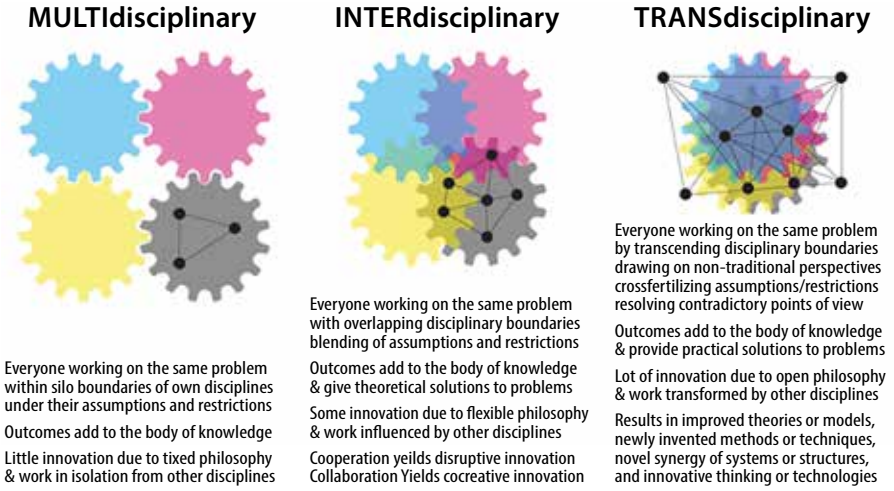
It is challenging for both teachers and students to get involved in interdisciplinary programmes. Many teachers have a background within single disci-

plines and therefore need to develop new pedagogical and didactic skill sets, and they need to establish a new identity within the concrete interdisciplinary educational concepts (Kans & Gustafsson 2018: Nordahl & Kofoed 2009). Students working with interdisciplinary problems/projects need to have basic knowledge and competence within their study area and be motivated to leave their safe standpoint within the known to build a new and stronger identity by combining their previous knowledge and skills with a new and deeper understanding of how their new competences can be used (Hansen & Kofoed 2017).

In theory, the connection between PBL pedagogy, interdisciplinarity, and disciplinary interaction can be described in a rather straightforward and clear manner. The figure (Figure 1) below shows one such model, proposing forms of interaction in different multi-, inter-, and transdisciplinary modes, combined with a problem- and project-based approach.

Figure 1

Overview of Forms of Cross-disciplinary Cooperation and Collaboration



Note. http://simonpriest.altervista.org/

In practice, the experience and knowledge of faculty designing programmes/courses and project work after such models are more limited, and so are the experience and knowledge about how students work with their projects and how the phases in their projects will be affected by such pedagogical designs. In the next two sections, we will look at this challenge from two sides. First, we focus on problem analysis and how this is related to ideas of PBL and complexity and interdisciplinarity. Second, we address an actual attempt to merge

a PBL approach with these new movements in the development and design of "megaprojects" at Aalborg University.

A closer look at problem analysis

Research in the problem in problem-based learning tends to focus on how to design problems (Holgaard et al., 2017; Hung, 2009, 2016, 2019). The trend is to focus on how teachers design a problem to exemplify a specific subject practice in authentic contexts; however, few studies focus on how students analyse the problem. In this regard, it is important to make a distinction between solving the problem and analysing what the problem is. In a problem analysis, the contents of the problem are analysed, stakeholders are identified, and important delimitations are drawn. The final goal of the problem analysis thus becomes to construct or acknowledge a real-world problem that is evident in the specific subject practice and aligned with relevant learning goals.

As the problems of today are complex and ill-defined, the need to conduct a problem analysis becomes more evident. Because problems can be varied in nature, the same case or problem can be scaled up or down. One case or one problem can thus present several problems, even in the same subject practice. Furthermore, as there are several correct answers to ill-defined problems it becomes important to have a nuanced concept of the problem in order to specify what aspects of a given problem space students must aim to address. Holgaard et al. (2017) argue that engineers of tomorrow need to work from a more holistic system perspective in order to properly solve problems. In this regard, the SDG goals also emphasise the need to work interdisciplinarily to solve the challenges that face the earth (Zielinski et al., 2018). One could argue that a holistic and interdisciplinary approach can be fostered by teaching the students how to analyse their problems before they engage in problem-solving. In this analysis, the students learn both the complexities of the problem and the limitations of their subject practice. To face the challenges of tomorrow, all candidates thus need competencies in both analysing and constructing problems. This becomes even more evident when working in an interdisciplinary environment where different perspectives on the same problem can be constructed (Jensen et al., 2019).

A research study on problem analysis in student projects at Aalborg University was carried out in 2020, as part of the PBL Future project. The study focused on bachelor's degree projects, that is, the final projects in the sixth semester for earning a bachelor's degree, across all education programmes at the university.

The study used both quantitative analysis and qualitative analysis. All bachelor projects included in these analyses were downloaded from Aalborg University's project library. Subsequently, the problem analyses for all projects were isolated from the project reports. The problem analysis is defined as all content up to and including the problem formulation excluding formalities such as the abstract, preface, reading instructions, and so on. The study initially included four bachelor's degree projects from 2019 for each programme at Aalborg University, however, it was not possible to access four bachelor's degree projects for all programmes, as there are not always that many, and some have been confidential. An additional requirement for inclusion has been that the text in the downloaded file can be marked for use in NVIVO as an analysis tool.

The quantitative part of the study ended up including 194 projects/problem analyses, distributed as 60 from the Engineering and Natural Science Faculty, 47 from the IT and Design Faculty, 39 from Humanities, 32 from Social Science and 16 from the Faculty of Medicine. Using Nvivo, the analysis allocated the a) author/personal representation, b) concepts most used, c) length, d) sources, and e) type of problem formulation.

In the qualitative part of the study, 15 projects/problem analyses were randomly selected from the generated database. The project the cursor landed on after 10 seconds of roulette was chosen. The inclusion criteria were that all faculties were represented in the analysis, and therefore projects were excluded if a project from the same education programme had already been included. One project was excluded, as it had a very different structure, which meant that the problem analysis was 30 pages long and therefore deviated substantially from the rest. The 15 projects were distributed as two from the Engineering and Natural Science Faculty, three from the IT and Design Faculty, three from the Humanities, five from Social Sciences, and two from the Faculty of Medicine. A thematic analysis was conducted based on Braun et al.'s (2016) thematic analysis approach. Five themes were developed, based on a pilot study of four projects. The five themes were: a) Who is the result aimed at? b) Is it a problem? c) How broadly does it start? d) What is the method (and theory)? and e) How much influence have the students had?

The details and the specific results of this study will be published later, but for the present purpose, the study showed some overall results of interest. The first was the clear and decisive differences across the university. In general, the problem analysis showed significant deviating patterns according to disciplinary allocation; assuming that disciplinary-defined approaches, values, and habits are the key factors in the construction and execution of the problem analysis.

Another interesting general outcome of the study was the apparent lack of *problems* and *analysis* in the problem analysis. Most projects did not have a problem as a starting point, and from there identified the state-of-the-art and knowledge gaps and so on, and ultimately formulated an investigation, that to some extent or in a disciplinary-specific fashion addressed the problem. Instead, most problem analyses were designed to represent disciplinary predefined learning outcomes and to appear simply as an introduction to the project. This result is of course devastating for the whole idea of learning through problems, and it questions a student's ability to acquire the supporting and meta-competencies associated with undertaking a problem analysis and working from a PBL pedagogical perspective.

The third result worth noting here concerns the student-directed learning process or the student's autonomy in selecting and working with a problem-based project. Again, there are observable differences between faculties and disciplines, but there are some slightly more promising results. According to the resources used, author/personal representation, and interpreting wonderings and interests as expressions of student autonomy do make a case that the principal or idea of student-directed learning is rather well established in AAU bachelor's degree projects. This is especially the case in Humanities, and to some extent in technical and design projects.

In all, our study clearly shows that it is a huge challenge to be successful in implementing interdisciplinary projects, based on complex problems developed by student autonomy. However, it also gives us a good idea of where the pitfalls and obstacles lie, many of them associated with disciplinary habits and specifically defined values and outcomes. A way forward could therefore be to be better at identifying unifying factors in habits and values and to allow for more open, and perhaps open-ended processes that satisfy both disciplinary and interdisciplinary perspectives by, for example, focusing more on the problem analysis and less on the results.

Aalborg University's response: AAU Megaprojects

Educational institutions employ different strategies to support students in developing such interdisciplinary and complex problem-solving competences; including interdisciplinary capstone projects and integrated programmes (MIT New Engineering Education Transformation (NEET), 2017; UCL, 2015) or even entirely new interdisciplinary educations and institutions (London Interdisciplinary School, 2021). Interdisciplinary semester projects have been part

of the PBL practice at Aalborg University for many years (Kolmos et al., 2020), however, the AAU Megaprojects concept was developed and launched in 2019 to further facilitate variation in interdisciplinary project work and support progression in the development of students' complex problem-solving competencies (Aalborg University, 2021). AAU Megaprojects as a concept include large-scale and interdisciplinary umbrella projects that address highly complex problems and grand societal challenges related to the UN's Sustainable Development Goals (SDGs). It offers students a platform for integrating interdisciplinary knowledge and large-scale collaborative learning into semester projects to develop transversal skills and competences for the future, while still meeting the learning objectives of the formal curriculum (Routhe et al., 2021).

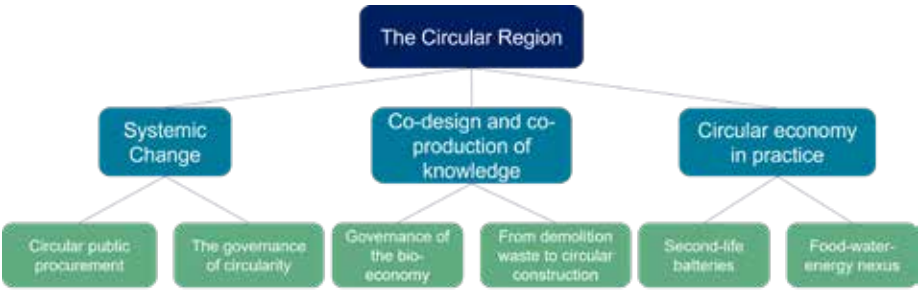
Each megaproject spans 2-3 years, with different SDGs framing a thematic setting for a shared field of interest, acting as indicators and a contextual framework for large-scale interdisciplinary projects across departments and faculties. The first megaproject was launched in September 2019, and three megaprojects have run so far: "Simplifying Sustainable Living" (2019-2021), focusing on making sustainable choices easier for organisations, companies, and individuals; "The Circular Region" (2019-2021), focusing on interdisciplinary aspects of the circular economy in Northern Jutland; and "Better Together" (2020-2022), focusing on innovation and inclusivity in the labour market (Aalborg University, 2021).

Figure 2

The megaproject "Simplifying Sustainable Living"

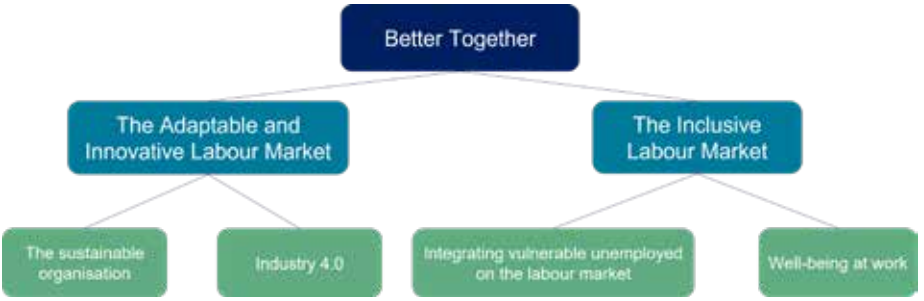
Initially, megaprojects at AAU were organised in 2-3 sub-themes (focus areas) as seen in Figures 2-4, further specified in up to two challenges each. Each challenge could contain several clusters, each containing up to five student groups with up to seven students in each group.

Figure 3
The Megaproject "The Circular Region"



In the initial phase of a megaproject, participating student groups choose a challenge of interest and are distributed into interdisciplinary clusters on this basis, all of which contribute with problem analyses, designs, and solutions related to the specific challenge and the overall megaproject theme.

Figure 4
The Megaproject "Better Together"



The research was conducted following the piloting of the first rounds of megaprojects in 2019 and 2020, informing the next phase of further development and the implementation of megaprojects at AAU. The research reports both staff and student perspectives on the megaprojects and interdisciplinary project work in general, and highlights conceptual work, challenges, and potentials in the implementation of large-scale collaborative projects in networks such as the AAU megaprojects (Bertel et al., 2021; Kolmos et al., 2020; Routhe et al., 2021; Winter et al., 2020).

The studies showed that whereas the participating students are highly motivated to collaborate across disciplines and programmes, the current structure of the megaprojects tends to invite coordination and cooperation rather than integrated collaboration between project groups in the clusters (Routhe et al., 2021). This is partly due to different timelines in project work across faculties, but especially since students are not currently assessed directly within the megaproject but rather according to learning objectives within the formal curriculum at the programme and semester level, which do not necessarily contain explicit learning goals related to interdisciplinary collaboration. This means that whereas students are eager to share knowledge, designs, and results with their cluster, this knowledge is not transferred between or integrated into other projects within the cluster, and projects tend to work independently of each other with limited interdependency (Routhe et al., 2021). Furthermore, students were found to require more structural guidance with regard to project management and communication, as they lack the means and competences to facilitate and manage the complex teamwork setting or 'adhocracy' in a megaproject; this, in turn, affects the level of collaboration across disciplinary boundaries, leaning more towards multi-disciplinary interaction or even just 'borrowing' between disciplines (Winther et al., 2020). Facilitators and supervisors also problematised the distinction between challenges and focus areas, and even SDGs within the megaprojects, as many of these are closely linked and not easily distinguishable (Bertel et al., 2021). The organisation and current visualisation of the AAU megaproject structure thus do not reflect the complexity and ecology of the collaboration between clusters in networks, and there is a need to facilitate more interdependency between projects in the loosely coupled system that is a megaproject, particularly in the early stages of problem identification and analysis (Bertel et al., 2021, Routhe et al., 2021).

In 2021, the AAU Megaprojects concept moved into its next phase of development, in which experiences and findings from the piloting in 2019-2020 were integrated into the further development of the concept along with the involvement of students, staff, stakeholders, and administration through workshops and interviews. These workshops and interviews took place in the autumn of 2021 addressing potentials and challenges related to themes such as:

- Facilitating student engagement and agency in defining megaproject themes, challenges, clusters, and problems as part of their problem-based learning process

- Blended and online learning spaces and activities supporting large-scale collaborative learning
- Forms of competency assessment (including peer feedback and authentic assessment) within the megaprojects
- Organisational barriers and structural challenges, such as those related to the curriculum requirements and study regulations currently restricting interdisciplinary collaboration across disciplines

Findings from this phase are transferred into the next phase of implementation in 2022, where new rounds of megaprojects will be piloted and evaluated.

Conclusion

In this chapter, we have looked at problems in the light of complexity and interdisciplinarity. Our purpose has been to explain what we identify as a movement toward complex problems and interdisciplinary projects in PBL and higher education. In general, we regard this movement as positive, since it provides answers to some of the current challenges for higher education when educating for a market that values constructive competences and collaboration higher than the disciplinary-defined title of the degree. At the same time, the movement is related to the developments that we see in science with the establishment of different forms of interdisciplinary and transdisciplinary perspectives, such as STS, Medical Humanities, and Artificial Intelligence. It seems reasonable for universities with a PBL foundation to embrace and apply the ideas of complexity and interdisciplinarity.

At the same time, we have pointed out some problems with applying these ideas. Referring to both the research study on problem analysis and the introduction of megaprojects at Aalborg University, we described some obstacles and challenges to implementing interdisciplinary approaches and complex problems in higher education. These are related to criteria for quality and evaluation, a lack of feedback processes, visibility and recognition of competences and knowledge that deviate from pre-established disciplinary learning habits, values and outcomes.

In short, we encourage the further development and application of complexity and interdisciplinarity within PBL and in Higher Education. At the same time, we remind the reader of the difficulties in implementing and designing such activities. It is, as one often discovers, a process of "two steps forward, and one step back".

References

Aalborg University. (7 May 2021). *Megaprojects. AAU Megaprojects*. https://www.megaprojects.aau.dk/

Bertel, L. B., Winther, M., Routhe, H. W., & Kolmos, A. (2021). Framing and facilitating complex problem-solving competences in interdisciplinary megaprojects: An institutional strategy to educate for sustainable development. *International Journal of Sustainability in Higher Education (Print Edition)*, 23(3). https://doi.org/10.1108/IJSHE-10-2020-0423

Brassler, M., & Dettmers, J. (2017). How to enhance interdisciplinary competence—interdisciplinary problem-based learning versus interdisciplinary project-based learning. Interdisciplinary *Journal of Problem-Based Learning, 11*(2), 12. https://doi.org/10.7771/1541-5015.1686

Braun, V., Clarke, V., & Weate, P. (2016). Using thematic analysis in sport and exercise research. In *Routledge handbook of qualitative research in sport and exercise* (pp. 213-227). Routledge.

Dewey, J. (1933). How we think: A restatement of the relation of reflective thinking to the educative process (2nd ed.). D.C. Heath and Company.

Dewey, J. (1938). *Experience and education*. Simon & Schuster.

Hansen, E. K., & Kofoed, L. B. (2017) The kick-off project: An engaging entry to a transdisciplinary master education. *Proceedings of the 45th SEFI Annual Conference*, 1214-1221.

Holgaard, J. E., Guerra, A., Kolmos, A., & Petersen, L. S. (2017). Getting a hold on the problem in a problem-based learning environment. *International Journal of Engineering Education, 33*(3), 1070–1085.

Hung, W. (2009). The 9-step problem design process for problem-based learning: Application of the 3C3R model. *Educational Research Review, 4*(2), 118–141. https://doi.org/10.1016/j.edurev.2008.12.001

Hung, W. (2016). All PBL starts here: The problem. *Interdisciplinary Journal of Problem-Based Learning, 10*(2), 2. https://doi.org/10.7771/1541-5015.1604

Hung, W. (2019). Problem design in PBL. In M. Moallem, W. Hung & N. Dabbagh (Eds.), *The Wiley handbook of problem-based learning*, (pp. 249-272). John Wiley & Sons.

Jacobs, A. E. J. P., Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., & Scherpbier, A. J. J. A. (2003). Validation of a short questionnaire to assess the degree of complexity and structuredness of PBL problems. *Medical Education, 37*(11), 1001–1007. https://doi.org/10.1046/j.1365-2923.2003.01630.x

Jensen, A. A., Stentoft, D., & Ravn, O. (Eds.). (2019). *Interdisciplinarity and problem-based learning in higher education: Research and perspectives from Aalborg University* (Vol. 18). Springer International. https://doi.org/10.1007/978-3-030-18842-9

Jonassen, D. H. (2011). Learning to solve problems: A handbook for designing problem-solving learning environments. Routledge.

Kans, M., Gustafsson, Å. (2018) Student perspectives on interdisciplinarity: findings from an interdisciplinary two year master program. In Proceedings of the 14th international CDIO Conference.

Khadri, D. H. O. (2014). A strategy for developing and enhancing interdisciplinary research and graduate education at Ain Shams University (ASU). *European Scientific Journal, 10*(28), 87–106.

Klein, J. T., Grossenbacher-Mansuy, W., Häberli, R., Bill, A., Scholz, W., & Welti, M. (Eds.). (2001). Transdisciplinarity: *Joint problem solving among science, technology, and society an effective way for managing complexity*. Birkhäuser. https://doi.org/10.1007/978-3-0348-8419-8

Kolmos, A., Bertel, L. B., Holgaard, J. E., & Worm, H. (2020). Project types and complex problem-solving competencies: Towards a conceptual framework. In A. Guerra, A. Kolmos, M. Winther, & J. Chen (Eds.), *Educate for the future: PBL, Sustainability and Digitalisation 2020*, (pp. 56–65) Aalborg Universitetsforlag. International Research Symposium on PBL.

Kuhn, T. S. (1962/1996). *The structure of scientific revolutions* (3rd ed.). University of Chicago Press.

London Interdisciplinary School. (2021). *A new undergraduate degree*. https://www.londoninterdisciplinaryschool.org/

MIT New Engineering Education Transformation (NEET). (2017). *New Engineering Education Transformation*. https://neet.mit.edu/

Nordahl, R., Kofoed, L.B. (2009). Staff development in an interdisciplinary education: Medialogy. *Proceedings of the ICEE & ICEER 2009*, 1(1), 354-360.

Routhe, H. W., Bertel, L. B., Winther, M., Kolmos, A., Münzberger, P., & Andersen, J. (2021). Interdisciplinary megaprojects in blended problem-based learning environments: Student perspectives. In M. E. Auer, & D. Centea (Eds.), *Vision and Concepts for Education 4.0: Proceedings of the 9th International Conference on Interactive, Collaborative, and Blended Learning (ICBL2020)*, (pp. 169–180). Springer

Servant, V. F. C., Schmidt, H. G., & Frens, M. A. (2016). *Revolutions and re-iterations: An intellectual history of problem-based learning*. Erasmus University Rotterdam.

Telléus, P. K. (2019). Trust me, I'm 'The doctor': Bridging disciplinary education and interdisciplinary professionalism. In A. A. Jensen, D. Stentoft, & O. Ravn (Eds.). *Innovation and change in professional education research and perspectives from Aalborg University* (pp. 21–34). Springer.

UCL. (2015, August 5). *The Integrated Engineering Programme (IEP) and how it works. Teaching & Learning.* https://www.ucl.ac.uk/teaching-learning/case-studies/2015/aug/integrated-engineering-programme-iep-and-how-it-works

Winther, M., Bertel, L. B., Routhe, H. W., Kolmos, A., Andersen, J., & Münzberger, P. (2020). AAU Megaprojects: An educational strategy for sustainable development. *Proceedings from the 2020 International Conference on Sustainable Development (ICSD)*. International Conference on Sustainable Development (ICSD).

Zielinski, T., Sagan, I., & Surosz, W. (Eds.). (2018). *Interdisciplinary approaches for sustainable development goals*. Springer International. https://doi.org/10.1007/978-3-319-71788-3

New Forms of Collaboration

Mia Thyrre Sørensen, Jon Ram Bruun-Pedersen, Thomas Ryberg & Giajenthiran Velmurugan

Collaboration is a central principle in the AAU PBL model. Students work closely together over an extended period to address a self-chosen problem, which they discuss, analyse, solve, and disseminate in their project report. This is particularly emphasised in the following three AAU PBL principles (Askehave et al., 2015): (a) *project organisation* as the framework for problem-based learning, (b) *collaboration as a driving force* for problem-based project work, and (c) that students have a *high degree of responsibility*. Principle (b) concerning collaboration in the AAU PBL is described as follows:

> A group of students work closely together in managing and completing a project over an extended period of time, taking a problem as the point of departure for their work. The students' mutual support is essential for the successful completion of the project. The group work includes aspects such as knowledge sharing, collective decision-making, academic discussions, action coordination and mutual critical feedback.

The time-limited, collaborative nature of AAU project work presents students with a need for team management, problem analysis, and application of their evolving knowledge, skills and competences (Kolmos et al., 2004). The project work is a learning space where students are given a high degree of autonomy and the freedom to pursue specific self-chosen problems. While focusing on addressing academic and societal problems, students are required to develop skills to navigate team processes, such as project management and conflict resolution. Thus, group work includes peer learning and social support, collective decision-making, discussions, and coordination. Furthermore, students have to manage group dynamics, relations with the supervisor, and possibly also relations with external collaborators. As part of this work, students develop important collaborative competences, or what we also refer to as *PBL competences*.

The project work in small groups over an extended period is considered the bread and butter of the AAU model.

In this chapter, we illustrate how terms such as "collaboration" and "project management" cover a varied, rich, and dynamic set of practices with which students engage during their project work. We argue for the importance of being aware of the diversity in students' actual practices. In relation to this, we focus on how they "do" collaboration and project management in practice. Hence, one of the goals of this chapter is to unfold the richness and variation of such practices within the application of the AAU model. However, despite clearly appreciating the richness and diversity of students' work, we also wish to critically address and discuss whether the students' experiences with collaboration could be further challenged and expanded.

The first part zooms in on the project groups and discusses the richness, diversity, and variations in PBL collaboration. With Sørensen's (2022) ethnographic study of project groups in a hybrid PBL environment as a starting point, we suggest some polarities to describe the variations and dynamics within the project groups. The polarities are a conceptualisation of ongoing negotiations and a continuous balancing between students on how to collaborate.

The second part of the chapter discusses how to challenge and expand pedagogies building predominantly on small-group work, such as the AAU model. Here, with further perspectives on variation, we wish to challenge the first part in terms of exploring alternative organisations for student collaboration. By zooming out, focusing on the format and its repeated approaches for framing the project work across semesters, we question the sometimes-low degree of variation within the current AAU PBL model. Building on Ryberg, et al. (2018), we suggest seven dimensions, which serve as possible outsets for variation to stimulate students' experience of the collaborative organisation of group work.

In the concluding third part, we summarise and discuss these two perspectives on collaboration and team processes in relation to the current PBL models building on collaboration in small groups, and we outline some possibilities for expanding the AAU approach to contemporary students' project work for extended periods.

Variations within the project group

Sørensen (2022) explores diversity and variations in PBL collaboration within project groups. The results are based on ethnographic studies of project groups across all faculties of AAU. More specifically, Sørensen studied project groups

during a semester, from the initiating group formation to the concluding project exam, both across online and offline field sites (approximately 3–4 months). The studies show variation both in diversity across the project groups and as a progression within the project groups over time. Sørensen presents noticeable variations amongst and within the project groups, including their preferred meeting frequencies, meeting spaces, and their adoption of digital tools and platforms.

This diversity illustrates that students' project work implies ongoing (progressive) negotiations of *where*, *when,* and *how* to collaborate. Sørensen captures and conceptualises these variations and dynamics in PBL collaboration through polarities that project groups must continuously navigate. The notion of polarities emphasises the interdependence and constant process of balancing between two poles and opens up a range of variation between these poles. While depicted as opposites, the polarities rarely constitute a direct or mutually exclusive opposition. Both parts are always present and interchangeably possible, sometimes in the foreground and at other times in the background. In the following, we briefly outline these polarities.

Social–Academic

Students' project work involves academic as well as social activities. Academic activities include, for example, professional discussions, report writing, and conducting experiments, while social activities encompass eating, playing games, or socialising. Though distinct activities, they often overlap in practice. For example, conversations can quickly change from purely project-relevant to social topics, such as conversations about weekend activities. The transition is often smooth, unproblematic, and entirely accepted. The social and the academic thus constitute a balance, which project groups have to navigate in different ways.

When shifts occur towards a social (and not project-relevant) conversation, a common way of re-orchestrating the balance is through one of the group members, who acknowledges the need to return to an academic discussion. While which group member changes the topic of the conversation varies, the other members usually follow. Some groups create sharp boundaries between social time and project time, for instance by planning specific time slots for each of them. If there is agreement that the day has exceeded the limit of acceptable "social time", groups can strategically change their work environment. An example could be an improvised work-from-home day to promote academic concentration and avoid social chats. Here, online platforms and tools

replace the physical group room to conduct meetings and communicate, when necessary, thus reducing emergent socialisation.

Given their role as students, the value of a strong academic focus would appear obvious, but if social interactions are disruptive and counterproductive, why do, for example, the AAU principles promote this unavoidable aspect within group work? This is because the aspect of *relatedness* to a task or process is well-established with respect to promoting intrinsic motivation within the practitioner. Interpersonal relations in student teamwork are a very good example. The social aspects, whether leisure-oriented communication or other engagements, help in the construction of relations (relatedness) and are important for productive collaboration. However, in this regard, it is important to balance academic and social activities.

PBL collaboration–PBL cooperation

Division of labour is necessary for group-based projects. According to Dillenbourg (1999) and building on Roschelle and Teasley (1995), cooperation and collaboration represent two distinct ways of working together. Cooperation is a form of work in which tasks are delegated to members and can be solved individually and independently, whereas collaboration requires a mutual focus and shared responsibility for the overarching project at hand. The concepts thus include differences between the degree and type of division of labour as well as the degree of interdependence between tasks. Observations of practical project work by AAU students, however, suggest that clear divisions between the two are far more blurred and complex than the definition immediately suggests. Observations of students doing group work suggest that most processes are more complex and dynamic. Groups alternate continuously between different constellations, including working individually, everyone together, or in smaller subgroups. When working individually, group members may regularly invite others "inside" their work process, for example, to get feedback on their work or to discuss specific issues of doubt. If working individually in a shared environment, joint conversations often run continuously with dynamic changes in the number of participants. Other members thus sign in and out of the conversation, shifting attention regularly between the computer and the conversation. The dynamic of these conversations can have several outcomes and can even result in important group decisions. Overall, the group shares the responsibility for the project in its entirety, and they need to maintain a shared focus. This form of small-group work is therefore essentially of a collaborative nature, but

in the course of the project work, many smaller tasks are delegated to members; striking a balance between the two is important for groups.

Together–Apart

Adding to the distinctions of cooperation and collaboration, there is also a related polarity of working together or apart. Student groups in AAU have the freedom to choose where, when, and how they work, and noticeable variations can be observed in meeting frequencies and the choice of workplace. Some groups meet daily, whereas others have weekly meetups. Meeting places can include group rooms, booked meeting rooms, open study areas, the library, at the homes of group members, at a café, and online. The addition of 'online' could suggest that the polarity of together–apart concerns the distinction between working together face-to-face vs working online, and again that collaboration occurs onsite, whereas cooperative processes occur online. However, the patterns are more complex, and groups can be physically co-located but work apart (i.e., each member attending to their own writing or reading). Equally, groups can be physically distant but can maintain a shared focus via social media such as Discord and collaborate closely on, for example, a shared document in Overleaf. While we often assume that online work means 'being apart' and physical co-location is 'being together', this may not necessarily be the case, and students need to reflect on how to best balance being together and apart.

Individual practice–Shared practice

Project work is a combination of individual and shared practices. A semester begins with the establishment of the project group. Here, members often compile a list of agreements as a foundation for their project collaboration. It aligns expectations concerning aspects such as work effort, meeting frequency, meeting locations, rules for writing as a team, preferred technologies to support the work, and guidelines for specific practices. During the project, it may become apparent that some agreement points do not work as intended. Agreements are thus continuously negotiated and adjusted during the project period. Meanwhile, some practices related to project work are primarily individual. This includes preparation for coursework or reading for the project, which can vary in time, duration, space, and choice of technology. In these cases, individual students are free to adopt their personal preferences, with no need for group consensus or procedural alignment. Both individual and shared practices affect each other and intersect. Students observe each other, share experiences, and develop shared practices. However, individual preferences may conflict with

other individuals or with the aligned practice of the group. Here, the group must both recognise the situation and revise the approach if needed. Due to these dynamics, individual practices align or change during the project.

Planning–Improvisation

Project work should include an effort to plan the project as well as leave room for improvisation, depending on the situational or circumstantial needs of the project (or the group). The groups' approaches to project planning vary from a strict and established organisation to a heavily improvised dynamic. Planning may thus entail detailing the entire project period, which includes scheduling all meeting dates, milestones, and deadlines in the project. For many groups, however, project work involves a combination of long-term and short-term planning. Groups even change strategies for planning throughout the project period, and often as the deadline nears, the need for milestones, deadlines and scheduling seems to arise. This suggests that project planning can stray far from conventional models of project planning or normative conceptions of good project management. This depends on the individual group and its circumstances, but students may initially neglect to plan and focus entirely on navigating the present. The team processes then become more improvisational, which may reflect the general state of uncertainty and unpredictability initially in the project. This behaviour is often missing in managerial models (Ciborra, 1999). Interestingly, such improvisational behaviour should not be considered irrational or random but rather situational, intuitive, and spontaneous. Similarly to how musical improvisation requires disciplinary knowledge, practical skills, and an acute sense of embedded rules and conventions, improvisation needs to be orchestrated within an established skillset. Playing the instrument of academic PBL practices includes abilities with disciplinary traditions and chain of reasoning as well as project group collaboration. Project work is indeed about recognising the ideal interplay between planning and improvisation. Planning and time management have often been described as essential for successful project work, but we argue that conscious improvisation is equally important for PBL student collaboration processes.

Richness and variation in group work

The polarities illustrate the richness and variation in terms of how project groups orchestrate their collaboration within the AAU PBL model. How groups orchestrate their work and balance the polarities varies considerably. Further-

more, some stick to particular strategies throughout the project, whereas others adopt a more fluid approach to the work.

The proposed polarities offer a detailed understanding of how students work in project groups, details, differences, and variations that are often glossed over under the broader headings of 'collaboration' or 'project management'. The polarities offer a nuanced understanding of how the work is undertaken in practice. Furthermore, the polarities can function as a means of reflecting critically on group-work processes, for the individual student, the group as a collective, and project supervisors. Students can use the polarities to reflect on questions such as the following: *How should we organise the work?*' W*hat does each of us prefer?* This can lead to relevant discussions of the advantages and disadvantages of particular practices within a group and can extend to discussions between the group and their supervisor(s).

Finally, the polarities show that when we zoom in more closely on the project work, as it is performed within the wider frame of the AAU PBL model, there is a richness and variation of practices amongst student groups.

However, if we zoom out and look at the wider frame of the AAU PBL model, it is fair to state that the dominant mode of organisation is restricted to a relatively limited format, in which 'small' group collaborations are repeated from semester to semester. While the richness and variation found within this specific format are inherently challenging and complex, it can also limit the spectrum of students' organisational experiences and the diversity of project types if not challenged by different formats. This is what we explore in the next section.

Expanding forms of collaboration

The previous sections add to what has been shown in other studies regarding how students acquire valuable transversal competences, such as communication, collaboration, critical thinking, and problem-solving skills through problem-based group work in smaller teams (Du et al., 2013; Guerra et al., 2017). As is evident upon closer inspection, group work unlocks a wealth of micro-level practices, variations, and balances that all unfold under the umbrella of the wider PBL principles.

However, as we identify the vibrant richness and nuance when zooming in on the individual groups in isolation, we also argue that if *zooming out,* parts of the PBL model (and its related practices) may presently be more formally contained to a static or recurring practice instead of being a progressive and format-expanding practice. For example, the dominant almost standardised way

of practising the Aalborg PBL model and its associated principles, for instance in project work, is the general procedure according to which all student groups function and work. This general procedure encompasses a single main project in a stable and monodisciplinary group over an extended period (3–4 months). The work is typically co-located, meaning that a group's students often sit together in the same room or space. Instead of expanding the scope of projects or increasingly steering students' vision outside the confines of the group itself, student collaboration is strongly tied internally, and there is a high level of mutual dependence within the group. However, as explored by Ryberg, Sørensen, et al. (2018), new forms of work within, across, or outside organisations are starting to emerge. Examples can be seen in the works of Spinuzzi (2015) and Engeström (2008), which challenge the general PBL adaptation found at AAU. Not to be seen as a replacement, the perspective can serve as an inspiration to shake the status quo and allow us to critically re-examine the case of AAU PBL practice. In the following, we will present and discuss the theoretical standpoints.

Knotworking and adhocracies

In his book 'From teams to knots', Engeström (2008) argues how historically new modes of work have been emerging and changing the notion of 'teams'. Engeström argues that the idea of teams, as relatively stable units with clear boundaries, is increasingly being challenged. He suggests that stable teams (similar to the typical AAU PBL group) may be just *one* form of 'collaboration', among many other more fluid forms. He highlights how teams are becoming increasingly networked, global, and mediated through digital technologies. In exploring and conceptualising how such teams work, Engeström turns to the metaphor of 'knots' and 'knotworking', as described below:

> The notion of knot refers to rapidly pulsating, distributed, and partially improvised orchestration of collaborative performance between otherwise loosely connected actors and activity systems. Knotworking is characterized by a movement of tying, untying, and retying together seemingly separate threads of activity. (Engeström, 2008, p. 194)

In this citation, the focus is moved from the team as a stable construct, such as the internally driven AAU PBL project group, towards a notion of collaboration and learning emerging as an outcome of improvisation and the bringing

together of loosely connected actors and activities. Unlike in a team, there is no 'centre' of activity.

Spinuzzi's ideas of all-edge adhocracies are in many ways similar to those of Engeström. Spinuzzi has studied small contractors and how they work. The contractors are often one-person firms, who take on larger projects, such as website development, but to complete the concrete project, they dynamically and ad hoc bring together a distributed team of people. In this manner, adhocracies are:

> […] able to rapidly link across organizational boundaries, combine into temporary work groups, swarm a project with a team of specialists, and disperse at the end of the project, often to re-form in a different configuration, with some different members, for the next project. (Spinuzzi, 2015, p. 2)

Project managers assemble and engage, with a loosely connected 'knot' of people (to adopt the term from Engeström). Also, noticeably, many of the project managers are engaged in multiple projects simultaneously, with different constellations of people (and technologies); and so are the other collaborators.

This is a form of work that can be identified amongst small contractors, but it is equally a form of work developing both inside organisations (Engeström, 2008) and inside the academic workforce. It is a type of work that has predominantly been enabled by digital technologies, as the ability to communicate and collaborate via various online tools is essential to the success of stitching together a successful adhocracy. Spinuzzi (2015), for example, explores how teams with shifting memberships create particular and singular constellations of technologies for the project at hand. This has also been explored in relation to group work amongst students, which shows similar assemblies of technological constellations (Rossitto et al., 2014; Ryberg, Davidsen, et al., 2018).

What we can deduce from the works of Spinuzzi and Engeström is that new forms of teamwork or collaboration are emerging, characterised by unstable or dynamic memberships, shorter-lived processes, parallel engagements, and interdisciplinarity. Further, they are enabled and empowered by digital communication technologies. The concepts of knotworking and adhocracies, therefore, represent a move away from focusing *exclusively* on individual teams and their inner dynamics and negotiations. Rather, they propose that we begin to understand the relations at the 'edge' and how teams or groups are related to other 'knots'. For the relatively unchanged format of project and group work

throughout students' academic programmes (well into the graduate level), the works of Spinuzzi and Engeström could fit well into a mould towards higher-level complexities within students' group work. It could thus provide one or possibly several approaches to naturally challenge and shape the progression of students' project-work experiences, conceptions and competences, and extend their (mostly) monodisciplinary project approach into multi- or interdisciplinary domains. This highlights the inherent potential of PBL principles in student learning, as well as the missed opportunity from not exploring such possibilities, and also the value, found in the acknowledgement of its complexities, related to expanding the utilisation of PBL in academic development with students. In the following, we will further investigate additional dimensions of PBL work to develop the illustration of complexity and move towards an enhanced understanding of how PBL work, such as the AAU PBL project work, may be undertaken and developed in practice.

Seven dimensions of group work

In the following, we compare and further discuss the notions of knotworking and adhocracies in relation to the dominant form of group work as practised at Aalborg University. In this regard, it should be noted that there are of course exceptions and variations in how group work is practised. We discuss, for example, megaprojects in chapter 4 along with alternative orchestrations of group work, such as case competitions, WOFIE and DADIU to mention a few. Meanwhile, the dominant form of group work shares characteristics that we highlight in the following and discuss in relation to knotworking and adhocracies.

The first dominant characteristic to highlight is how students work together in the same group over a lengthy period (3–4 months), often physically co-located with access to a group room or group space. Secondly, students' main focus for this extended period is the collaboration on a single project, where the 'team' construction is *stable*. Thirdly, students predominantly work with students in both the same educational programme and semester even if many educational programmes are inherently oriented towards inter- or multidisciplinarity. There are some further aspects or dimensions that cut across the AAU PBL group work, which were explored initially by Ryberg, Sørensen, et al. (2018). We have summarised these and illustrated them in Table 1. In the following, we discuss each of these dimensions, partly in relation to knotworking and adhocracies, to compare and contrast these in terms of how they fit or could extend the current AAU PBL model.

Table 1

Contrasts between AAU PBL and Knotworking/Adhocracies across Seven Dimensions

Dimension	AAU-PBL	Knotworking/ adhocracies
Expertise	Monodisciplinary	Interdisciplinary
Membership and scale of collaboration	Stable	Dynamic
Space	Co-located	Distributed
Decision making	Central	Distributed boundary work
Collaborative orientation and dependencies	Internal/Inwards	Edge/outwards
Task focus	Singular	Parallel
Temporality	Extended/fixed	Shorter lived/dynamic

The first dimension concerns the notion of *expertise* and, more specifically, whether the expertise in the team/group is mono- or multi-/interdisciplinary. As stated above, the dominant compilations of students in AAU project groups are monodisciplinary, as they are constructed from students in the same educational programme. So while groups are often encouraged to draw on theories and methods from multiple disciplines, their main objective is not to seek the function of an interdisciplinary team. Rather, groups must complete the project within the learning objectives associated with their one particular programme or discipline. Adhocracies and knotworking processes on the other hand are characterised to emerge and be formed as inter- or multidisciplinary teams. Their capacity to function is dependent on the individual actors bringing their unique disciplinary perspectives into the process and negotiating their position and contributions with the other members.

The second dimension concerns *membership* and *scale of collaboration*. Membership relates to whether members of the group change over time (and thus become *dynamic*) or remain unchanged (and could be considered *stable*) throughout the collaboration. By collaboration of scale, we refer to how the group (or parts of the group) engage outwards, with wider and more complex networks. In a PBL student-project context, this could take several forms. For example, a group could deliver outputs, that other groups need or are depen-

dent on for their work, or collaboration of scale could be participation in work processes, where a larger network is summoned to work on a specific task not immediately solvable by the individual group. Such shifts in membership, or the scale of collaboration, are aspects of knotworking and adhocracies. Membership of the group can change dynamically due to various collaborative or interpersonal circumstances, as can the scale of collaboration, that is, the breadth of the external parties with which a group must collaborate and coordinate to fulfil their goals. However, these constructions are less frequent in AAU PBL, where memberships are usually more stable and where groups are rarely dependent on other groups or larger networks for the completion of their project. There are, however, exceptions to this. Examples include the 'satellite-project' type, where groups have to collaborate with other groups across the globe (Zhou et al., 2011), or the more recent 'giraffe-project' type, where third-semester groups hand over software projects to a subsequent cohort of third-semester students and where a part of the development process depends on coordination with the other groups in the same semester.

The third dimension relates to *space*, (i.e., whether members are *co-located* or *distributed*). For example, the AAU PBL model ideally facilitates a group space for students. Meanwhile, this is not the reality for all students, in which case they often work in a nomadic fashion. Examples include sitting together in makeshift places, moving around during the day to find new spots for their work, or working together from their homes (Ryberg, Davidsen, et al., 2018). The latter comes closer to processes of adhocracies and knotworking, as participants are often geographically dispersed or engaged in other activities and thus are connected exclusively online for large parts of the collaboration. In actuality, students may not even meet physically at all in many cases or only in smaller fractions of the larger group.

The fourth dimension relates to *decision-making* as *centralised* vs *distributed boundary work*. With this, we point to the fact that the AAU PBL model invites students to enjoy a considerable degree of autonomy. Many decisions made for the project are centralised and negotiated primarily within the group, though possibly also with the supervisor (Velmurugan et al., 2021a, 2021b). In contrast to this, decision-making in processes of knotworking and adhocracies is often of a more distributed nature, where the team will need to reconcile perspectives across different actors and activities, (i.e., involving more stakeholders beyond the team).

The fifth dimension relates in many ways to the former dimension. It concerns the *collaborative orientation* and *dependencies* and whether these are

more *internally/inward-focused* or are more oriented *outwards* and towards the *edges*. Whereas the fourth dimension is related to decision-making, we see the fifth dimension as more related to a group's social dynamics, for example, in terms of maintaining good social and collaborative relations amongst participants and avoiding or positively resolving conflicts. In the AAU group work, students are primarily oriented towards their own common project and are heavily dependent on successful internal collaboration and coordination, for example, maintaining good collaborative relations (as touched upon in the balance between the social and academic). In processes of knotworking and adhocracies, there is a stronger orientation towards the periphery, as the team is often more dependent on productive collaboration with other actors and activities. Here, students' success depends more heavily on being able to work at the 'edge' by continuously negotiating with neighbouring people and activities, crossing boundaries and by maintaining product social relations beyond the immediate team.

The sixth dimension is *task focus* and whether this is mainly *singular* or *parallel*. In the AAU model, the task focus is centred on the *concrete* project work. This is the primary focus of the group; however, in processes of knotworking and for adhocracies, there may be multiple conflicting projects in play simultaneously. Thus, projects and tasks often run in parallel rather than as singular entities.

The seventh and final dimension concerns *temporality* and whether the collaboration period is *extended* and/or *fixed* or *shorter-lived* and/or *dynamic*. In the AAU model, the project report and group collaboration are set within the bounds of the semester, and this is usually the same across the different semesters in a programme (spanning typically from September to December or January to May). In contrast, for adhocracies and in knotworking processes, the temporality of projects and activities can span from intense and dynamic shorter-lived bursts to collaborations extending over longer periods or temporarily lying dormant before then reigniting.

In the following, we discuss what possibilities the dimensions and considerations of decentralised knotworking-oriented adhocracies could open concerning new ways to regard and possibly implement PBL, in concurrence and contrast to the case of the current AAU PBL.

Discussion

In drawing up these distinctions between the AAU PBL model and adhocracies or processes of knotworking, we do not mean to belittle the extremely important collaborative PBL competences which students develop through their AAU PBL project work, nor do we wish to suggest there is no variation or diversity in AAU PBL group work. On the contrary, the first section of this chapter is a vivid illustration of the dynamic nature and complexity found in students' group work. Furthermore, variations of the 'small-group project collaboration over an entire semester' have indeed been tested and practised. However, we do believe that going forward the pedagogical model of AAU faces two challenges. The first challenge is to ensure that awareness and utilisation of the current AAU PBL project format's richness of complexities, as represented by the polarities, becomes a proper tool for project supervisors and students alike, namely that AAU PBL can navigate, operate, and reflect on its *zoomed-in* format of student project work. The other challenge is to understand how to extract useful practices from the *zoomed-out* propositions entailed within the seven dimensions from Ryberg, Sørensen, et al. (2018) and to connect them to the current *zoomed-in* standard.

The first challenge is mainly an internal dissemination task. The polarities could be adopted as a standard item in the curriculum content for AAU's introductory courses on PBL for students. These run for all AAU students, both at the undergraduate and graduate levels, in addition to intermediate PBL workshops aimed at progressively developing AAU students' PBL awareness and competences. Perhaps a bigger challenge lies with teachers; as the spectrum of experiences and disciplines differs, AAU has been hosting mandatory PBL workshops for all teaching staff, including seasoned teachers, to ensure that broad knowledge levels of PBL are both introduced and further cultivated. As our research and understanding of PBL constantly develop, we also further our observations on how the practice of PBL encompasses huge complexity. Additionally, in a society where workflows change faster than ever, new formats of interaction and collaboration develop alongside them. PBL needs similar adaptation, which demands constant maintenance, cultivation, and development. A PBL institution, such as AAU, needs to regularly reach out to its staff, not only the inexperienced but also the very experienced to educate the new, regulate the very seasoned, and create a community where experiences are collected and discussed. Of course, the PBL research community plays a major role here, as the facilitators and leading innovators have the overall responsibility to see the

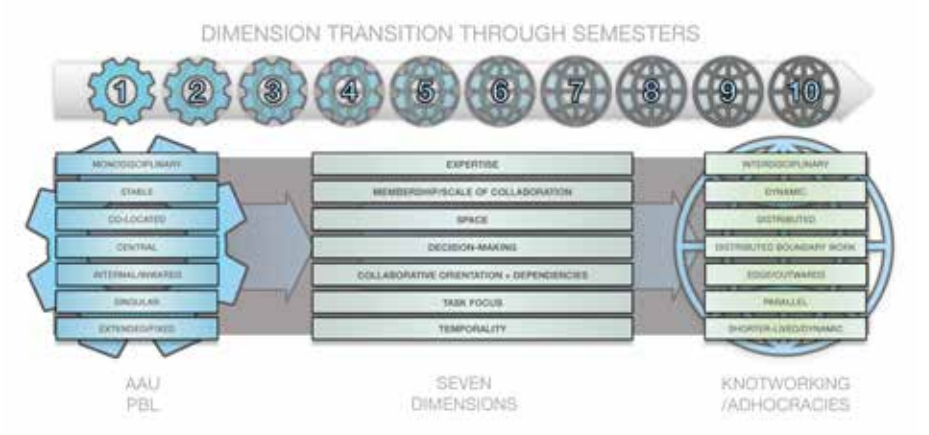
patterns, deepen the understanding of the present and develop the ways of the future. Any PBL model needs to constantly adapt and develop.

A possible innovation of the AAU PBL model can be found in the second challenge, which likely is also more difficult than the first. As shown in Table 1, the seven dimensions, as seen from both the perspectives of AAU PBL and knotworking/adhocracies, suggest differences and similarities at the same time. For the AAU PBL model, it suggests a contrast but also a possible transition. The second challenge for the PBL practice of AAU suggests that both the current 'stable' and 'inwards looking' PBL model and the 'dynamic' and 'outwards looking' model could be synthesised and implemented into one future AAU PBL model. As depicted in the first part of this chapter, the current model contains a wealth of considerations, which students and supervisors need to work together on to establish. This is a good starting point to learn and appreciate the intricacies of project work. With a group confined to itself and its own practices, the current model allows the time, awareness, and space to explore the complexities of interpersonal project management and metacognitive dynamics within a single project unit. These are valuable experiences, with which students must familiarise themselves and learn to operate. Meanwhile, over time, this model risks the negatives of repetition for the sake of repetition. While learning objectives change each semester, the format remains 'stable', which could be considered another word for static. This has regularly been mentioned by AAU students and observed by AAU supervisors, and it may lead to the perception of developmental stagnation. However, it is also an opportunity for the more dynamic, chaotic, and expanding aspects of the knotworking and adhocratic approach, which in many aspects challenge what students have been practising with the current model. The opportunity may be a revisiting of mechanisms (dimensions) that are very familiar to most experienced PBL students but with new stakes, new territories, and new inputs to boot, from expanded boundaries, alternative collaborators, unfamiliar disciplines, and the challenge of combining it all with the acquired monodisciplinary approach of the current AAU PBL model's adaptation of the seven dimensions. A future version of a synthesised AAU PBL model, designed around a timely combination of the current model with a gradual transition into a knotworking and adhocratic model, could represent a solution to students' perceived stagnation regarding their project skills. An illustration of this is shown in Figure 1. This hypothetical model could also introduce what AAU has historically claimed it desires: to reflect and even bridge to professional disciplinary practices. Here, this is supported by increased multidisciplinarity and collaboration with in-

dustry (or other relevant stakeholders), enforced by the gradual transition into adhocratic knotworking as part of project group work.

Figure 1

Hypothetical Model of Gradual Transition from the Current AAU PBL Model into a Knotworking/Adhocracies Model



To achieve this practically would however represent certain investments and a considerable increase in resources from academic staff, both within the individual disciplines as well as in the AAU-bound PBL research community. To support the expanded *expertise* spectrum inherent to the adhocratic knotworking approach, considerable resources from each academic discipline would be needed to design and find relevant interdisciplinary field combinations for the specific professional profile in which student projects should be placed. Working *spaces* for projects involving students of each discipline and additional collaborators would need to be systematically established as an integrated mechanism of semester coordination by the academic departments even if each party would primarily have their own local placement. Also, the knotworking dimension of the *temporality* of projects would need to align with conventional semester project restrictions, such as the fixed set of learning objectives and the fixed time frame of a semester. While not impossible to achieve, serious changes to the current model practices would be needed for the dynamics of the adhocratic knotworking concept to represent its dimension properly. The complexity level of managing students' project work, especially at the graduate level, would entail a much higher complexity level and require substantial resources compared to the current model. However, the AAU-bound PBL com-

munity would face central challenges related to the introduction and training of both students and teaching staff as well. For example, the mechanisms found within adhocratic knotworking would need systematisation and implementation as a structure, especially for students (but also for supervising and semester coordinating staff). Students would require extra teaching and PBL-specific supervision/consultation to extend their previous 'inwards looking' PBL skills to become 'outward looking'. Students would need to relearn what they had already learned, switching some things on their heads, which would be primarily represented by the inherent opposite of 'the stable' becoming 'the dynamic'. The central would become distributed, memberships that were previously fixed would become fluent and rapidly changing, and the well-known disciplinary formats and formalities of, for example, decision-making would no longer serve their disciplinary backbone roles due to the introduced multidisciplinarity. The individuality of students' roles in their project work, separated from disciplinary peers and sent to work with uncharted teams and with unfamiliar competences, would likely be nothing less than shocking for many. Keeping students grounded and providing a sense of fundamental support and security would be a combined effort from both PBL-bound and disciplinary resources.

However, if properly implemented, executed, and sufficiently supported, competence development within project work and interdisciplinary collaboration (and thus professional positioning of a student's academic profile) on the part of individual students would likely be hard to neglect. The sense of personal development tied to project work could be substantial and highly motivating, for instance, for competent students who feel that the reoccurring format of the current AAU PBL model has caused their personal interest and professional development to stagnate.

With the inclusion of this progressive PBL model, institutions like AAU would be prompted to connect much more frequently and interactively with a variety of partners, both internally (with other departments) and externally (e.g., with industry).

References

Askehave, I., Prehn, H. L., Pedersen, J., & Pedersen, M. T. (2015). PBL – Problem-based learning. Retrieved from https://www.aau.dk/digitalAssets/148/148025_pbl-aalborg-model_uk.pdf

Ciborra, C. U. (1999). Notes on improvisation and time in organizations. *Accounting, Management and Information Technologies*, *9*(2), 77–94. https://doi.org/10.1016/S0959-8022(99)00002-8

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp. 1–19). Elsevier.

Du, X., Emmersen, J., Toft, E., & Sun, B. (2013). PBL and critical thinking disposition in Chinese medical students – A randomized cross-sectional study. *Journal of Problem Based Learning in Higher Education*, *1*(1), 72–83. https://doi.org/10.5278/ojs.jpblhe.v1i1.275

Engeström, Y. (2008). From teams to knots: Activity-theoretical studies of collaboration and learning at work (1st ed.). Cambridge University Press.

Guerra, A., Ulseth, R., Jonhson, B., & Kolmos, A. (2017). Engineering grand challenges and the attributes of the global engineer: A literature review. In J. C. Quadrado, J. Bernardino, & J. Rocha (Eds.), *Proceedings of the 45th SEFI Annual Conference 2017* (pp. 1222–1235). SEFI: European Association for Engineering Education.

Kolmos, A., Fink, F. K., & Krogh, L. (2004). *The Aalborg PBL model—Progress diversity and challenges*. Aalborg University Press.

Problem-Based Learning. (2015). Aalborg University. http://www.aau.dk/digitalAssets/148/148025_pbl-aalborg-model_uk.pdf

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning* (pp. 69–97). Springer-Verlag.

Rossitto, C., Bogdan, C., & Severinson-Eklundh, K. (2014). Understanding constellations of technologies in use in a collaborative nomadic setting. *Computer Supported Cooperative Work (CSCW)*, *23*(2), 137–161. https://doi.org/10.1007/s10606-013-9196-4

Ryberg, T., Davidsen, J., & Hodgson, V. (2018). Understanding nomadic collaborative learning groups: Nomadic collaborative learning groups. *British Journal of Educational Technology*, *49*(2), 235–247. https://doi.org/10.1111/bjet.12584

Ryberg, T., Sørensen, M. T., & Davidsen, J. (2018). Student groups as 'adhocracies' – challenging our understanding of PBL, collaboration and technology use. In S. Wang, A. Kolmos, A. Guerra, & W. Qiao (Eds.), *7th International Research Symposium on PBL* (pp. 106–115). Aalborg Universitetsforlag.

Spinuzzi, C. (2015). *All edge: Inside the new workplace networks*. The University of Chicago Press.

Sørensen, M. T. (2022). *Students' orchestration of group work and the role of technology* [PhD thesis] (submitted for publication) Aalborg University.

Velmurugan, G., Stentoft, D., & Davidsen, J. (2021a). *Students challenging supervisors in higher education: How and why?* (submitted for publication)

Velmurugan, G., Stentoft, D., & Davidsen, J. (2021b). Disagreeing about the Problem in PBL: How students negotiate disagreements regarding the Problem in PBL. *Journal of Problem-Based Learning in Higher Education*, *9*(1), 42–62.

Zhou, C., Nielsen, J. D., & Kolmos, A. (2011). Foster creative engineers by PBL: A case study of student satellite project (AAUSAT3) at Aalborg University in Denmark. *2011 2nd International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace Electronic Systems Technology (Wireless VITAE)*, 1–5. https://doi.org/10.1109/WIRELESSVITAE.2011.5940808

Reflections. What Are They and How to Work With Them?

Elisabeth Lauridsen Lolle, Antonia Scholkmann & Nanna Svarre Kristensen

The discussion of the purpose and the justification of higher education is not a new one, and it raises questions about the establishment of institutions (Hansen, 2017), and how those institutions equip their students to prepare them for entering the job market (Andersen & Jacobsen, 2017; OECD, 1999; World Bank, 2011). At Aalborg University it is assumed that the problem-based learning model supports, among other things, the students' development of collaborative competences by engaging with group members, supervisors, and external partners and that this will make the students more attractive to the job market (AAU, 2015). The students have a tendency toward implicit learning, however, this makes it difficult for the individual student to grasp specific learning outcomes from their project work once entering the job market.

Despite the inclusion of reflective practice in the curricula of many study programmes at both bachelor's and master's levels, this has been focused primarily on collective reflections. The aim of this research project was thus to study the process-oriented aspect of reflection: how students work with an individual reflective process and if the integration of digital tools could help this process. We also wanted to examine the more product-oriented aspects of reflection, that is how students become aware of their reflection and can translate both the discipline-specific ones and the ones they acquire by working in the dynamic learning environment of PBL into specific competences.

In this chapter, we are particularly interested in determining the specific stage at which knowledge and experience turn into learning so the students will get the most out of their studies and can turn this into experiences that can be drawn upon in other contexts (Boud et al., 1985). This is where reflection comes in, which is closely connected to the process of learning and the representation of that learning. This might seem very simple; some authors even point out that reflection comes naturally, almost like breathing (Boud et al., 1985). It would then be simple to say that all we as teachers and supervisors should do is encourage students to reflect. When examining reflection as a con-

cept, however, there is nothing simple about it, nor about how to encourage students to work with their reflections. In this chapter, we begin the first section by unravelling the concept of reflection theoretically to gain an understanding of the concept itself. In the second section, we explore the different levels and perspectives at which reflection occurs, including in a PBL setting, and in the third section, we will, based on our research, suggest how to help students work with their reflections.

Unravelling the concept

Reflection is a relatively complicated process, and the extent of this is demonstrated by the extensive terminology and definitions of the concept (Moon, 1999; Rogers, 2001). These include Schön's "reflection in action" (1983), Boyd and Fales' "reflective learning" (1983), Mezirow's "critical reflection" (1990), Fogarty's "metacognitive reflection" (1994), Langer's "mindfulness" (1989/1997), and Dewey's "reflective thinking" (1933) (Rogers, 2001).

These terms all describe the same process, and some similarities stand out across the definitions. First, reflection is conceived of as a cognitive process that also involves examining an emotional response to a given situation, where negative feelings can obstruct and positive feelings can enhance the outcome of the reflective process (e.g., Boud et al. 1985; Dewey, 1933; Moon, 1999; Rogers, 2001).

Reflections require the individual's active engagement or readiness and openness to engage in the process (Rogers, 2001). Other researchers describe this as intent or a purpose that the reflections will engage the student (Boud et al. 1985; Moon, 1999). The individual needs the willingness to attempt to understand the issue or doubt that triggered the reflection (Leung & Kember, 2003). It is even suggested that engagement, openness, and responsibility is the most important part of the reflective process (Loughran, 1996).

Reflections also presuppose a trigger, something that sets off the process, either in form of a process of exploration (Boud et al., 1985), a relatively complicated mental issue or problem without an obvious solution (Moon, 1999), or a situation of complexity, uncertainty, instability, uniqueness, or values-conflict (Schön, 1983). Dewey (1933) defines two elements which are involved in every reflective activity: a problem defined as this something (whatever) that perplexes and challenges the mind to the extent that all belief becomes uncertain, and then an act of searching or investigating for additional data that will develop the suggested belief and serve to confirm or discard this.

The purpose of reflection is that the new understanding gained from reflection is integrated into the experience to enhance what some call overall effectiveness (Rogers, 2001), and what others call emancipatory goals (Moon, 1999). This conclusion gives a better understanding of how the problem is solved and helps the individual learn from the experience due to the meaningful nature of the enquiry into that experience (Loughran, 1996).

Some definitions include a specific time-related perspective, a before, during, and after. Boud et al. (1985), for instance, talk about phases of preparation, activity, and processing. According to Schön's (1983) concept of reflection-on-action, practitioners sometimes think back on a project or a situation they have experienced and reflect on the understanding they can draw from the handling of the case. Loughran (1996) divides the reflective process into five phases: suggestions, problem, hypothesis, reasoning, and testing. The phases do not necessarily appear in that order but constitute a reflective cycle that informs another reflective cycle that informs the next one and so on (Loughran, 1996). Rogers (2001) also sees the reflective process as a continuous or ever-expanding spiral, where challenging situations lead to reflection and a new understanding that leads to a new challenging situation and so on. This cyclical approach is very similar to the findings in our research, particularly our suggestions for working with reflections. This will be explained in Section 4 of this chapter.

When we as teachers and supervisors ask students to reflect, we, therefore, need to understand that it is of utmost importance that the students are ready and open to be triggered by a problem or an unusual situation that will require this cognitive process which will ultimately lead them to a new understanding. Our research furthermore showed that a cyclic and iterative process is the most fruitful environment for such activities.

Levels and perspectives of reflection

The reflective process described above is often conceived of as happening at an individual level, that is within the student's mind: however, reflections can also be described as taking place at a collective level, and from two perspectives, one involving reflections as processes and one involving reflections as outcomes (cf. Table 1).

Table 1

Reflection levels and perspectives

		Reflection as	
		Process	Products
Reflection levels	Individual	Individual elaborations as ongoing self-education and reflection practices	Individual competence reflections, portfolios, self-presentations
	Collective	Co-constructions, reflections about joint practices	Products that document the group process and reflective activities

Note. Source: Developed by the authors

Reflection at the individual and collective level

As described above and in the literature on how to engage students in reflection, we can see that reflection is often treated as something that takes place as an individual activity. This notion, much in line with a goal-oriented focus, prioritises the individual student's reflective thinking and searches for pedagogical solutions to engage them in reflective activities (e.g., Deslandes et al., 2018; Kandiko et al., 2013; Larkin & Beatson, 2014; Sykes, 2011; Tucker et al., 2003). A focus on individual reflection accentuates the student's ability to convert experience to learning through critical metacognitive inspection. As mentioned, the approach taken in this research project was directed toward such individual reflective activities (cf. Scholkmann & Lolle, 2021).

Other approaches described in the literature focus on the collective nature of reflection, which points out the sociality and co-creativeness of thought and knowledge. From this perspective, collective reflections are treated and modelled so that a group of students engage in meaningful conversations. This is often done with groups who have worked together over some time, as is also the case in the Aalborg PBL model (e.g., O'Shea & Kearney, 2016); however, the literature also describes models where collective reflection takes place not based on a joint group project, but as an approach to reflecting on the joint professional practice that a group of students shares, for example in health, nursing

or medical programmes (e.g., McLeod et al., 2015; Zarezadeh et al., 2009), or in service-learning (Reed & Koliba, 1995).

Looking at reflection in the terms of practices instead of an individual's cognitive processes, we move our focus from the individual, cognitive-emotional understanding to a social and more activity-oriented understanding of reflection. It is a "turn to practice" as it is called and identified by several academic disciplines, including philosophers such as Theodore Schatzki (1996, 2010), Stepen Kemmis et al. (2014), Charles Taylor (1995) and sociologists such as Andreas Reckwitz (2002). This focus on practices instead of individual cognitive processes moves the question of reflection and how to support reflective learning into the field of organisational learning. The Problem-based Learning approach at Aalborg University can be seen as an example of how groups of students engage in social, political, discursive, cultural, economic, and material arrangements that produce and reproduce learning and reflection (cf. Kemmis et al. 2014). PBL group work and the use of digital study tools are compatible with co-construction that enables collective reflection. While individual reflection processes have to be scaffolded and facilitated, collective reflection processes in joint practices have to be organised to support the reflection process.

Different practice theorists will look at the organisation around collective reflection in different ways, depending on how they define practice and activities. As an example, Theodore Schatzki (1996; 2010) would look at the different "understandings" of co-construction and group work that are enacted in practice and how students are navigating their use in different situations. At Aalborg University this organisation-framing collective reflection can be seen as enabling a range of different understandings of how to enact project work, problem-oriented work, and group and teamwork, and the students are given different tools to act within group communication, conflict management, project management and so on. In collective reflection processes, students are able to navigate and adapt to different approaches depending on the situation. This can include organising teaching and studying practices within study plans that enable collaborative work, study groups, and collaboration with the industries, while also offering problem-based tools and time to adapt the co-constructive processes to the specific situation enabling collective reflection. Organisational requirements, for example, that all groups must hand in a product such as a process analysis, also support the collective reflection.

Reflection as focused on processes and products

As stated above, reflection is not only distinguished as being individual and collective but also treated as processes or as products.

From a process perspective, reflection is what is happening while we reflect, that is, the actual activity of thinking about content, strategies and meaning (Scholkmann & Lolle, 2021). To consider reflection from a process perspective means to look at acts and activities of reflection, that is, situations and practices in which subjects reflect. A process perspective, much in line with social-constructivist and pragmatic philosophy, is interested in how students reflect, and in the individual and collective activities that are undertaken to engage in reflective thought. Under this, of course, is the notion of learning as a continuous process, in which it is less the "what" than the "how" that is of interest. This process can be seen as meaningful in itself because it establishes a routine of being critically reflective, which has been advocated as a meaningful competence with which to meet the demands of a complex and incalculable world (e.g., Segev & Nadan, 2016). The process becomes a means to an end, that is, to develop a critically reflective mindset (e.g., Glazer et al., 2004). In the portfolio approach, which is closely connected to the idea of reflective thinking integrated into the learning process, this has been addressed through the "process portfolio", where techniques such as flow-writing and reflective introspection serve as tools with which to engage in ongoing reflective activities (Jenson, 2011; Yancey, 2009).

Conversely, a product perspective prioritises the outcome of the reflective process and thus treats reflection as the (often tangible) result. From a product perspective, which leans towards a more goal-oriented and therefore goal-driven paradigmatic understanding, reflections are the documentable and communicable results of learning activities which find their form in tangible products, but also in a language that documents higher-order reflective thinking. Product portfolios originate from this perspective; these often focus on documentable competences and skills, including formative and summative assessment (e.g., Davies & LeMahieu, 2003; Galán-Mañas, 2016). Reflections as products are important, however, since the expectation that students should reach high levels of critical thinking skills throughout their studies creates a need for students to be able to document such skills and make them communicable, for example, to possible employers.

Interplay between the two dimensions in a PBL environment

The dichotomy between individual and collective reflection has specific relevance in a PBL setting. Traditionally, the Aalborg PBL model places a strong focus on collective reflection and prioritises the process aspect: PBL groups engage in collective reflection about their collaboration processes, which is often facilitated by specific PBL competence teaching that traditionally accentuated knowledge about collaboration and learning processes (see chapter 7; also Holgaard et al., 2020). A small(er), more product-oriented aspect is involved at the end, where a written reflective statement is often required as part of the final project rapport, elaborating on the collaboration processes of the group that took place over the semester.

In many ways, therefore, Aalborg University organises its resources to support collective reflection processes in teaching practice. Study plans, curricula, and teaching all support collaborative work, and students are trained in reflecting, particularly on the group process. New initiatives to expand the AAU PBL model will support this process further. Progressive PBL activities framed as collaborative workshops will ensure systematic engagement in reflective learning activities, and megaprojects will improve collaboration and collective reflection on a larger scale.

While the collective part of reflections in the Aalborg PBL model can be seen as well-established and even as a blueprint with which to engage students in collective reflections, AAU's leadership also identified shortcomings (see also Chapter 7). AAU students seemed to struggle to communicate their learning outcomes from the collective experience to external stakeholders, especially potential employers. The often-tacit nature of the PBL group process also makes it difficult for students to transform their reflections from one group semester to the next, and from the group context to an individual perspective.

A suggestion for helping students work with reflections

As mentioned at the beginning of this chapter, one objective of the project was to find a method to help students become aware of and work with reflections and to be able to use them both during their studies and when they enter the job market. Although reflections may seem familiar to us, since we all reflect intuitively because we need to in order to learn from our experiences, it does not seem to be something that most students do by themselves (Jenson, 2011). Reflections in a pedagogical setting need to be scaffolded or co-constructed

with someone. We have developed an approach that can be used to show how students reflect on their learning outcomes and competences (Scholkmann & Lolle, 2021). Focusing on capturing and analysing the various stages in the process of the reflective practices, it consists of cycles of actions and reactions that will push the students to reflect and constantly relate to their reflections, and thus eventually make their tacit knowledge explicit. The cycle comprises an iterative element, that of practice and finally the element of analysis. In the following, we unfold the three elements separately and describe their use. In order to make it easier to follow the process in the method, we will use a different order than that given by the acronym.

Practice

Practice is a reflective task prompted by the teacher or supervisor. This task should trigger the reflections of the students on the specific topic, for example by drawing up a mind map of their competences. The result of this reflection should be preserved as a physical or digital artefact, for example by using pen and paper to write and draw. In some of the tasks in our research, the students could choose between different kinds of tools when producing the artefact, such as websites, pen and paper, or sensory postcards, to mention just a few. The cycle can be started face-to-face with the students at a workshop, or on an online forum where it is possible to upload the artefacts. We found that the type of tool was not relevant to the type of reflection. The essential factor was that the students used the tool that inspired them the most.

Analysis

The analysis element constitutes the reaction to the student's artefact, as well as the student's reaction to this reaction. More specifically, the supervisor starts by examining what constitutes the presentation of the student's reflection, for example, the mind map, handed in or uploaded, and responds to the student. The response is not a matter of evaluation, but more a kind of exchange between the supervisor and the student, where the supervisor asks supplementary questions and the student talks about the artefact, the mind map, and explains it. This exchange will scaffold the student to take their reflections even further and thereby make it easier for them to become aware of their competences, or the objective of the reflective task. If the exchange is part of a face-to-face workshop, the response can take the form of a discussion between the student

and the supervisor. This part is more challenging if it takes place on an online forum. Here it is imperative that the supervisor is very attentive to the student and pays close attention to what the student "says" so the student feels closely scaffolded and the response becomes as effective as possible for them. The reaction and response of the supervisor form the impulse of the cycle.

The iterative

As mentioned, the reaction to the documented reflections will take the student's reflections a step further. The student will then react to the reaction. This will trigger new reflections that also need to be preserved and will be the object of a new analysis, which triggers a new reflection and so the cycle goes on. At one point it might be necessary to introduce a new task or a new prompt to change the direction of the reflections. In that case, the process starts over with an artefact that will be the object of analysis and discussion, and this will activate new reflections or perhaps require a new task, and so on. The entire process thus forms an iterative cycle that can go on for as long as necessary.

Conclusion: what are reflections and how we can see students work reflectively

We have approached the fluffy concept of reflection in this chapter. Across the different terms and definitions, some characteristics stand out and bring us closer to a definition. First of all, the literature seems to agree that reflection is a cognitive process where emotions such as being open and ready play an important role. That the student is willing to engage in the process for the outcome to be successful is even considered by some authors to be the most important factor. Reflections are triggered by an unusual situation or a problem that does not have an immediate solution, and as a result of the reflections, a new understanding is integrated into the students' individual and collective knowledge base. This new or better understanding of how to solve a complex issue or problem and how the individual can learn from the experience is precisely the purpose of reflections. Finally, there is a time-related perspective of the process. Where some authors use specific timing, for example in phases or before-during-after, the findings in our research are more in line with those of Rogers (2001), that the reflective process constitutes a cycle that can go on for as long as necessary.

It is important, however, to distinguish between different levels and perspectives of reflection, particularly how reflection is practised in a problem-based setting such as Aalborg University where students do reflective work in connec-

tion with their project work. In order for students to get the most out of their studies and to be able to articulate their competences to external stakeholders when they enter the job market, reflections must be treated as both individual and collective, and as process- and product-oriented at the same time. Paying attention to how to facilitate the transitions between these categories becomes particularly important, that is, how reflections can go from the collective to the individual and back to the collective again; or, how a reflective process and documentable and communicable products of reflections can be modelled as complementary aspects in a pedagogical approach.

Based on our research we suggest that by showing how the students reflect, these reflections can be pushed even further by constantly prompting the students to relate to their reflections and thereby make their tacit knowledge explicit. In our study, the students worked with reflections on their competences, and it became clear that although they had all worked with reflective practices at some point during their studies, it was only through the iterative cycles that they became aware of the pathway of competences from the individual perspective to the collective from their studies, and back to the individual. It also became clear that working with the iterative cycles of actions (practice) and reactions (analysis) can continue for as long as necessary.

References

Aalborg University (2015) *PBL. Problem-based Learning*. Retrieved March 8, 2022, from https://www.aau.dk/digitalAssets/148/148025_pbl-aalborg-model_uk.pdf

Andersen, H. L., & Jacobsen, J. C. (2017). Til dannelse eller nytte. Universitetsuddannelser mellem forskningsbaseret faglighed og relevans for arbejdsmarkedet. Frydelund.

Boud, D., Keogh, R., & Walker D. (Eds.) (1985). *Reflection: Turning experience into learning*. Routledge-Falmer Taylor and Francis Group.

Boyd, E., & Fales, A.W. (1983). Reflective learning: Key to learning from experience. *Journal of Humanistic Psychology, 23*, 99–117.

Coulson, D., & Harvey, M. (2013). Scaffolding student reflection for experience-based learning: A framework. *Teaching in Higher Education*, *18*(4), 401-413

Davies, A., & LeMahieu, P. (2003). Assessment for learning: Reconsidering portfolios and research evidence In M. Segers, F. Dochy, & E. Cascallar (Eds.), *Optimising new modes of assessment: In search of qualities and standards, 1*, 141-169. Kluwer Academic Publishers. https://doi.org/10.1007/0-306-48125-1_7.

Deslandes, R., Lucas, C., Hughes, M. L., & Mantzourani, E. (2018). Development of a template to facilitate reflection among student pharmacists. *Research in Social and Administrative Pharmacy, 14*(11), 1058-1063. https://doi.org/10.1016/j.sapharm.2017.11.010.

Dewey, J. (1933). How we think: A restatement of the relation of reflective thinking to the educative process. D.C. Heath.

Dreyfus, S. E., & Dreyfus, Hubert L. (1980). *A five-stage model of the mental activities involved in directed skill acquisition*. California University Berkley Operations Research Center.

Fogarty, R. (1994). *Teach for metacognitive reflection*. IRI/SkyLight Training and Publishing.

Galán-Mañas, A. (2016). Learning portfolio in translator training: The tool of choice for competence development and assessment. *The Interpreter and Translator Trainer, 10*(2), 161–182. https://doi.org/10.1080/1750399X.2015.1103108.

Glazer, C., Abbott, L., & Harris, J. (2004). A teacher-developed process for collaborative professional reflection *Reflective Practice, 5*(1), 33–46. https://doi.org/10.1080/1462394032000169947.

Hansen, E. (2017). Professorer, studenter og politʼer. Om velfærdsstatens universitetspolitik 1950 – 1975. Museum Tuscalanums Forlag.

Holgaard, J. E., Ryberg, T., Stegeager, N., Stentoft, D., & Thomassen, A. O. (2020). *PBL: Problembaseret læring og projektarbejde ved de videregående uddannelser*. Samfundslitteratur.

Jamieson, A., Kolmos, A., & Holgaard, J. (2016). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education*, *103*(2), 253-273.

Jenson, J. D. (2011) Promoting Self-regulation and Critical Reflection Through Writing Students' Use of Electronic Portfolio. In *International Journal of ePortfolio* 1(1), 49-60.

Kandiko, C., Hay, D., & Weller, S. (2013). Concept mapping in the humanities to facilitate reflection: Externalizing the relationship between public and personal learning. *Arts and Humanities in Higher Education, 12*(1), 70–87. https://doi.org/10.1177/1474022211399381.

Kemmis, S., Wilkinson J., Edswards-Groves, C., Hardy, I., Grootenboer, P., & Bristol, L. (2014). *Changing practices, changing education*, Springer Science+Business Media

Langer, E.J. (1989). *Mindfulness*. Addison-Wesley Publishing. Og Langer, E.J. (1997). *The power of mindful learning*. Addison-Wesley Publishing.

Larkin, I., & Beatson, A. (2014). Blended delivery and online assessment: Scaffolding student reflections in work-integrated learning. *Marketing Education Review*, *24*(1), 9-14. https://doi.org/10.2753/MER1052-8008240101.

Leung, D. Y. P., & Kember, D. (2003). The relationship between approaches to learning and reflection upon practice. *Educational Psychology, 23*(1), 61-71.

Loughran, J. J. (1996). Developing reflective practice: Learning about teaching and learning through modelling. Falmer Press.

McLeod, G. A., Barr, J., & Welch, A. (2015). Best practice for teaching and learning strategies to facilitate student reflection in pre-registration health professional education: An integrative review. *Creative Education, 06*(04), 440. https://doi.org/10.4236/ce.2015.64044.

Mezirow, J. (1990). Fostering critical reflection in adulthood: A guide to transformative and emancipatory learning. Jossey-Bass.

Moon, J. (1999). Reflection in learning & professional development. Theory & practice. Routledge-Falmer.

OECD (1999) *OECD Employment Outlook 1999 - Giving Youth a Better Start*. Retrieved March 8 2022 at https://www.oecd.org/employment/emp/oecdemploymentoutlook1999-givingyouthabetterstart.htm.

O'Shea, P., & Kearney, M. (2016). A cognitive strategy scaffolding approach to facilitating reflection in engineering students. *Australasian Journal of Engineering Education*, *21*(1), 17-26. https://doi.org/10.1080/22054952.2016.1214097.

Rogers, R. (2001). Reflection in Higher Education: A Concept Analysis. *Innovative Higher Education*, 26(1), 37-57.

Reed, J., & Koliba, C. (1995). *Facilitating reflection: A manual for leaders and educators. Understanding reflection*. http://www.uvm.edu/~dewey/reflection_manual/

Reckwitz, A. (2002). Toward a theory of social practices. A development in culturalist Theorizing. *European Journal of Social Theory*, *5*(2), 243–263.

Schatzki, T. (1996). Social practices: A Wittgensteinian approach to human activity and the social. Cambridge University Press.

Schatzki, T. (2010). The timespace of human activity. On performance, society and history as indeterminate teleological events. Lexington Books.

Scholkmann, A. & Lolle, E. L. (2021) Opportunities, Challenges, Tools and Helpful Relations: Development of a Model of How to Foster Reflections in Higher Education. In *Journal of Problem Based Learning in Higher Education*. 9, 1 Special Issue.

Schön, D. (1983). The reflective practitioner: How professionals think in action. Basic Books.

Segev, E., & Nadan, Y. (2016). Facing reality: Context-oriented reflection in social work education. *British Journal of Social Work, 46*(2), 427–443. https://doi.org/10.1093/bjsw/bcu138

Sykes, J. (2011). Facilitating reflection on implicit learner beliefs through metaphor elicitation. *Pan-Pacific Association of Applied Linguistics*, *15*(1), 91–113

Taylor, C. (1995). Lichtung or Lebensform: Parallels between Heidegger and Wittgenstein. In Taylor, C. (Ed.) *Philosophical Arguments*, Harvard University Press. pp. 61–78.

Tucker, B., Jones, S., Straker, L., & Cole, J. (2003). Course evaluation on the web: facilitating student and teacher reflection to improve learning. *New Directions for Teaching & Learning*, 2003(96), 81–93. https://doi.org/10.1002/tl.125

World Bank (2011). *Learning for all. Investing in people's knowledge and skills to promote development*. https://openknowledge.worldbank.org/handle/10986/27790 (Accessed 14-02-21)

Yancey, K. B. (2009). Reflection and electronic portfolios. Inventing the self and reinventing the university. In D. Cambridge, B. L. Cambridge, & K. B. Yancey (Eds.), *Electronic portfolios 2.0. Emergent research on implementation and impact* (pp. 5–16). Stylus Publishing.

Zarezadeh, Y., Pearson, P., & Dickinson, C. (2009). A model for using reflection to enhance interprofessional education. *International Journal of Education, 1*(1). https://doi.org/10.5296/ije.v1i1.191.

PBL Competences and Progression

Antonia Scholkmann, Anders Melbye Boelt, Elisabeth Lauridsen Lolle & Anette Kolmos

PBL competences at Aalborg University – a success story with further potential

Since Aalborg University's (AAU) establishment, competences of problem-based learning (PBL) have been an integrated part of the university's curriculum; and throughout the years, the integration of PBL competences into AAU's various curricula has been formulated, implemented, and organised in various forms. Analyses of these developments have identified three phases (see Kolmos et al., 2019).

Early on, during the 1970s, PBL competences were primarily defined as practices of collaboration and project management (Algreen-Ussing & Fruensgaard, 1992; Algreen-Ussing & Kolmos, 1996), since for most of the students, collaboration in a project was a new practice, and they lacked experience in how to organise a project process adequately and effectively. In this phase, no formal competence development courses existed since the focus was solely placed on the group's problem work.

Since the mid-1980s and reaching well into the 1990s, several initiatives were established to support the students' acquisition of PBL competences in more structured ways (Kolmos et al., 2019). This was specifically done by establishing courses to support students' learning of how to handle the process involved in conducting their study projects. At the Faculty of Engineering and Science, for example, these PBL courses were positioned within the first-year programme and contained a systematic introduction to PBL competences combined with the requirement of a process analysis, which was part of the project (and assessed together with this for the final grade). These introductions to PBL were mainly theoretical but deemed necessary to get the students to work much more professionally in the project teams. In this phase, the focus shifted towards equipping the student with individual competences that could help complete the task of group work.

The prioritisation of a more explicit and reflected acquisition of competences, also in PBL curricula at AAU during the 1980s and 1990s, was partly an effect of high school curricula in Denmark putting an increased focus on project work, which led to new students having prior experiences with this approach. However, project skills taught at the high school level never matched the degree of problem-based project work at AAU, so additional competency development for PBL projects was still necessary. In addition, companies also began to express their desire to see (documented) PBL competences in addition to discipline-specific competences when hiring AAU graduates. These were competences such as project management, various types of collaboration skills, and the competence to reflect in an articulated language of practice (Kolmos & Kofoed, 2002) – which then together were considered core employability skills (Graham, 2012; Kolmos & Holgaard, 2010; Nigel et al., 2006). Therefore, since the 2000s, PBL courses at AAU, have changed focus to facilitate students' collective reflection on the project process and have been combined with tools and methods to analyse problems and collaboration patterns, solve conflicts and manage knowledge sharing and project management.

In essence, the development of pedagogies engaging students in an exploration of their PBL competences can be described as ongoing at AAU, from an early model of instruction about PBL competences (presenting theories and methods on "how to do PBL") to an experiential learning approach (reflection on learning content and experiences as part of the group process) towards an approach of instrumental learning (combining theory and experiences in a more routine reflection on PBL competence developments; see Kolmos et al., 2019). What has remained stable are courses teaching PBL competences explicitly in the study entrance phase, and that competence reflection is primarily focused on the joint group processes.

AAU has received a lot of acknowledgement for its PBL model and the fact that graduates have been easy to integrate into the labour market. Several national reports from industrial societies have ranked Aalborg University highly on graduates' employability competences and their research collaboration and accessibility (Danish Industry). However, in a rapidly changing and globalised world, students need to have a clear and communicable understanding of what they can offer after completing their studies. The discipline-specific advisory boards of the educational programmes have repeatedly expressed that AAU's graduates do not emphasise their PBL competences enough in their communication with, for example, employers. Therefore, AAU's top management decided to implement PBL competences more prominently throughout the cur-

riculum and not only as part of the study entrance phase. However, this meant revisiting understandings of PBL competences, as well as treating them as progressive (as opposed to static in the existing approaches). Additionally, there was the need to work on the conceptual and pedagogical underpinnings of what allows students to continuously reflect on their learning with and through PBL. The disentanglement and modelling of these conceptual and pedagogical underpinnings, therefore, were important aspects of the research conducted within the PBL Future Project.

The purpose of this chapter is to elaborate on the notion of PBL competences and the idea of their progressive development. To pinpoint a definition of a PBL competence for the Aalborg PBL model, the next section of this chapter will dig into the historical and empirical underpinnings of the competence concept and relate it to the specific conception of PBL competences practised at AAU. The third section of this chapter will then ask how the progressivity of competence development can be understood and modelled throughout the study life cycle. In this section, as well as in the concluding remarks, we point out the importance of reflective activities in PBL competence development. Here, we supplement our elaborations with elements of a case example of how PBL competences and their development are being modelled and practised at AAU's Faculty of Engineering and Science and the Technical Faculty of IT and Design.

Competence definitions and PBL

The many – yet limited – faces of current competence definitions

Defining PBL competences is a necessary step to help teachers, educational leaders, and students alike to integrate them into curricula transparently and actively. However, the scholarly discussion shows that "competences" is one of the most ambiguous and contested concepts in teaching-learning research, and it is not an easy task to define what competence is, how competences can be fostered, and to discern which type of learning opportunity leads to which type of competences.

In their analysis of competence definitions in human resource development from the USA, UK, France and Germany, Le Deist and Winterton (2005) stress that what is defined as "competence" is dependent on the philosophical and normative standpoint of the respective researchers. They describe three approaches: *behavioural*, *functional,* and *multi-dimensional and holistic*. Each of these is described as stemming from different traditions and orientations towards models of personality, education, and practices. The *behavioural ap-*

proach is an orientation that pre-sets competences as the attributes of successful job performers and how they differ from those less skilled, and the engineering of education is a way to teach students these attributes. A suitable comparison is that of scientific management, observing the most effective performers set a standard for benchmarking activities (Callahan, 1962). In the *functional approach,* a group of experts (for example, employer representatives and trade union officials) validate qualifications based on professional standards rooted in work requirements. To act competently is then to be able to demonstrate performance meeting these requirements. *Multi-dimensional and holistic approaches* toward defining competences include both theoretically inferred competence aspects (specifically, domain-specific knowledge), but also a practical and functional dimension as well as a behavioural component. In this approach, the emphasis is on specifying learning input rather than anticipated outcomes to perform competently within a particular trade, that is, as an input rather than output-driven approach.

Sandberg (2000) notes that rationalistic approaches to competence can be discerned in *worker-oriented*, *work-oriented*, and *multimethod*. The worker-oriented approach aims to capture and classify the required attributes of (competent) workers through interviews with groups of employees and supervisors. Often, these requirements are described in KSAs (knowledge, skills, and abilities). The work-oriented approach has similar aims and is conceptualised in a set of specific qualities derived from activities, but in the output, the activities are transformed into personal and more specific competences than the former. Both approaches have met criticism either for being too broad or for assessing activities that cannot readily capture individual attributes needed for efficient work (Sandberg, 2000). To mitigate this, a multi-methods approach has also been applied drawing on the work- and worker-oriented approaches.

Both of the above-mentioned conceptions share that they see competences defined through a set of attributes. What is problematic, though, is that such a definition does not consider the context-relatedness of competences, which means that, for example, communication competence in one context can mean something different in another (see Sandberg, 2000). Raven (2001) is more direct in his critique. Managerial competences, Raven writes, are not something that occurs in a human being, rather, 'it is determined by an interaction between roles requirements and personal qualities' (p. 254). Context-free concepts, however, become nodal points devoid of meaning (Mannion et al., 2011). Also, many of the well-known competence definitions suffer from the confinements of an underlying dualistic ontology: person and the world are conceived

of as distinct entities and work, and the worker are separate rather than one entity in lived experience.

PBL competences as context-bound meaning-making

A view that can help to overcome this shortcoming can be found in approaches that connect competences to the concrete context in which they unfold. This view has been labelled 'interpretive' (Sandberg, 2000) by some; however, we would like to argue for defining competences as the emergent properties of concrete situations, in which tasks and problems serve as the starting point of any experience of a competence – very much in the sense of a 'practice turn' in social sciences study (e.g., Buch, 2017). This also resonates with some of the most prominent empirical findings on PBL competences (although from the Maastricht Case-based PBL model): here it could be shown that only several years after completion of their studies, students were able to see and express the relevance and meaning of their PBL learning experiences in light of their then-prevalent experiences in their working life (in the case of these studies as medical doctors, see Cohen-Schotanus et al., 2008; Schmidt et al., 2009).

An important perspective in understanding competences as emergent and context-bound can be found in studies that look at how individuals experience their competence development and trajectories. In his seminal phenomenographic study, Sandberg (2000) found three conceptions of competence in the view of a group of automotive engineers. He distinguished them into the categories of *single*, *inter-relations,* and *extra-relations*. In the first category, participants conceived of competences as something that helped them to understand the inner workings of an engine in isolation; participants in the second category understood them as understanding the engine in relation to the rest of the car, and participants in the third category defined them as not only the relation between engine and car but also the people driving in the car. This is slightly reminiscent of Biggs' (1999) SOLO taxonomy, where understanding is described in terms of a simple and mono-dimensional ending in more complex and intertwined patterns of recognition and action. It should be noted that while Sandberg's (2000) study concerns competence at work, Biggs (1999) focuses on the study of observable learning outcomes in education. In addition, other phenomenographic studies have come to similar results – for example, Wilhelmsson et al. (2011), who distinguish medical doctors' conceptions of anatomy in a very similar line as Sandberg does for automotive engineers. And a similar result, although preliminary at this point, also comes from one of our own research projects, where we found that students in a PBL curriculum

themselves seem to transition between competence stages during their study trajectories (Scholkmann et al., in prep.).

What stands out from these findings is the tight interwovenness of an individual's conception of the task at hand and their conceptions of the competence needed to address this task (see Sandberg, 2000). Following this line of thought, we can assume that competence development is more than a display of specific knowledge and enactment of socially accepted behaviours, that is, a reproduction of socially desirable traits and practices (see, for instance, Biggs, 1999; Bloom et al., 1956; or more critically, Bourdieu & Passeron, 1977/1990). This notion encourages us to take one step back from a perspective on competence development being a linear step-by-step process.

A working definition of AAU PBL competences

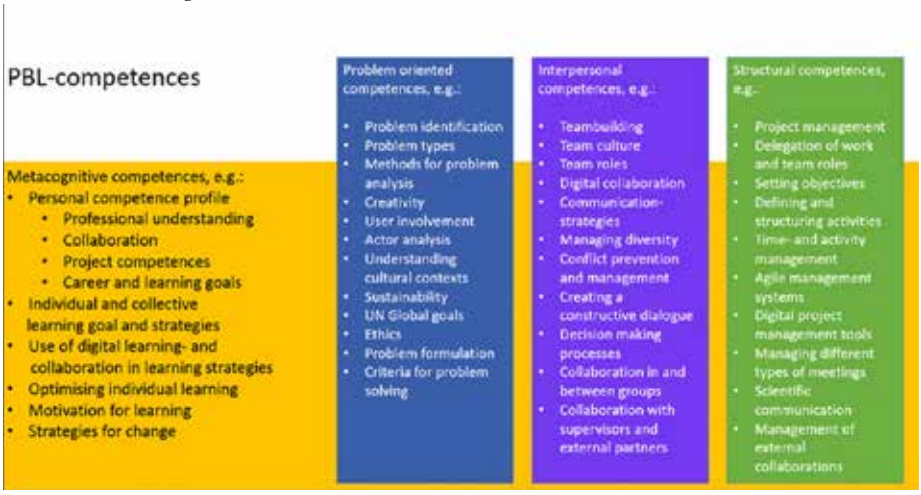
The notion of competences as being both context-bound and individually constructed in interplay with said context resonates well with the pragmatic and practice-oriented underpinnings of the Aalborg PBL approach, where variation and the personal competence trajectory also play an important role (Scholkmann, 2020). What is central to the PBL process is the focus on said process and an identified problem throughout the learning process rather than product development (Kolmos & De Graaff, 2014). By that, competences developed in PBL are tightly connected to the contextual conditions defined by the problem identified. However, they are not as such bound to a specific domain but relate to the PBL process that the students experience while they undergo it. Therefore, PBL competences are to be considered a type of practice experience, out of which tangible and transferrable parts can only be extracted through reflection. However, this also means that PBL competences must be defined differently than more 'traditional' competences.

The recent approach at Aalborg University roots its definition of a PBL competence around the skills needed for project work, and it has been argued that PBL, in its various forms, is suited to make students competent to address the major environmental and societal challenges the world is facing (Thomassen & Stentoft, 2020). One example of how a working definition of PBL competences comes from the Faculty of Engineering and Science (ENG), and the Technical Faculty of IT and Design (TECH). Here, four types of competences were identified partly by research and partly by practitioner experiences from developing the curriculum. These are 1) problem-oriented competences, 2) interpersonal competences, 3) structural competences, and 4) meta-cognitive competences (Holgaard et al., 2021; Holgaard & Kolmos, 2019). This is slightly reminiscent of the four dimensions Le Deist and Winterton (2005) suggest as a holistic ty-

pology, including aspects from the different conceptions described above, distinguishing *functional competences* and *cognitive competences* aimed at occupation, and *personal competences* and *social competences* that cover the individual aspects of the holistic typology (see Figure 1).

Figure 1

Process/PBL Competences



Note. Domain-specific and metacognitive PBL competences (Holgaard & Kolmos, 2019)

The three vertical competences in the model can be considered domain-specific within the Aalborg PBL model; problem-oriented competences cover the ability to be able to identify and analyse contextual problems and then reduce the problem to an educational setting that can be disciplinary or interdisciplinary. Interpersonal competences are characterised by the collaborative aspects that can be influenced by digital, cultural, and personal communication, and in which students need to learn how to handle these dimensions constructively. Structural competences cover project management, knowledge management, leadership, and the establishment of partnerships. These three PBL domain-specific competences are complementary and will also overlap each other in practice, but they also each represent their epistemology as the problem is cognitive, the interpersonal is affective and the structural is logic (Holgaard & Kolmos, 2019).

The fourth competence dimension, depicted as horizontal in the model, is meta-cognitive competences. Domain-specific PBL competences are cross-cutting (i.e., meaningful across several disciplines); however, they are related to

a given context/practice, such as engineering. Meta-competences are higher-order competences (in the sense of "competences to develop competences"), which develop the way domain-specific PBL competences are related to different practices/contexts and developed. In further developing the PBL competences, reflective meta-competences are needed. The meta-competences are defined by reflection and development of the specific competences and therefore, at a higher reflection level (Brown, 1993; Le Deist & Winterton, 2005). Whereas the specific PBL competences reflect the questions, "Are we doing things right?" and "Are we doing the right things?", the meta-competences are reflected in the question "How do we decide what is right and how do we develop our PBL competences?" By that, the metacognitive competences comprise the reflection of both individual and collective experiences. They also entail the above-mentioned awareness and subsequent communicability of one's learning and competence development. Through reflection in and on practice, increased awareness can be created of the tacit knowledge embedded in collaboration in a project group. This should result in a competence profile indicating the strengths and weaknesses and the ability to adjust to new situations.

Progression. The "blank page" in PBL competence development?

In the previous parts of this chapter, we elaborated on how PBL competences should be conceived of as rooted in concrete contextualised practices and on PBL meta-competences as the ability to adjust to new situations. However, one question remains unanswered: how do we address the fact that competence development does not happen at one point in time only, but instead must be understood as an iterative and progressive process spanning the entire study life circle, and beyond?

Competences developing progressively throughout a study programme should not be considered mysterious since it is obvious that students will become better, more proficient and/or reflective about their competences based on various iterations of the problem-based learning cycle. However, to pedagogically discern and model this progression remains challenging, as does the translation of this into concrete study programme descriptions. On the one hand, research on competence development has always conceptualised this as being progressive, drawing on, for example, Anderson and Krathwohl's taxonomy of cognitive learning goals (Anderson & Krathwohl, 2001) or the idea of progression from novice to expert of Dreyfus and Dreyfus (1980). On the other hand, there is a notable lack of examples of how progression regarding competence goals has been modelled for the teaching-learning process, especially

beyond the level of single courses. To the best of our knowledge, Brabrand and Dahl (2009) have conducted the only study on progression above the course level. The authors could show that only some of the programmes at both University of Aarhus and the University of Southern Denmark modelled notable progression in their written-down, intended learning outcomes.

In the tradition of the cognitive learning sciences (which also have had a strong influence on the competence research discourse), progression in competence acquisition is often seen as building up from more simple procedures to complex thinking, analytical, and creative skills. Well-known taxonomies on learning progress such as the ones by Anderson and Krathwohl (2001), Bloom et al. (1956) or John Biggs' SOLO-taxonomy (Biggs & Collis, 1982; Biggs & Tang, 2011) can be seen as feeding into this line of thinking. It is important to note, though, that treating such taxonomies as linear templates for the development of competences, or even as pedagogical models, has never been their intention (for further elaboration on these two aspects, see Upmeier zu Belzen et al., 2019). Instead, they aim for a qualitative and analytical distinction between categories of students' thinking processes and/or intended learning outcomes. In this sense, they provide a powerful tool to describe the quality of engagement with certain aspects of the learning process, which can, for example, be of good use in the description of competence progression in study programmes.

Regarding PBL competences, progression becomes specifically difficult to grasp due to the complexity of the pedagogical approach and the fact that progression also shows itself in concrete practices. The Aalborg project-based problem-oriented study programmes are built around group work spanning an entire semester that revolves around authentic problems, which in themselves will not necessarily be less or more complex, depending on whether students are studying their first or tenth semester. Moreover, the types of competences that can be expected to be fostered through a complex PBL arrangement are complex in themselves and eventually hard to compartmentalise in easier and advanced stages. An example here is the competence that is gained through collaborating with external stakeholders who are usually the owners of the problem in the project; it seems irresponsible to formalise the competence to collaborate with these actors as anything other than a high-quality interaction – thus, it cannot be compartmentalised in a beginner or advanced stage. However, as many competence development models have shown, progression is an indispensable part of this journey, and students will refine their interactions with external stakeholders upon each iteration.

The shortcomings of taxonomic approaches when it comes to competence development progression in our view are comprised of three aspects: they tend to focus on the cognitive aspects of the learning process (due to their origin in the more cognitively oriented learning sciences) and they do not address the iterative nature of competence development, specifically not in a PBL context. Moreover, they do not provide guidance on how their assumed different levels of complexity are to be achieved (which in certain cases has led to their aforementioned misuse as a linear tool). Consequently, we suggest that competence development progression within a problem-based curriculum must integrate the aspects of *iteration(s)* and *transfer*.

Iteration or *iterations* mean(s) the repetitive use, evaluation, and refinement of an idea, product, or prototype (Dohn et al., 2019; Visscher-Voerman et al., 1999). Based on a pragmatic understanding of the learning process (Dewey, 1933; Kolb, 1984), the idea is that through the gaining of experiences and their subsequent reflection, development is being initiated. In a PBL curriculum, each project and even part of it can be seen as bigger or smaller iterations of the handling of a complex and challenging situation, which, in the sense of the German action-competence tradition, can be seen as serving the acquisition and deepening of professional action competence (Heiner, 2012; Mogensen & Schnack, 2010).

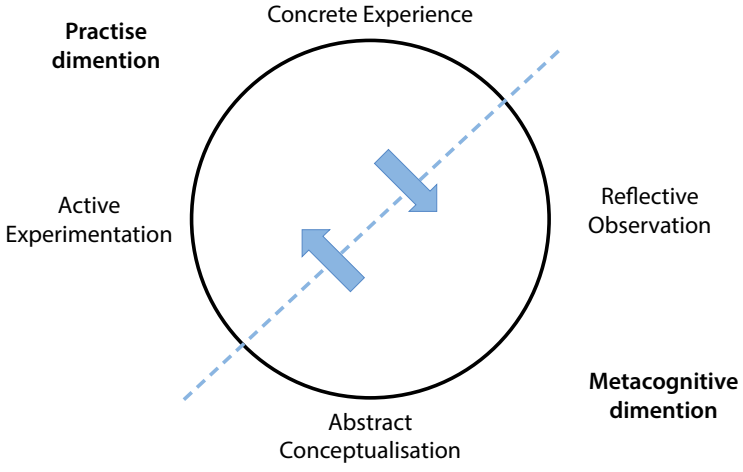
Iterations in the PBL learning design allow students to revisit structurally equivalent situations, such as group collaboration, interaction with learning content, or negotiations with external stakeholders, and continuously refine and redesign the competences elicited by these quasi-professional situations that will be different from each other. This also entails the *transfer* or *transformation* of earlier experiences into new, albeit similar situations, and, here, the aspect of variation might be a factor in the learning process as these situations may be compared to each other. In this sense, competence development progression touches upon the individual student's construction of meaning and trajectory throughout their studies. This becomes apparent in an analysis from the PBL Future Subproject 3, where over three semesters, students were repetitively engaged in activities to reflect upon their personal competence development. The analysis indicated that competence development neither starts with the first day at university nor ends with the end of a study programme, but that it is a continuous journey in which prior experiences serve as a starting point for development through attempts of transfer and accommodation processes (Scholkmann et al., in prep.; see also Boud et al., 1985).

Transfer and transformation gain a special angle in a PBL curriculum since this also means that tacit knowledge built during the group process undergoes multiple conversions: the first of these being from the tacit to the explicit level and, along with that, from the collective to the individual level. Competences at the group level are built up and emerge rather than made explicit. The tacit collaboration makes it difficult to transform knowledge and competences from one project to the next. However, we must assume that the individual student, who is the bearer of competences, will be able to activate and transform knowledge and experiences in a meaningful way from one project to a new project. Individual learning, therefore, must integrate the competences developed by an entire team as well as an individual awareness of the individual contribution to the team. This is not an easy task, as it not only contains a cognitive and rational process but often depends on several other factors, such as the ability to understand one's own function and role, the individual's interpretation of the interpersonal interaction, contextual factors, the group's focus in the discussions, and whether there is a reflective discourse present in the situation – that is, the metacognitive PBL competences from the working definition above.

An example of how this iterative process looks can be found through the application of Kolb's learning cycle (Kolb, 1984), which has been used to understand these processes at the Faculty of Engineering and Science and the Technical Faculty of IT and Design at AAU (Holgaard & Kolmos, 2019; see Figure 2).

Figure 2

Illustration of the Interaction between the Practice and the Metacognitive Dimension



Note. (Holgaard & Kolmos, 2019)

Kolb (1984) emphasises active learning by experimentation and concrete experiences as fundamental aspects of learning. To avoid a process of trial and error, this is combined with reflective observation and abstract conceptualisation that can help navigate between an analysis of the concrete situation and the general perspective and vice versa. The reflection starts with an observation of the concrete practice. The metacognitive part is facilitated by linking and comparing experiences from practice together with a theoretical framing. There is a constant iteration between the practice and the metacognitive dimension, which must be understood in the sense of a spiral. In order to obtain progression towards competence development, the active/situational, and the reflective/theoretical side of the experiential learning circle have to be both present and combined – hence, the cycle has to be completed. By that, the progression here is understood as continuity and interaction or sameness and difference. Continuity or sameness refers to the way past experiences will influence current experiences and learning happens in continuous spirals. By that, progression appears when students build on past experiences in addressing new and different situations and interactions.

The analysis of the two-fold process between spirals of concrete experiences on the one hand and metacognitive scrutiny of these experiences on the other hand as seen through the lens of Kolb's (1984) learning cycle points out the importance of reflective practice for students to become aware and communicable about their own competences. This entails engaging students in reflective activities that combine opportunities to reflect on challenges, tools, and helpful relations (Scholkmann & Lolle, 2021). Both iterations and transformations are closely tied to reflection. Reflection, as elaborated in chapter five, is what converts experience to learning by metacognitive scrutiny and cognitive representation and framing (Boud et al., 1985; Mezirow, 1991). This applies to competence development, specifically, since a transferable competence requires exactly this – a metacognitive and abstract representation of a concrete experience. The same holds true (although not elaborated extensively in the reflection literature) for the reframing of competence in a new context and situation, where reflective processes can be assumed to help shape the fit between the new concrete affordances and the "learning" embodied in the individual. In this sense, the transformation of competences and their iterations can, along with reflection, also be considered acts of de-contextualisation, abstraction/transformation, and re-contextualisation of the Scandinavian New Institutionalist research tradition (Sahlin & Wedlin, 2008; Scholkmann, 2020).

Concluding remarks

In the present chapter, we elaborated on the history and definition of PBL competences at Aalborg University and explored several aspects that constitute and facilitate progression in competence development and awareness – namely iterations, transformation, and the role of reflection. This exploration is based on the extensive experience gained through working with the Aalborg PBL model and on the research conducted in the PBL Future initiative. Based on our insights, we think that the conceptualisation of pedagogical enactment of competences in a problem-oriented curriculum must adhere to the following points:

- PBL competences are tied to the learning process, that is, as co-constructed rather than preset.
- They are worked up in iterative processes that enable both transfer and transformation (both from the group to the individual level and subsequently across projects).
- These iterations bear the need for reflection that needs to be facilitated to develop their full potential.
- Facilitated reflection might not only foster transformation across the group and individual levels and across projects but might also provide students with the language to express their personal PBL competences, and hence transform them to contexts outside the university.

As can be seen from the elaborations, not only do competences need to be progressively integrated into curricula, but also students must become more aware of what they are competent in and find a language to communicate their competences to future employers. The awareness and communicability of competences might well be a blind spot on the map of competence research and competence-oriented pedagogies. Our research has shown that even PBL students struggle to understand what competences are and how to communicate them (Scholkmann et al., in prep.). This might (also) be because competences – as written in study programme descriptions – are often treated normatively, whereas there might be mismatches with what students learn instead (see Küng et al., 2012; Scholkmann, 2017).

When it comes to the pedagogical facilitation of such reflections, various models and templates have been suggested (see chapter 5). Some of them focus on the pedagogical elements that hold the potential to engage students in reflection – such as challenges, tools, time and space to reflect, and helpful interpersonal relations (Scholkmann & Lolle, under review; see also chapter 5).

Other approaches have focused on the iterative nature of the reflection process (Holgaard & Kolmos, 2019), and the Iterative Process Analysis approach (Lolle & Scholkmann, under preparation). Either way, the reflective cycles students go through can be seen as learning opportunities that allow them to scrutinise their experiences, emotions, and values and transcend these into durable learnings as a basis for professional action. In this sense, we hope that this chapter provides inspiration and guidance for future steps to integrate PBL competence development progression – at AAU and beyond.

References

Algreen-Ussing, H., & Fruensgaard, N. O. (1992). *Metode i projektarbejdet: problemorientering og gruppearbejde*. Aalborg Universitetsforlag.

Algreen-Ussing, H., & Kolmos, A. (1996). *TEKNATBAS-projektet*. Institut for Samfundsudvikling og Planlægning, Aalborg Universitet.

Biggs, J. (1999). *Teaching for quality learning at university*. SRHE and Open University Press.

Bloom, B. S., Engelhart, M. B., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives. The classification of educational goals. Handbook 1: Cognitive domain. Longmans Green.

Brown, R. B. (1993). Meta-competence: A recipe for reframing the competence debate. *Personnel Review, 22*(6), 25-36. https://doi.org/10.1108/EUM0000000000814

Bourdieu, P., & Passeron, J. C. (1977/1990). *Reproduction in education, society, and culture*. Sage.

Buch, A. (2017). Praksisteori og arbejdslivsforskning. *Tidsskrift for Arbejdsliv*, *19*(4), 36–50. https://doi.org/10.7146/tfa.v19i4.109051

Callahan, R. E. (1962). *Education and the cult of efficiency*. University of Chicago Press.

Cohen-Schotanus, J., Muijtjens, A. M. M., Schönrock-Adema, J., Geertsma, J., & van der Vleuten, C. P. M. (2008). Effects of conventional and problem-based learning on clinical and general competencies and career development. *Medical Education*, *42*(3), 256-265.

Dewey, J. (1933). How we think: A restatement of the relation of reflective thinking to the educative process (2nd ed.). D.C. Heath and Company.

Dohn, N. B., Markauskaite, L., & Hachmann, R. (2020). Enhancing knowledge transfer. In Bishop M.J., Boling E., Elen J., Svihla V. (Eds.), *Handbook of research in educational communications and technology* (pp. 73-96). Springer, Cham. https://doi.org/10.1007/978-3-030-36119-8_5

Graham, R. (2012). Achieving excellence in engineering education: The ingredients of successful change. The Royal Academy of Engineering.

Heiner M. (2012) *Referenzpunkte für die Modellierung der Kompetenzentwicklung in der Lehre – Impulse für die hochschuldidaktische Weiterbildung*. In Egger R., Merkt M. (Eds.) Lernwelt Universität. Lernweltforschung, vol 9. VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-18941-3_10

Holgaard, J. E., Søndergaard, B. D., & Kolmos, A. (2021). *Guidelines for Progression of PBL Competencies: In Engineering and Science Education*. Aalborg Centre for Problem Based Learning in Engineering, Science and Sustainability under the auspices of UNESCO.

Holgaard, J. E., & Kolmos, A. (2019). Progression in PBL competences. In *Proceedings SEFI 47th Annual Conference: Varietas delectat… Complexity is the new normality* (pp. 1643-1652). SEFI: European Association for Engineering Education. https://www.sefi.be/wp-content/uploads/2019/10/SEFI2019_Proceedings.pdf

Kolmos, A., Bøgelund, P., & Spliid, C. M. (2019). Learning and Assessing Problem-Based Learning at Aalborg University: A Case Study. *The Wiley Handbook of Problem-Based Learning*, 437-458.

Kolmos, A., & Holgaard, J. E. (2010). Responses to Problem Based and Project Organised Learning from Industry. *International Journal of Engineering Education*, *26*(3), 573-583.

Kolmos, A., & Kofoed, L. B. (2002). Developing process competencies in co-operation, learning and project management. In 4th World Conference of ICED.

Kolmos, A., & De Graaff, E. (2014). Problem-based and project-based learning in engineering education. In A. Johri & B. M. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 141–161). Cambridge University Press. http://dx.doi.org/10.1017/CBO9781139013451.012

Küng, M., Scholkmann, A., & Ingrisani, D. (2012). Problem-based learning: Normative Ansprüche und empirische Ergebnisse. In S. Keller & U. Bender (Eds.), *Aufgabenkulturen fachliche Lernprozesse herausfordern, Begleiten, Reflektieren* (pp. 266–280). Klett Kallmeyer.

Le Deist, F. D., & Winterton, J. (2005). What is competence? *Human Resource Development International*, *8*(1), 27-46.

Mogensen, F. & Schnack, K. (2010) The action competence approach and the 'new' discourses of education for sustainable development, competence and quality criteria, *Environmental Education Research, 16*(1), 59-74.

Nigel, S., Nick, S., & David, B. (2006). Educating engineers for the 21st century: The industry view. Retrieved from http://www.raeng.org.uk/publications/reports?p=7#sthash.0yS6yhdX.dpuf

Mannion, G., Biesta, G., Priestley, M., & Ross, H. (2011). The global dimension in education and education for global citizenship: Genealogy and critique. *Globalisation, Societies and Education*, *9*(3–4), 443–456. https://doi.org/10.1080/14767724.2011.605327

Raven, J. (2001). The Conceptualisation of Competence. In J. Raven & J. Stephenson (Eds.), *Competence in the Learning Society*. Peter Lang Publishing.

Sandberg, J. (2000). Understanding human competence at work: An interpretative approach. *Academy of Management Journal*, *49*(1), 18.

Schmidt, H. G., Cohen-Schotanus, J., van der Molen, H. T., Splinter, T. A. W., Bulte, J., Holdrinet, R., & van Rossum, H. J. M. (2009). Learning more by being taught less: A "time-for-selfstudy" theory explaining curricular effects on graduation rate and study duration. *Higher Education. 60*(3), 287-300. http://www.springerlink.com/content/eu74722t76648244/fulltext.pdf

Scholkmann, A. (2020). Why don't we all just do the same? Understanding variation in PBL implementation from the perspective of Translation Theory. *Interdisciplinary Journal of Problem-Based Learning*, *14*(2). https://doi.org/10.14434/ijpbl.v14i2.28800

Scholkmann, A., Tretow-Fish, T. A. B., Otrel-Cass, K., & Lolle, E. L. (under preparation). Students understanding of (their own) competences in problem-based curricula. Ananalysis through the lens of Cultural Historical Activity Theory (CHAT).

Wilhelmsson, N., Dahlgren, L. O., Hult, H., & Josephson, A. (2011). On the anatomy of understanding. *Studies in Higher Education*, 36(2), 153-165.

Semester Structure and the Question of Coherence Between Courses and Projects

Jon Ram Bruun-Pedersen, Lise Busk Kofoed, Nanna Svarre Kristensen, Lars Birch Andreasen

> A coherent science curriculum should build ideas across time and disciplines by connecting ideas between relevant topics and by aligning the development of instructional materials, instruction, and assessment. In order to accomplish this, coherent instructional materials must be developed that provide students with learning opportunities that enable them to use and link ideas to explain and predict phenomena as well as to solve problems. (Shin et al., 2009)

In this chapter, we introduce and discuss some of the potential effects of including considerations of *coherence* in certain aspects of a problem-based learning (PBL) curriculum and learning design, looking primarily at the semester level. We argue that thinking about semester design through the lens of coherence may help shape and define PBL-based semester directives and activities. Effects may include the solidification of a student's meta-cognitive construction of learning, in which semester organisation and operation can be instrumental.

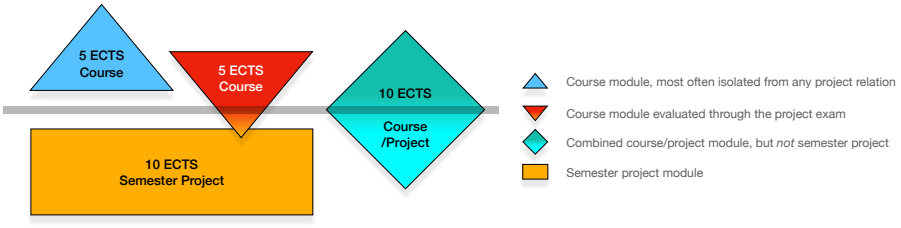
Coherence, as a term and concept for learning and academic teaching practices, can be understood as "shared understandings among faculty and in the manner in which opportunities to learn have been arranged (organisationally, logistically) to achieve a common goal" (Tattoo 1996, p. 176). Here, the authors refer to coherence as a kind of strategic confluence of aims, where several entities embrace, and align with, a shared direction for their organisation, logistics, and practitioners. Every part of an organisation affects the successful (or otherwise) implementation of the common goal or vision. The reason coherence is an important consideration, as suggested by Shwartz et al. (2008), lies in the learning process in which particulars (topics, discrete knowledge) evolve into deeper, interconnected structures or understandings. The authors found that curricular coherence occurs through the mechanisms of alignment and sequencing of topics and the depths that such alignment allows. Problems arise when a broad range of topics are presented in an unrelated fashion. Curricular coherence is

necessary for the cognitive coherence needed to place and connect knowledge in relevant contexts. For this reason, Shwartz et al. (2008) argue that curricular coherence is the main predictive factor in effective student learning, but note that it is a complicated and challenging task to develop coherent curricula. Fortus et al. (2015) also explain the importance of the conception that knowledge and ideas are built and cultivated incrementally over time. Fortus et al. (2015) suggest that effective execution requires a systematic structure for instruction, a) where learners are progressively supported to develop their foundations within the system, b) where learning modules within the system (also often referred to as 'units') operate within shared objectives, and c) where the shared objectives are both represented and explicitly positioned inside a coherent map of the learner's field or area of professional application. If implemented well, this system of coherence should enable and support a scaffolding type of learning development, where learners can understand the position of a knowledge piece or skill set, and eventually understand the logic of their past or future learning progression (Fortus et al., 2015). This includes facilitation to revisit previous learning points, to keep uncovering, exploring, and deepening the learner's understanding, for example by extending it with new knowledge, or connecting prior knowledge to new formats, contexts, problems, or application areas.

Many PBL-oriented learning environments have good potential for coherence structures. For example, Aalborg University (AAU) semesters have historically promoted a coherence-centric system with a variety of module types available for study plans, to design their semesters. For example, a one-course module type would have its learning objectives integrated into that of a larger semester project. The course module would be assessed through the project exam. Another example is having smaller projects formally embedded in courses (Kolmos & Holgaard, 2012). Examples of different module options can be seen in Figure 1.

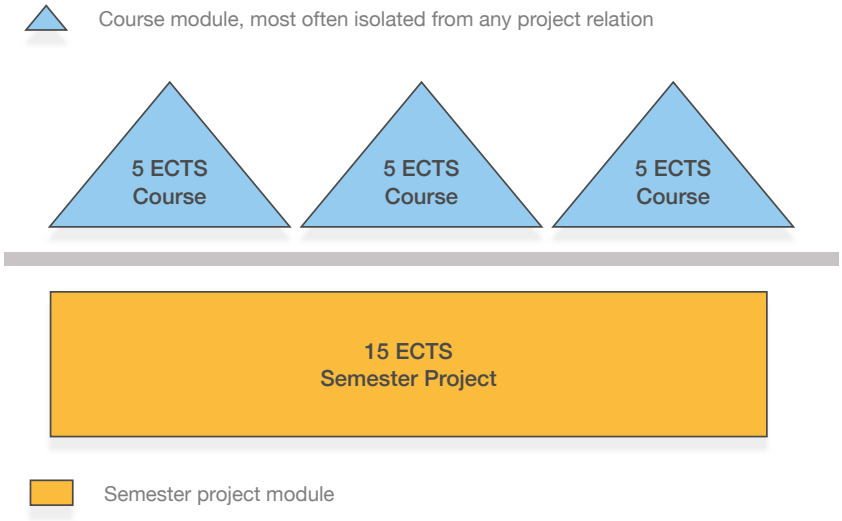
Figure 1

Examples of possible course/project relations/integrations at AAU



The aspiration to improve the AAU Model is always ongoing, with each iteration solving certain issues, while incidentally introducing others. At the time of writing, the current model (Figure 2) could be argued as a step away from a coherence-centric design, as it focuses purely on self-isolated modules, with no formal connection or transfer between modules.

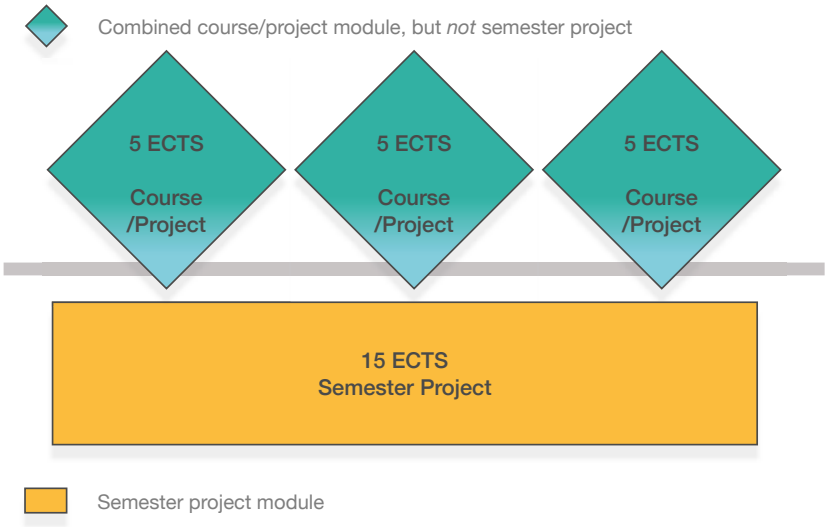
Figure 2
Current semester model



The effect on creating coherence is obvious, in missing formal options for both inter-course modules and course-project connections. Meanwhile, it has spawned an interesting trend in some AAU education degree programmes, as certain programmes have slowly developed over the last decade, with an autonomous transition into hybrid course/project modules, thus unofficially replacing the more conventional, self-isolating course modules (Figure 3). Here, teachers are embedding mini projects into the five ECTS workload for students, often as a written assignment that is submitted before the exam and is included in the basis for the evaluation.

Figure 3

The common appearance of semesters



As an example, Figure 3 represents an interesting emergent situation, in the conversation about learning-oriented coherence structures. Figure 3 shows how teachers - likely teachers who are experienced in the PBL-based learning environment - gradually gravitate their courses towards the inclusion of project work. Here, students can revisit, explore, and expand their relationship with the course curriculum, and are given autonomy to challenge the practical application of the curriculum. To an extent, this autonomic insertion of projects into non-project courses invigorates a necessary conversation on the value of the course-to-project transfer, a concept that has historically been advocated as one of the core principles in the AAU model, but then, this should also be a conversation on the value of having coherence-centric structures in the AAU learning model.

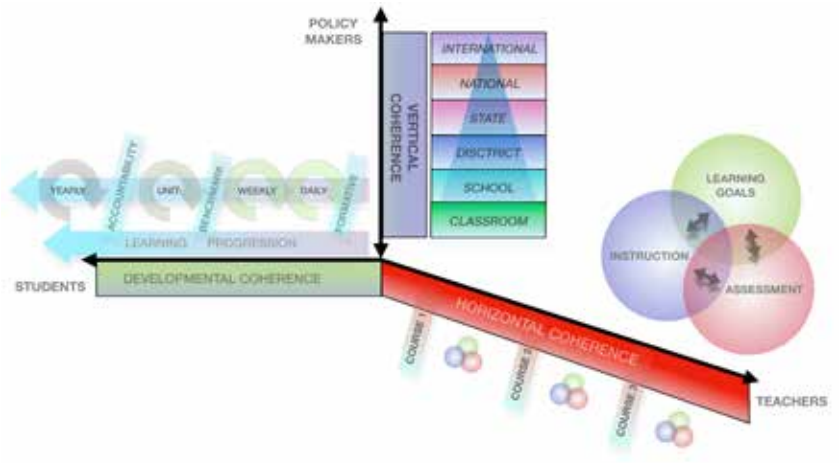
We use this chapter to look more specifically at areas where coherence can contribute to a PBL learning process. We discuss how a coherence-centric directive needs organisational structures and personnel engagement from coordinators, teachers, and supervisors. We also discuss the barriers to introducing coherence, as it will require a different effort and team-centric approach, with more planning and communication across semester modules.

A closer look at coherence

"Designing a coherent curriculum involves creating a set of interrelated units that incorporate explicit connections and interdependencies between the ideas and practices that students learn in each unit within a grade and as they advance through the grades" (Shwartz et al., 2008). A popular way to look at curriculum-based coherence is through the construct of developmental, horizontal, and vertical coherence (see Figure 4). It is a system that seeks solidity in learning, based on learning progression over time, through both the reiteration of prior knowledge, and the introduction of, or connection with, new knowledge, towards the eventual point where the learner is expected to have developed a particular level of understanding and applied experience (*developmental coherence*). This is achieved through the instructional (teacher) approach of aligning learning goals, instruction, and assessment and seeking feedback through assessment to align instruction (*horizontal coherence*). Both are based on a shared strategic and methodological directive (or vision), supported through the ranks of decision-makers on all levels; from the classroom to the schools, to the school district, to the state, and even onto the national and international level (*vertical coherence*) (Herman, 2010).

Figure 4

Developmental, horizontal and vertical coherence



Note: figure content is based on both Herman (2010) and Oon & Fischer (2018).

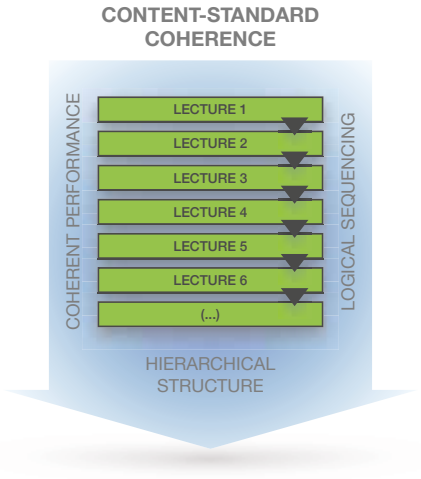
Developmental coherence is the aim of horizontal and vertical coherence (Fulmer et al., 2018). Developmental coherence is about the nature of learning and

teaching, addressing the logical structure of science disciplines, a student's prior knowledge and experiences, and the integration of knowledge and practices. In contrast, horizontal coherence and vertical coherence are the approaches used to promote productive learning for all students. Developmental coherence requires that learning goals, instruction, and assessment are continuously aligned for the entire duration of education and that it promotes a learning progression at all points in time. Depending on the variety of units involved, assessments need strong coordination to support the shared goals (Jin et al., 2019).

But how can developmental coherence be designed or achieved, and how can horizontal coherence be applied advantageously in a PBL learning environment, so both students and teachers understand and rely on both the within-unit and the progressive coherence in their programme?

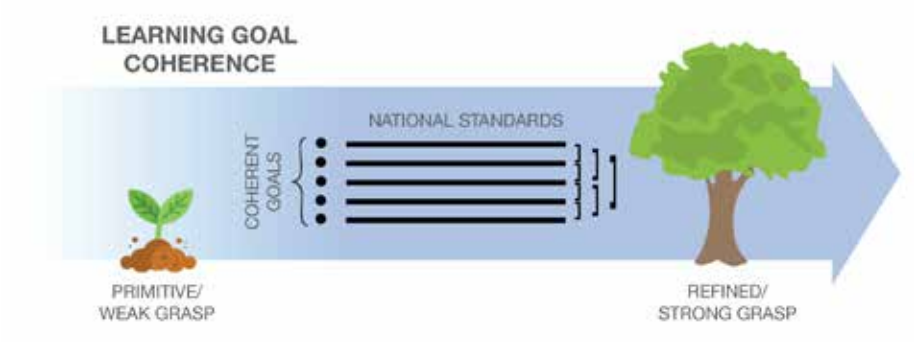
Another way to view coherence is through the optics of *content-standard coherence, learning-goal coherence, intra-unit coherence,* or *inter-unit coherence* (Fortus et al., 2015). As with previous depictions, this perspective of coherence acknowledges that it involves a systematic and progressive approach to learning, where several aspects of the learning design need alignment, and all contribute to the whole. As such, *content-standard coherence* (Figure 5) is a coherence type for logical learning content sequencing, with a content hierarchy that builds a learner's topical foundation logically and increases overall performance incrementally, and where the subject matter gradually shapes the overarching narrative of the topic. A course unit is an example of this.

Figure 5
Contents-standard coherence



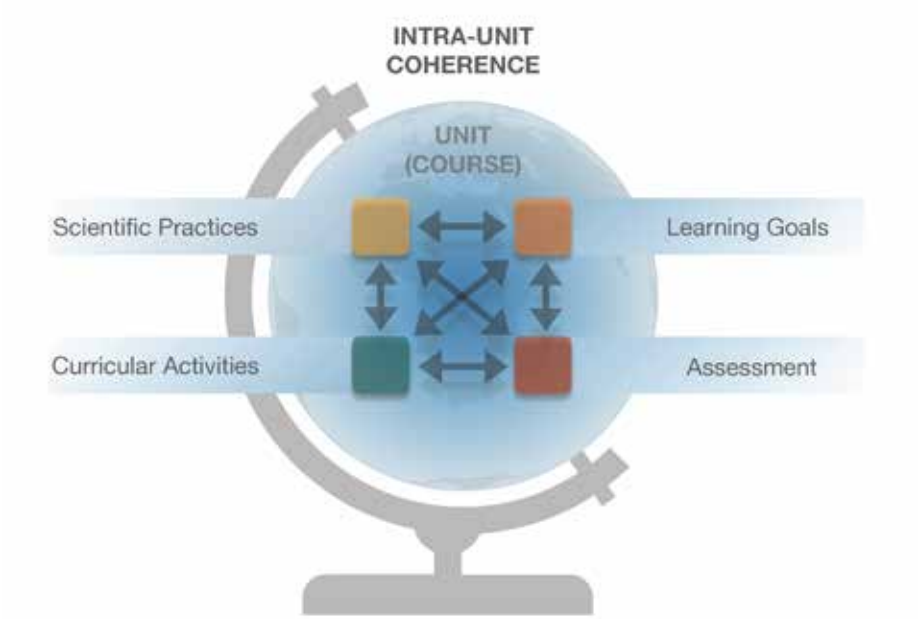
Learning goal coherence (Figure 6) is found in a well-constructed body of individual points that represent specific (coherent) aims for the learning process. It should ensure the desired disciplinary development with the learner, such as increased levels of complexity and depth, and the refinement of knowledge, skills, and so on. Learning goal coherence should help a learner to transition from a so-called 'weak or primitive grasp' of the intended subject-matter to a 'refined and powerful grasp' (Fortus et al., 2015).

Figure 6
Learning goal coherence



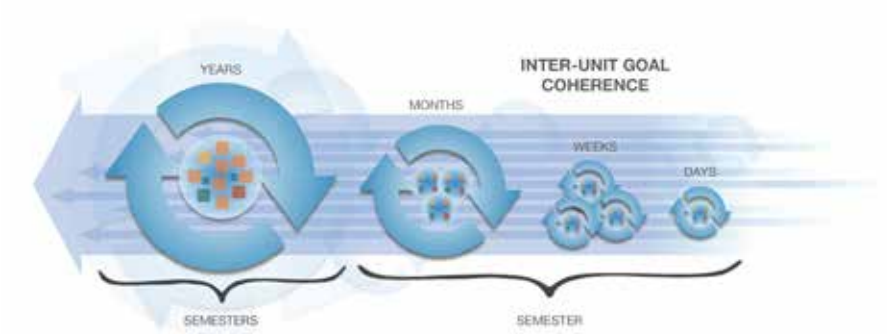
Intra-unit coherence (Figure 7) is achieved when learning goals, inquiry into the context and subject matter based on scientific practices and other curricular activities and running assessments of a learner's progress are combined (and logically sequenced) to develop a progressive and integrated understanding. Here, the focus is placed on working with fewer but key ideas, thereby aligning the learning with depth and connection, rather than breadth and isolation, with many discrete and unconnected focus points (Shin et al., 2009).

Figure 7
Intra-unit coherence



Lastly, *Inter-unit coherence* (Figure 8) refers to the coherent learning process that is achieved through years of unit sequencing, cross-unit connections, and interdisciplinary work. Here, learners undergo their long-term progressive learning, refine their contextual understanding and sharpen their idea development. Curricula that are based around inter-unit coherence allow prior learning to be revisited, extended, and expanded, through new combinations of prior knowledge, or from combinations to completely new contexts or disciplines.

Figure 8
Inter-unit coherence



Cross-cutting, conceptual understanding is a central result of inter-unit coherence, and expands the 'reach' of a unit, due to its connection to other units (Fortus & Krajcik, 2012) (Linn et al., 2004). This connectivity between units expands the perceived importance of each of those units and could even be argued to cognitively make certain units appear as hybrid units, for some learners (Fortus & Krajcik, 2012).

Schwarz, Bransford, and Sears (2005) offer a way to understand the dynamic when focusing on a coherent and connected 'grid' of knowledge units available to continue learning, as knowledge transferring-out (when knowledge from one unit is used in another unit, either as a tool to understand or a tool to solve problems) or transferring-in (internalisation and consolidation of knowledge to prepare for future learning, for instance, the result of continuous exposure to inter-unit coherence) (Bransford & Schwartz, 1999).

Fortus et al. (2015) argue that curricula should instead focus away from the bulk of isolated or discrete learning goals, as the connection between them will be hard to maintain, and as the depth of learning will be challenged by insufficient time with each goal. Ericsson, Krampe and Tesch-Romer (1993) also agree that repeated experiences with a set of conceptual ideas, along with continual opportunities to practice skills, modes of thinking and analysis, support deeper learning, and the development of expertise. Instead of using learning (goals) as a long sequence of individual checkpoints (goals), a shift could be made towards 'learning progressions' instead, where the philosophy revolves around fewer (learning) 'goals', longer periods of exposure, and deeper learning, including revisiting topics and time spent on topic connections or combinations. In other words, there should be a stronger focus on constructing a

grid of connections between knowledge, which also allows learners to cultivate knowledge, and thereby create ideas, or expand on known application areas.

According to Shwartz et al. (2008), an inter-unit coherence needs the following conditions, "(i) the curricular materials must be learning-goal coherent, (ii) have intra-unit coherence, and (iii) must make explicit reference to concepts and activities in other units, those that have already occurred and those that are to come." The authors also note that inter-unit coherence could be considered the most important - but also final - coherence type on which to focus. If the latter three coherence types are not in place, then inter-unit coherence is not feasible.

Education programmes should consider whether they clearly explain the overall aims and can easily outline their inter-unit coherence map. Knowing how to apply theory in practice involves knowing how to map knowledge into contextual application. This is central for all PBL environments. Each PBL-oriented semester, in itself, is a platform for content-standard, learning goals, intra-unit, and inter-unit coherence.

Coherence in a PBL environment

There are several aspects of the current 'baseline' AAU model that could easily adopt coherence-centric learning constructions. For example, each semester has historically been encouraged to contain a *semester theme,* which *ideally* represents the overarching semester vision and the progressive position of a student's learning journey. The semester theme should either directly or indirectly represent the suite of its units, such as *semester courses* and the *semester project*. In this model, individual units can be built to involve content-standard coherence, learning goal coherence, and intra-unit coherence, while the complete suite of units should include the mapping of explicit inter-unit (coherence) connections. These coherence considerations are not a formal requirement at AAU (for example, as a vertical coherence-based decree), and in many cases, the coherence potential is poorly utilised, as semester themes are only theoretically encouraged. As there are no formalities or standards, however, they can be vaguely-, non- or even ill-defined, with no control or requirements to create any inter-unit relationships. A lack of inter-unit awareness or interest also involves the risk of there being little top-down monitoring of the degree of project topics or material used in projects that fall far outside the semester's learning goals or overarching mission. Practically, this has been shown to give some students the experience of almost unlimited freedom in which to inter-

pret their thematic project direction and to diverge noticeably from the study plan, with no regulation (Kristensen et al., 2019).

The recently updated 2021 medialogy study plan, in its second semester (MED2) (medialogy study regulation 2020) is a specific example of a semester construction. Here, the semester theme, or semester description, is nothing but a headline; *Human-Computer Interaction*. The content closest to a formal semester description or theme in the MED2 study plan comes from the semester *project* description, which in the MED2 description is merely a short, formulated repetition of the unit's bullet point-based learning goals. The MED2 course units follow the same spartan formula, here with only 1-2 lines of course description, followed by bullet-pointed learning goals and assessment frameworks (Medialogy Study Regulation 2020).

The short and precise format of the MED2 study plan depicts how complex or thematic considerations were not desirable in this case. Given the inclusion of certain course unit traits, the semester project description is the closest entry in the semester study plan, to an overarching and unit-connecting directive. It thus informally becomes the study plan's closest formal representation of a semester description, but with no thematic layers. The construct of a semester 'theme' is thus completely absent.

Meanwhile, the 2021 MED2 (Medialogy) study plan is in many ways well-constructed. According to our internal knowledge, much work and thought were placed into its 2021 revision, concerning both its units and the placement of the MED2 semester, in the medialogy learning holistic. Its format and approach to curriculum construction and presentation probably diverge very little from many engineering study plans (Melbye Boelt et al., 2020). From a coherence-perspective, however, it illustrates certain challenges. It begs the question of what role any semester holistic, implicit or explicit, will play in a student's educational journey. The lack of thematic focus means that the application of any semester 'theme' constructs to the semester learning goals may be unknowingly dismissed as merely a tool, or even consciously disregarded as a superfluous task, by semester teams.

Isolating the description of each unit, and thus dismissing any formal expectations to cultivate collective connections across units, makes it uncertain whether stakeholders (which includes both students and teachers) will prioritise semester homogeneity, purpose (goals), and position in the long-term educational scope. It also ignores the idea of any interdependence between units, for the semester to succeed. While this would not be an issue with education models, where students construct their education based on electives, the AAU

Model PBL principles explicitly state that units need to rely on each other (AAU, 2015).

It would certainly be attractive to suggest a vertical decree (from within the top university organisation) around which to build study plans and curricula based on coherence principles, but pragmatism requires the consideration of realistic options for increasing coherence. Luckily, the current semester teams, such as in our MED2 semester case, should be able to autonomously adapt coherence mechanisms for their current implementations.

Looking specifically at the semester level, a contributing factor to making inter-unit coherence possible lies in a more active (but again, autonomously driven by semester teams) adaptation of the semester descriptions. A positive aspect of the approach to the MED2 revision has been a consciously short and generic study plan format (descriptions, learning goals, etc.) The incentive for the study plan group was to extend operation flexibility for semester teams, enabling them to regularly change curriculum content or instruction methods based on, for example, prior experience or the emergence of new technologies, or to test new ideas and concepts. In the absence of a vertical coherence directive, a format such as the 2021 MED2 study plan allows many useful customisations, including coherence-centric initiatives, where more substantial changes should be initiated. Applying those customisations, however, solely depends on the semester team.

Options for the semester teams to introduce coherence

Similarly to the way teachers interpret a course unit's learning goals and implement them accordingly to this interpretation, the practical implementation of a semester's study plan goals always includes an interpretation by the semester team. In this process, the semester team is free to introduce specific objectives that are not directly formulated in the more generic study plan. This can be done for both project- and course units and can easily include supplementary material to support the semester implementation, as seen fit by the semester team.

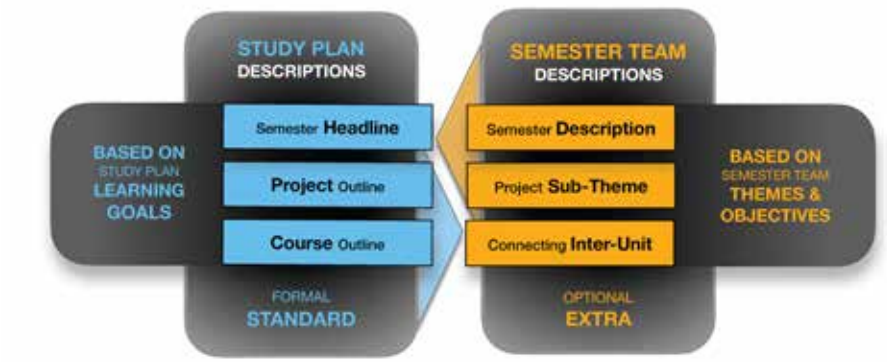
If the semester team does not have a shared interpretation or set a shared direction, individual team members are left to interpret this direction themselves. For course units, this means the individual teacher, and for the project, it means the individual supervisor. In this case, goals between course units will probably not be aligned. The project is even riskier from a coherence perspective, as one project unit often has many individual supervisors. If they do not share a

directive toward the project's learning goals, there is a risk that same-semester student groups will produce *vastly* different projects, where the curriculum for the projects does not even seem comparable. This should be considered a risk for long-term curriculum coherence, programme accreditation, and its disciplinary identity.

The semester interpretation phase is an obvious opportunity for the semester team to introduce or amplify coherence-centric mechanisms, especially inter-unit coherence, and seek productive scope-delimitations for student projects. Options include efforts to a) position the disciplinary relevance of the specific semester in comparison to other semesters, b) to introduce delimitations, directives, overall thematic orientations, or contextual framings to the semester project, which fit the practical direction of the disciplinary context, or c) to place shared focus areas between course units, including the goals of the project unit. A conceptual example is shown in Figure 9, where the formal, short, and generic unit descriptions given by the study plan are listed on the left. Supplementary and coherence-extending descriptions are listed on the right in Figure 9 and are all made by a semester team.

Figure 9

A conceptual example of how coherence may be increased on the semester level



The semester's standard study plan has thus been extended in this conceptual example, this is done firstly with a formulated *semester description*, which seeks to explicate the meaning behind the MED2 study plan's semester headline. In this case, the semester description is a qualitative explanation of the role and position of the specific semester, in the context of the discipline or field, and how the knowledge in this semester will affect the future learning

progression during education, either becoming a prerequisite for future semesters (long-term inter-unit coherence) or simply finalised during the semester, as part of a student's fundamental disciplinary arsenal upon graduation. The semester description in this case does not look specifically at the practical level of the semester project or course units.

Secondly, the project outline has been extended from the study plan with what we call the *semester project sub-theme*. Unlike the semester description, the project sub-theme does not look outwards (e.g., to compare and position the semester's position into the whole programme). Instead, it looks inwards at the inherent objectives of the specific semester and provides a concrete directive to both students and teachers, interpreting the abstract and generic descriptions of the study plan into tangible requirements or areas of application.

The project sub-theme can vary in its specificity but can be quite specific. It should be based on feasible aims within the multi- or interdisciplinarity of the semester's inter-unit coherence. The project sub-theme can also adopt topics or contexts external to the semester's formal learning goals. As Shwartz et al. (2008) put it:

> Real-world problems can easily branch out and lead students to seek knowledge that is not included in the learning goals. Similarly, the driving question may be linked to some of the learning goals, but not all of them. Answering a driving question may emphasise some learning goals over others, leading to uneven coverage of them and to potential lack of coherence.

This promotes AAU's PBL principle for real-world application of generic theory or methods (AAU, 2015), and provides a specific target for the study plan's generic learning goals. A difference between the sub-theme proposition and the current approach is that the external or contextual directions are defined by the semester team, not the students, but this is dynamic. The project sub-theme should also allow students to feel (and be) able to define certain aspects of the project, and to an extent, also be able to define how they want to interpret the abstract nature of the learning goals for the sake of their project ideas. We will look into this further shortly, in relation to Figure 11.

Coherence-centric projects and course unit interactions

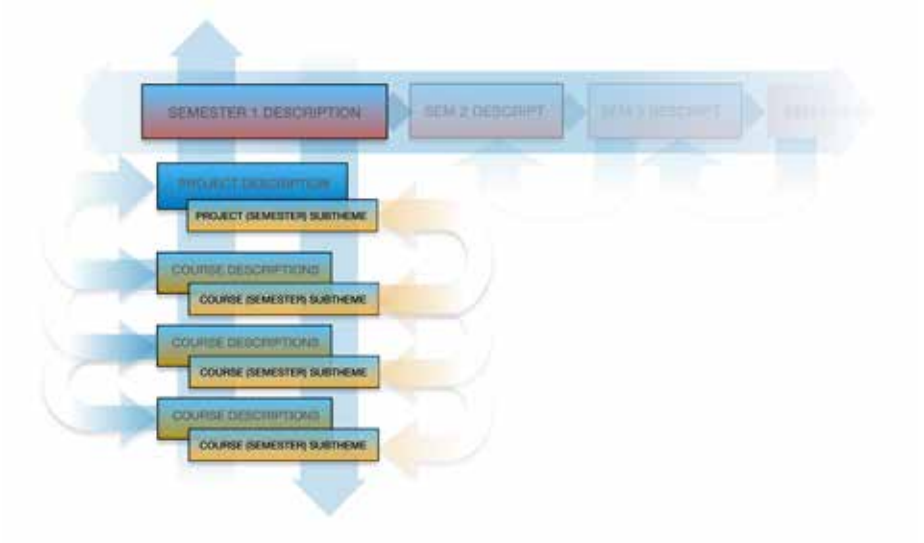
Just as the project sub-theme looks at inter-unit combinations, the units should, in turn, be compelled to look at the project subtheme. Course units should consider adjusting both their content-standard coherence and their intra-unit coherence mechanisms to connect their learning goals to the directives and goals of the project sub-theme. Examples include planning lectures and topical sequencing from content-standard coherence, to fit the needs and goals of the project at given milestones, and aiming some of the unit's (intra-unit) *scientific practices* or *curricular activities* towards application within the project sub-theme. Another consideration is to effectively include pointers, examples, and open discussions (e.g., in-class, during a lecture, or through curricular activities) on how the certain theory, methods, or practices of that unit, *could* be useful for sub-theme application. We say *could*, as individual projects will rightfully diverge from each other, despite the delimitations of a sub-theme.

This entails an effort from the teacher team. In addition to their own courses, teachers seeking inter-unit coherence will be faced with connections from their unit to other course units as well, as described by Shin et al. (2009): "(...) curriculum-specific professional development for an inter-unit coherent curriculum cannot present units as stand-alone entities; teachers must learn key elements of units that they may not teach". It makes sense that this is recommended, but it also suggests that forming a complete and effective inter-unit coherence-centric undergraduate/graduate curriculum can be a comprehensive undertaking. Even if the structure is in place, the enacted curriculum (instruction) can suffer, as suggested by Fortus et al. (2015): "For enactment to occur that fully implements a curriculum's coherence, the curriculum must explicitly highlight connections between and among units, and teachers must be aware of know-how to build on them". This is especially true if the ambition is for all teachers to always be able to discuss the disciplinary (or multi/interdisciplinary) positions, of all units, along with the long-term progressive learning.

The project sub-theme description should also introduce examples of (or requirements to) direct crosscuts to all other semester units. The semester project thus becomes the *epicentre* of the semester, through a more directed sub-theme description. As suggested in Figure 10, the project would be a catalyst for testing the semester's coherence, both downwards and upwards. The overarching semester description would 'test downwards' through the project's sub-theme, to the course units, whereas each course unit would test their descriptions and learning goals 'upwards', towards the project and into the semester description. Meanwhile, project and course units would feed forward and back from each

other, and experience proper inter-unit connections, both within the semester and externally, and to the other semesters, based on the overview of the semester description and pointers to both past and future semesters.

Figure 10
Conceptual example of complete inter-unit coherence between all semester units, and where all semesters look to - and position themselves amongst - each other.



The option to do this, lies within all AAU semesters and semester teams, no matter the specific study plan content, and could aid student (and teacher) perceptions of the semester - *and* education coherence. It also offers teachers the ability to integrate student learning within all semester units, towards the overarching semester goal. The project would thus feed on the courses, and the applied nature of the AAU PBL project would position the course curriculums, and make later extending repetitions of these logical. Meanwhile, balancing the degree of inter-unit connection correctly, so that it does not obstruct the purpose of the individual units, is an important and open question.

Delimitation and anchoring of a sub-theme

An example of such balance can be found in the case of anchoring the sub-project theme within the semester course units. A sub-theme may derive its thematic emphasis from what Shwartz (2008) refers to as its central 'driving

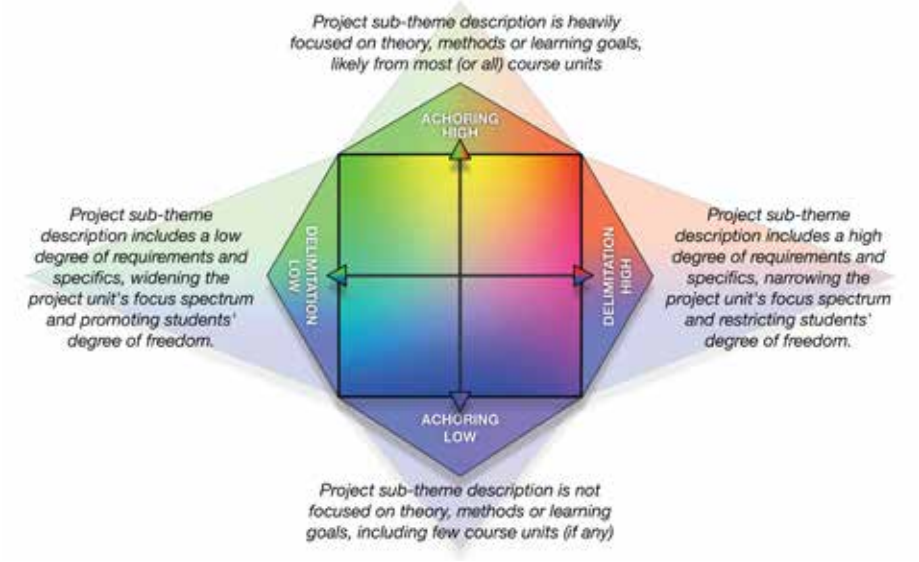
questions'. This may partly include an added, external context or real-world problem, to set the project's stage of operations and introduce requirements to certain delimited problem areas and overall expected outcomes. An example could be that the project needs to work with the UN Sustainable Development Goals for a certain target group. The driving questions may also partly include specific learning goals, which may relate to the disciplinary, theoretical or methodological approaches that are expected to be included in the project. Learning goals directly derived from each semester course unit are an example.

The result should be a semester project directive that seeks to combine a fixed, but relevant application context with a controlled disciplinary direction, into the project unit's goal. The project thus becomes a 'disciplinary anchor' that stabilises the project unit and works to direct its fundamental focus within the semester's directive. Such an anchor could introduce increased disciplinary consistency between each project and limit the risk of projects straying from the semester's position in the long-term coherence of the education. Meanwhile, the weight of the course unit inclusion in the sub-theme directive, while not providing complete freedom, should not remove the individuality of each unique project. We will focus below on the weight and approach of this inclusion, and how it may be gauged.

In Figure 11, we present a two-axis model of dichotomies. The horizontal axis represents the level of sub-theme *delimitation*, from 'low' to 'high'. It serves to illustrate how many requirements and restrictions the subproject description contains. It therefore also suggests the degree of student freedom to set a project's focus. The delimitation includes both external contextual focus and any forced usage of theory and so on in the subproject description.

Figure 11

The Project Sub-theme Balancing Model



Note. mapping the degree of project delimitation and course unit anchoring, within a project sub-theme.

The vertical axis represents the degree of course unit *anchoring* within the sub-theme description, from low to high. Using this metric means that the semester team can position the project as either closely tied to the course units or as operating on a remote domain. Examples could include taking only one or very few theoretical or methodological aspects (learning goals) from a single course unit (low anchoring), or many of these from all course units (high anchoring). A question about the usefulness of this model could involve its more extreme hypothetical cases, such as the construction of a hugely delimiting project sub-theme while excluding any anchoring. Logically (perhaps especially after reading this chapter), this would not be very sensible, but it remains theoretically possible, especially if the decision was somehow unintentional or accidental. The model in Figure 11 serves as an easy placement of any semester team choice and offers a reflection on how this choice relates to delimitation and anchoring.

The question of an appropriate level of delimitation and anchoring is not trivial. The AAU PBL project model also relates to student motivation and the development of a disciplinary identity, which partly stems from a student's autonomy to choose a contextual problem area in which to form practical expe-

rience of their learning goals. The balance between student motivation and a project sub-theme description is important. *Autonomy*, as a predictor of intrinsic motivation (Deci & Ryan, 2008), is interesting here. A subproject delimitation may remove a student's perceived sense of freedom to introduce unique contexts or other external topic inclusions to their project direction (Kristensen et al., 2020b). Meanwhile, we would argue that this is not a definite barrier, as the sub-theme itself can contain ample openings for students to make individual project customisations. We would also argue that other cornerstones to support intrinsic motivation, such as *competence* and *relatedness*, could be constructively supported by a more anchored and delimited project sub-theme. Competence could be negatively affected if autonomy (as the main predictor of intrinsic motivation) is not possible, due to the sub-theme being perceived as a barrier. It could also be positively affected by inter-unit coherence, as students may be able to practice and repeat learning goals in both courses and projects in areas, where course units share directions with a delimited and anchored subproject theme. Relatedness is one of the key features of how a project group may either excel (if they relate positively to each other) or fail (if the group dynamic is destructive). Poor group dynamics can be caused by many things, but sometimes stem from disagreements on subject understanding, which subject materials are relevant, and how to set the project direction. The introduction of a delimited and anchored sub-theme would positively support relatedness, in the way that individual project groups share an overall directive, and thus gain the option to have discussions and seek advice between groups, on background material, academic challenges, and learning reflections (Bruun-Pedersen et al., 2020).

There are known issues when projects have low levels of delimitation and anchoring. A known risk to low-level scenarios arises when students spend too much time in the project initiation phase, exploring, defining, and choosing their project problem area (i.e., project focus). This includes the time to research the overall validity of the problem, background material, potential evaluation methods, and inherent problem logic. Sometimes students may even conclude such processes with the realisation that the problem precludes further progress. They then need to start anew, with lost time. One consideration is how a greater degree of project delimitation and anchoring may increase efficiency for project progression. Providing delimitations for the project scope and direction may circumvent such situations to a degree.

On a similar note, the similarity between projects formed from anchoring an inter-unit coherence from coursework means that courses can effectively pre-

pare and hit targets within that alignment. They can thereby contribute directly to the project work, at scheduled points in their content standard coherence, allowing students to be introduced automatically to project-relevant material, enquire and challenge connections with teachers, and repeat learned material progressively through (and across) both project and course units. This, in turn, also increases a student's learning efficiency and effectiveness.

A related consideration in how a greater degree of project delimitation and anchoring may have a positive effect involves another known situation, where students choose a project focus where a considerable share of the problem material lies outside the formal semester learning goals. Students will in this case spend time and cognitive resources absorbing material formally positioned outside the scope of the semester's learning goals. While this can return valuable learning experiences and increase intrinsic motivation to learn, it logically removes resources from the intended disciplinary learning objectives. There are examples where projects have diverged so far from the semester theme that they could logically be mistaken for projects under an entirely different curriculum (Bruun-Pedersen et al., 2020). Allowing this divergence is a risky game for both students and the academic institution. It may erode student perceptions of disciplinary identity and may therefore affect the programme accreditation in the long term, as it complicates the positioning of students in the job market and the academic identity of the programme. Here, inter-unit coherence through delimitation and anchoring a project sub-theme into course units may prove constructive.

These aspects of balancing delimitation and anchoring show how a semester team willing to increase coherence has a lot to gain but needs to be aware of their coherence approach. Including too many learning goals from all course units cannot be rationally nor reasonably expected to fit within a sub-themed project unit. Placing an extreme limitation on a project is likely to remove part of what forms many students' intrinsic motivation to learn. As a deceptive part of the Figure 11 model, if the delimitation and anchoring do not share *clear connections* between the shared goals (i.e., coherence), there is a high risk that the setup will not make approachable sense. Meanwhile, if the balance is feasible and the goals are clear, it may contribute positively to student learning progression.

Discussion & conclusion

Supplementary unit and semester descriptions have been used at AAU as a written resource to help students understand semester unit goals and practices. The examples known to us have succeeded as qualitative presentations for the semester but have not included any inter-unit (short/long term) coherence aspects.

There have been cases where inter-unit coherence has indeed been attempted. In one case, coherence structures were implemented over two years, and results showed improvements in several aspects of the semester output (Kristensen et al., 2020a). Where semester projects had previously been known to students as a playground with complete freedom of topical choice, a focus on inter-unit coherence including course unit connections to the project unit made sure that students kept their projects aligned with the semester's themes (Kofoed et al., 2019). Course unit instruction also attempted to include more inter-unit coherence. This included more project unit considerations regarding curricular activities, and discussing applications of the course units' scientific practices, as possible tools for project work (Kristensen et al., 2020a). Course units also collaborated with cross-cutting curricular activities, such as workshops combining unit disciplines. The reason the case was initiated, and the reason teachers agreed to test a coherence-based approach, arose from years of frustration about student learning attitudes and struggling academic understanding. The final straw was an initial investigation into student attitudes, which resulted in questionnaire responses akin to "you simply need to make a project about something that your supervisor knows nothing about, and make sure you know more in the exam. Then they will be more easily impressed and will not be able to challenge you in the exam". This dataset made the semester team engage. Over the following years, coherence mechanisms very similar to the figures found in this chapter were introduced across the semester units. The results can be found in the following (Bruun-Pedersen et al., 2021; Kristensen et al., 2019; Kristensen et al. forthcoming), but included the advantages proposed in the above sections in this chapter.

It is also clear from the example just mentioned how semester team collaboration and semester coordination have become an increased necessity, compared to running isolated units. An orchestra requires a different type of conductor, to that required by a single act, and more time was spent organising, planning, and coordinating, compared to previous years. The opening phases were very demanding, as it was necessary to reimagine the semester construction. After two years the semester team had a much stronger collaboration, a

stronger knowledge of the semester, better connections with students, control over project delimitation, stronger anchoring, and better alignment. New coordination and planning tasks became more routine-based. The semester team comprised quite experienced teachers, but they still considered the change to be one of the more profound and positive shifts in semester construction they had experienced (Kristensen et al., forthcoming).

Any serious revision is demanding. Initiatives such as those described in this chapter will naturally need work and thought. Designing a complete study plan (1-10 semesters) around a coherence-centric system, for instance, one that follows the suggestions provided in this chapter will take time. It will test the connections between the units in each semester, test the connections between semesters, and test the overall goals (mission) of the entire degree programme. Clear mapping here would have the advantage of guiding choices for coordinators and teachers in all semesters, given how their units needed to inform later units. It could also make exam situations clearer, in terms of where prerequisite knowledge could be expected or even required of students.

Looking into a few aspects where coherence can also be effective, including introducing consistent structures to how teachers, and especially the semester coordination, provides information about each single activity students are expected to perform. This also includes how assignments are communicated to students, on which channels and how procedures generally are run. A coherent organisational approach limits the risk of students spending unnecessary cognitive effort discovering 'yet another new' procedure or resolving an issue based on confusion.

Returning to the case referred to in the introduction, isolated courses construct mini projects to allow students a chance to experience applied work with the discipline's theoretical material. If course units were more explicitly able (required) to integrate their units into the project and align their curricular activities to the semester project, this could replace the need for mini projects. Advantages could include less time spent by students in making multiple projects per semester, it could align their work processes, and support a smaller but stronger set of learning objectives per semester, including more time for repetition and depth.

References

Askehave, I., Prehn, H. L., Pedersen, J., & Pedersen, M. T. (2015). PBL – Problem-based learning. Retrieved from https://www.aau.dk/digitalAssets/148/148025_pbl-aalborg-model_uk.pdf

Bransford, J. D. & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*(1), 61-100. https://doi.org/10.3102/0091732X024001061

Bruun-Pedersen, J.R., Kristensen, N.S., Andreasen, L.B, & Kofoed, L.B. (2020). Flipping all courses on a semester: Students' reactions and recommendations. In: J.V.D. Veen, N.V. Hattum-Janssen, H.-M. Järvinen, T.D. Laat, & I.T. Dam (Eds.), *Engaging, engineering, education. Book of abstracts. SEFI 48th Annual Conference* (SEFI 2020), p. 113-120.

Bruun-Pedersen, J.R., Kristensen, N.S., Kofoed, L.B., & Andreasen, L.B. (2021). Student reactions to simultaneously flipping all courses on a semester. In: A. Scholkmann, P. K. Telléus, T. Ryberg, W. Hung, L. B. Andreasen, L. B. Kofoed, N. L. S. Christiansen, & S. R. Nielsen (Eds.), *Transforming PBL Through Hybrid Learning Models: Timely Challenges and Answers in a (Post)-Pandemic Perspective and Beyond*. Aalborg University Press (pp. 410-414).

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology/ Psychologie Canadienne*, *49*(3), 182-185.

Ericsson, K. A., Krampe, R. T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363–406.

Fortus, D., & Krajcik, J. (2012). Curriculum coherence and learning progressions. In B. Fraser, C. McRobbie, & K. Tobin (Eds.), *Second international handbook of science education* (pp. 783– 798).

Fortus, D., Adams, L. M. S., Krajcik, J., & Reiser, B. (2015). Assessing the role of curriculum coherence in student learning about energy. *Journal of Research in Science Teaching*, *52*, 1408-1425. https://doi.org/10.1002/tea.21261

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the next generation science standards. *Journal of Research in Science Teaching*, *55*, 1076-1100. https://doi.org/10.1002/tea.21481

Herman, J. L. (2010). *Coherence: Key to Next Generation Assessment Success (AACC Report)*. Assessment and Accountability Comprehensive Center, University of California.

Jin, H., Mikeska, J. M., Hokayem, H., & Mavronikolas, E. (2019). Toward coherence in curriculum, instruction, and assessment: A review of learning progression literature. *Science Education*, *103*(5), 1206-1234.

Kofoed, L.B., Andreasen, L.B., Bruun-Pedersen, J.R., & Kristensen, N.S. (2019). Integration of courses and projects: Disrupting the traditional PBL semester structure. In B. Vince Nagy, M. Murphy, H.-M. Järvinen, & A. Kálmán (Eds.), *Varietas delectat... Complexity is the new normality: Proceedings SEFI 2019 - SEFI 47th Annual Conference*, p. 1469-1480. (SEFI: European Association for Engineering Education)

Kolmos, A., & Holgaard, J. E. (2012). *Evaluering af ændringerne i PBL modellen på TEKNAT AAU*. UCPBL, UNESCO Chair in Problem Based Learning in Engineering Education.

Kristensen, N.S., Andreasen, L.B., Kofoed, L.B., & Bruun-Pedersen, J.R. (2019). Balancing a change management process: A case study of how to approach curriculum change in higher education. In B. Vince Nagy, M. Murphy, H.-M. Järvinen, & A. Kálmán (Eds.), *Varietas delectat... Complexity is the new normality: Proceedings SEFI 2019 - SEFI 47th Annual Conference*, p. 1926-1936. SEFI: European Association for Engineering Education.

Kristensen, N.S., Kofoed, L.B., Andreasen, L.B., & Bruun-Pedersen, J.R. (2020 a). Implementing ICT when teaching in higher education – a question of supporting teachers' motivation. In: J.V.D. Veen, N.V. Hattum-Janssen, H.-M. Järvinen, T.D. Laat, & I.T. Dam (Eds.), *Engaging, Engineering, Education. Book of Abstracts. SEFI 48th Annual Conference* (SEFI 2020), p. 277-285. SEFI: European Association for Engineering Education.

Kristensen, N.S., Kofoed, L.B., Bruun-Pedersen, J.R. & Andreasen, L.B. (2020 b). Flipped learning in a PBL environment – An explorative case study on motivation. *The European Journal of Social and Behavioural Sciences,* EJSBS, *27*(1), 3084-3095. https://doi.org/10.15405/ejsbs.268.

Kristensen, N.S., Bruun-Pedersen, J.R., Kofoed, L.B., & Andreasen, L.B. (forthcoming). Sharing is caring: Building PBL coherence supported by IT to integrate semester courses and projects. In review at *Journal of Problem-Based Learning in Higher Education*.

Linn, M. C., Eylon, B., & Davis, E. A. (2004). The knowledge integration perspective on learning. In M. C. Linn, E. A. Davis, & P. Bell (Eds.), *Internet environments for science education* (pp. 29–46). Lawrence Erlbaum Associates.

Medialogy Study Regulation (2020). https://moduler.aau.dk/course/2021-2022/MSNMEDB2211C

Melbye Boelt, A., Svarre Kristensen, N., & Riise Clausen, N. (2020). Classification and framing in PBL: A case study. In A. Guerra, J. Chen, M. Winther, & A. Kolmos (Eds.), *Educate for the future. PBL, sustainability and digitalisation 2020 (International Research Symposium on PBL)*, p. 343-353. Aalborg University Press.

Oon, E. P. T., & Fisher, W. P. (2018) Coherently connecting computer and information literacy classroom and accountability assessment. *Journal of Physics: Conference Series* 1065(2) p. 022010.

Schwartz, D., Bransford, J., & Sears, D. (2005). Efficiency and innovation in transfer. In J. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 1-51). Information Age Publishing.

Shin, N., Stevens, S. Y., Short, H., & Krajcik, J. (2009). *Learning progressions to Support coherence curricula in instructional material, instruction, and assessment design*. Paper presented at the Learning Progressions in Science (LeaPS) Conference, June 2009, Iowa City.

Shwartz, Y., Weizman, A., Fortus, D., Krajcik, J., & Reiser, B. (2008). The IQWST experience: Using coherence as a design principle for a middle school science curriculum. *The Elementary School Journal*, *109*(2) pp. 199-219. https://doi.org/10.1086/590526

Tattoo, M. (1996). Examining values and beliefs about teaching diverse students. Understanding the challenges of teacher education. *Educational Evaluation and Policy Analysis*, *18*, 155-180.

Bringing it Together - Four Problem-Based Learning Scenarios

Anette Kolmos, Thomas Ryberg

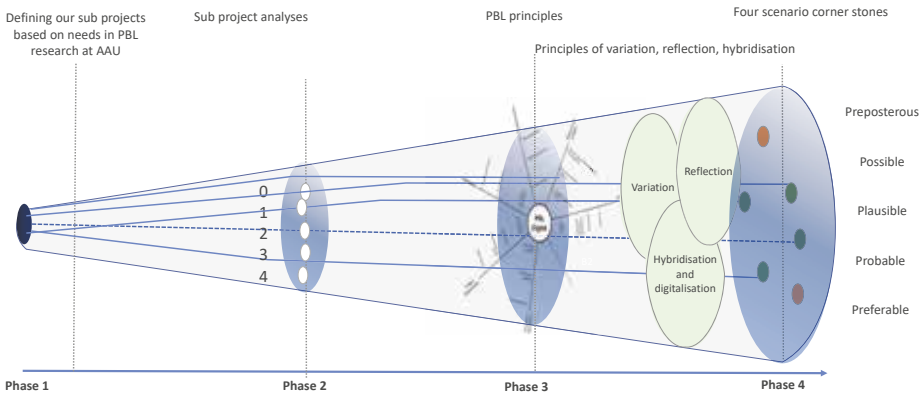
Aalborg University (AAU)'s problem-based learning (PBL) model was from its outset an innovative idea, and it is still at the educational forefront of many other university systems. However, the traditional educational model and the institutionalised system were developed as a response to societal challenges that occurred 50 years ago. Since the inauguration of AAU in 1974, many new challenges have emerged (Chapter 1). These include sustainability challenges requiring an urgent response; the flexibility agenda linking lifelong learning and the educational system; new skills and competences; the digitalisation agenda; and not least, interdisciplinarity.

In Chapter 2, we outlined the basic new principles that must come into play in the development of contemporary education. These principles go beyond the more concrete PBL principles; they are part of how we see future scenarios.

The process of developing scenarios has been integral to the entire PBL future project. It consists of four phases in accordance with Kosow & Gaßner's (2008) methodology: (a) determination of scenario field or scope; (b) identification of key factors; (c) analyses of key factors; and (d) scenario generation. However, it is significantly different in that the PBL Future project has not tried to identify driving forces but has rather identified potential in the PBL Future models and the theoretical thinking underpinning them.

Figure 1

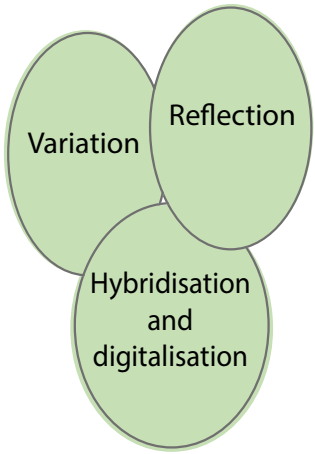
Overview of the Scenario Process



For the first stage, the PBL Future project was established, and the scope and questions of the study were identified. A literature review identified four research areas within PBL: the function of the problem; digital collaboration; the enhancement of PBL competences; and the semester approach in the AAU PBL model, which combines courses and projects. Furthermore, a baseline study was added that identified existing PBL practices in the curriculum as well as academic staff and students' perceptions of PBL. We focused on research questions, theories, and methods for particular areas in this stage.

The second stage involved the research itself. The researchers in the subprojects identified key factors that might influence how the future would unfold. The methodologies presented in the previous chapters could each be used as part of further discussions with stakeholders and practitioners.

Figure 2
Three Basic Principles



In the third stage, the outcomes of the factors and how they might influence the future were examined. This phase was participatory and collaborative and informed by research and practice. Additional data were collected by running workshops amongst academic staff and internally in the PBL Future project. The attempt to identify variations in PBL principles was collaborative; however, the principles were too fragmented when outlining the variations in single PBL variables such as problem, project, collaboration, exemplarity, and so on (Chapter 2). Although we had identified the common concept of variation, we were not at a stage where we could form new scenarios without ending up making fragmented proposals. Therefore, we began to play around with three more basic principles: variation, reflection, and hybridisation and digitalisation.

Variation in terms of, for example, subjects, semesters, project length, problem types, degree of digitalisation, and semester structures was just one aspect of what we could see in our crystal ball. Another of the core concepts, reflection, was considered not only in relation to the acquisition of PBL competences but as a means to achieve meta-competences or higher-order skills. The third concept, hybridisation and digitalisation, will influence and create new collaborative cultures and provide new possibilities for practice and understanding. But it is also a hybridisation process as new cultures, practices, and understandings will be created along the way. These three core principles described in Chapter 2 can inspire us to see possible futures as part of a more coherent vision and influence thinking in all subprojects. However, in developing new principles, it is important to remain acutely aware of the existing core values that underpin PBL, for example, participant direction, which is explored in Chapter 3. This is a foundational principle on a par with problem orientation.

The four scenarios began as part of subprojects 1-4 but went beyond them by creating a new understanding of the findings in light of these general principles. There might be many more future paths, especially because we have refrained from looking into drivers that might create disruptive future conditions, such as a 10% cut in all educational activities. We have not looked into what might be preposterous, possible, probable, or preferable, as this would be part of an academic-political discussion. But of course, not all the ideas will be applicable or acceptable to the various faculties. Nor are we aiming towards presenting only scenarios that would be applicable or acceptable. On the contrary, the aim is to create inspirational models to think about, look at, and draw inspiration from.

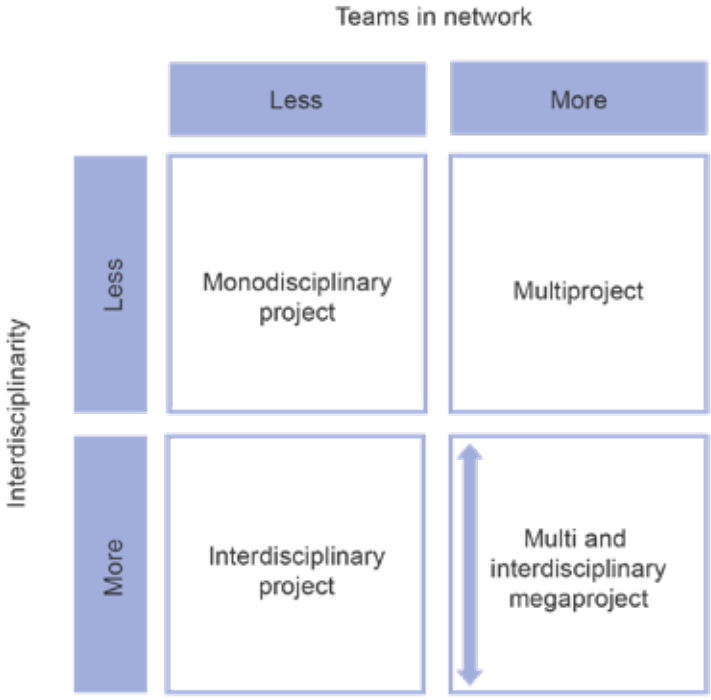
Scenario 1: Variation in Problems, Projects, and Curricula

Subproject 1 examines the nature of the problem in the project process. It is clear that the understanding of the problem is a boundary object for the students. They try to understand it and formulate it. They think they have a common understanding but return again and again to grasp it. They manage to negotiate their understandings and discuss the impact on the rest of the process. The initial framing of a problem is important, and students should learn how to deal with various types.

In Chapter 4, the problem was seen in the light of interdisciplinarity and complexity. It was pointed out that this would influence the choice of scientific domain and thereby the framing of the collaboration (see also Chapter 5). As the problem becomes more complex (e.g., problems relating to sustainable development goals), the organisation of the learning process and collaboration amongst project participants become much more complex. If both social science and engineering are involved, they will have difficulties understanding each other's scientific language.

Figure 3

Types of Projects



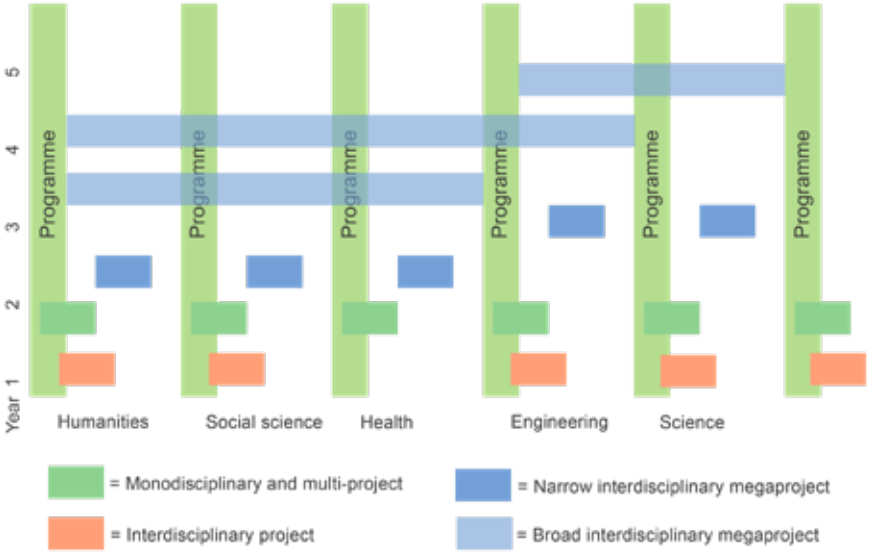
All problem types will be closely related to various types of projects – the more complex the problems are, the more complex the project will be. Therefore, there is a need to understand different types of problems and projects (Holgaard et al., 2017). Kolmos et al. (2020) identified two dimensions in creating variation in projects: (a) the size and organisation of the teams; and (b) the scientific content and problem scoping, ranging from simple to complex and interdisciplinary problems. Combining these two dimensions results in four educational project types: the discipline project and multi-projects, addressing single discipline learning objectives on a scale from individual discipline teams to larger team clusters; as well as interdisciplinary projects and megaprojects, which cover contextual, complex, and interdisciplinary learning outcomes from smaller interdisciplinary teams to larger *teams of teams*, or clusters in collaborative networks (Figure 3).

These four ideal types of projects can frame students' learning of various problem-solving competences such as problem identification, analysis and solving, collaboration skills, and project management in different ways, and all

are relevant in engineering education. The different project types also relate to different problem types from disciplinary problems to broad interdisciplinary problems or from simple to complex and chaotic problems (Snowden, 2000). A future scenario might be that students experience all variations and learn to reflect on the differences and the impact on their collaborative competences as part of a team and reflect upon and learn different ways to analyse and solve problems. This process is represented from a curriculum point of view in Figure 4.

Figure 4

Examples of Variation in the Curriculum



Other variations might be considered:

- Projects of a few credits to many credits
- Project length varying from shorter to longer courses, from ½-to-one semester to *x* years
- Group size varying from smaller to larger groups and teams in networks
- Group composition varying from local to international teams including other diversity issues
- Group formation varying from student-initiated to teacher-initiated or theory-based
- Types of collaboration varying from a specific division of labour to integrated collaboration

- Supervisory and collaborative forms
- External collaborators varying from external project cases to project partners
- Variation in physical and digital facilities and learning spaces

Problem-based learning methodologies must be chosen according to scientific learning outcomes as well as PBL competence outcomes. Not least, there must be variation in the application of digitalisation. A feasible scenario might then be to have an overall variation in the curriculum regarding problems, projects, interdisciplinarity, and collaboration with external partners. However, variation in itself does not improve learning. It is a condition that varies in the PBL variables is combined with reflection on practice combined with theories and methods (Scenario 3).

Scenario 2: New Forms of (Digital) Collaboration

Subproject 2 focuses on students' collaboration and how this is underpinned by and tightly interwoven with digital technologies (Davidsen et al., 2020; Ryberg, Davidsen, et al., 2018; Ryberg, Sørensen, et al., 2018). There is already great variation amongst students in terms of how they adopt digital technologies, and in Chapter 5 we explored several polarities that can be used by students and supervisors to reflect upon and discuss the current project work. We also outlined new forms of collaboration.

As was pointed out in the previous scenario, there are many ways in which one can design variation. Variables can be altered to develop new forms of collaboration, all of which are underpinned by hybridisation and digitalisation in different ways (Table 1).

Table 1, which was presented in Chapter 5, expresses dimensions that we can change and experiment with to create greater variation in the students' experience of group collaboration. For one thing, we can think of group formations that span disciplinary, multidisciplinary, and interdisciplinary categories. A group can be disciplinary, consisting of members from multiple disciplines who each bring their own expertise to a particular subset of the problem, or interdisciplinary, where members from different disciplines have to arrive at a shared understanding of a problem to solve it.

Table 1

Challenges to the Aalborg University Problem-Based Learning Model

Dimension	AAU-PBL	Knotworking/ adhocracies
Expertise	Monodisciplinary	Interdisciplinary
Membership and scale of collaboration	Stable	Dynamic
Space	Co-located	Distributed
Decision making	Central	Distributed boundary work
Collaborative orientation and dependencies	Internal/Inwards	Edge/outwards
Task focus	Singular	Parallel
Temporality	Extended/fixed	Shorter lived/dynamic

We can also imagine groups where membership changes over time and alternates in size. For example, a group might find it relevant to bring in specific expertise for a short period. We might also design a scaled collaboration from small groups to several hundred students working on a similar challenge, and although being distributed in time and space working on developing e.g., common resources or solutions, one could imagine short bursts of large-scale collaboration where students collaborate intensively over 2 days on developing a particular resource (e.g., a Wikipedia page or similar types of online resources for public use).

We can equally imagine experimenting with decision-making and depending on others (e.g., groups awaiting the decisions of other groups, negotiating their decision with others, or incorporating *external decisions* while working on a problem). Different forms could be explored across semesters (as suggested in Chapter 5) and realised within different types of projects (such as was presented in Scenario 1). These collaborations could take place entirely or partly online (as part of a hybrid approach). The inclusion of digital technologies opens up the possibility of more variation and boundary work, particularly across time and space.

Scenario 3: Flipping the Core to Meta-Reflection and PBL Competences

What if the core of a subject consists not only of the content but also the meta-competences required to learn it? Subproject 3 dealt with the acquisition of PBL competences and showed how difficult it was to have students reflect. Several experiments were set up by the researchers to facilitate students' reflections on their PBL competences. Even when students were sent weekly reflection questions and interviewed about them, they continued to ask "What is a PBL competence? When have I achieved it?" They knew when they had learnt to solve a third-degree equation, carry out statistics calculations relating to iron beams, or construct a survey, but the more blurred process competences were difficult to measure.

However, such competences are the foundations of scientific communication and innovation. All academics work in systems or communities where new insights or innovations depend on them (along with individual knowledge). We may have underestimated their impact; are they perhaps more fundamental than the basic sciences in each discipline? Should the core of the PBL curriculum be reformulated?

The subprojects have led to an understanding of the need to reflect on PBL competences, to become more aware of one's practice and one's contributions to practice in general. They have opened the door to the creation of new meta-competences and transformations. We have known for a long time that students feel they are starting from scratch in each new project. They should be encouraged to reflect on what they have done in the past and what they might want to change in the future.

Students can transfer some of their (declarative) knowledge within a project, but they cannot transform it directly to a new one because the conditions will be different. They must learn to read the new project according to the new type of problem, the length of the project, and the composition of the team. The new team might be interdisciplinary or disciplinary, and the collaboration with external partners might be new. So, the manner in which the students have learnt to collaborate in Project A will have to be reconstructed in Project B.

For students to be able to transform their experience to a new context, they need to learn to analyse the problem, which is a boundary object, and the new situation. Reflecting on PBL experiences might not be enough as this involves questions such as "Did I collaborate well, or did I choose the right way to collaborate? What is needed to go from A to B, and what have I learned? What possible collaboration strategies do I have? What possible methods do I know of?" To

reach this level, they not only need to compare experiences but also relate them to the theory. It might be that the acquisition of meta-competences becomes more significant in the curriculum from both a scientific and PBL point of view.

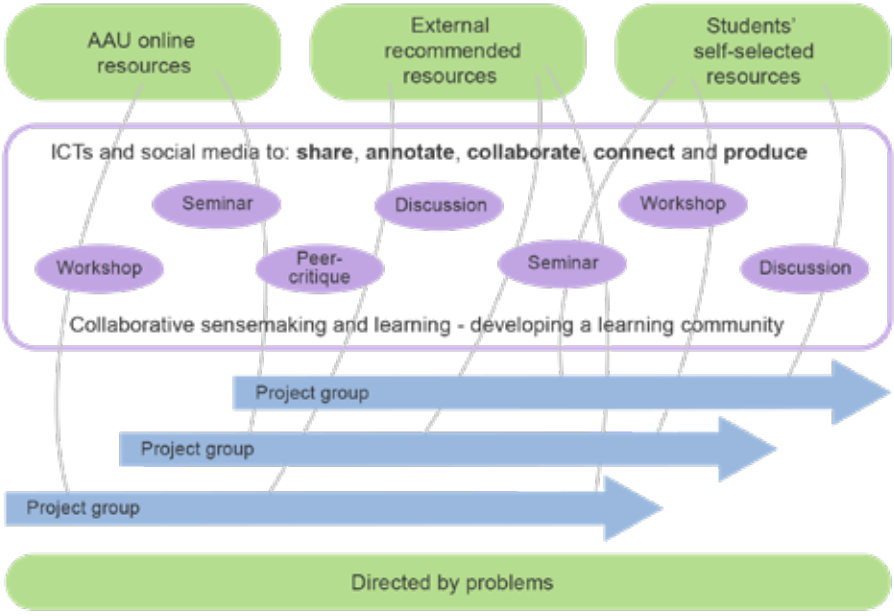
Scenario 4: Flipping the Semesters - New Possibilities for the Relationship Between Projects and Course Modules

Subproject 4 focused on the relationship between projects and taught courses. Aalborg University takes a semester approach where, in principle, there should be a strong correlation between the content of the courses and the projects. However, as was mentioned in Chapters 1 and 8, the relationship or *coherence* between courses and projects has been challenged by the prominently adopted semester structure (3*5 European Credit Transfer and Accumulation System [ECTS] courses + 15 ECTS projects). Courses have tended to gravitate towards a stronger focus on disciplinary skills (such as theories and methodologies) and less on how skills and content can be realised and appropriated as part of the semester project. In the PBL Future research group, there was a widespread concern that the local and global emerging interest in and emphasis on flipped learning and the flipped classroom would only exacerbate this tension. The danger was that pedagogical development might be directed solely towards individual courses at the expense of a more holistic or coherent focus on the semester in its entirety (Chapter 8). This is why we coined the term and started to explore the idea of a *flipped semester* rather than a flipped course or classroom. The idea was to rethink radically the semester structure beyond the *three-courses-one-project* and return to a situation where the problem itself would be at the centre, as it was originally described in the PBL Future project application:

> Digital resources and learning activities will increasingly be integrated into education and affect the organisation of PBL. […] Through employing the technological possibilities, a semester curriculum could be changed or 'flipped' as for the project work to become the main guiding activity. Teachers could experiment with more dynamic course designs that respond better to the projects and challenges identified by the students. For example, teachers could guide students towards available Open Educational Resources and Massive Open Online Courses [MOOCs]. […] Whereas flipped classroom initiatives are often focused on the teaching activities of a specific course, moving towards 'flipping' a whole semester curriculum puts focus on a broader scale of structural changes which especially needs coordination and communication among the group of teachers and supervisors.

While in the course of the project there have been several experiments and studies of various orchestrations of a flipped semester structure, the idea in its more radical incarnation has not come to fruition (Bertel & Kristensen, 2018; Svarre Kristensen et al., 2020). Svarre Kristensen et al. (2020) pointed out that attempting to flip a semester, while maintaining the three courses in one project format, requires intensive teamwork and buy-ins from all parties and the team of teachers in the semester. Successfully flipping a semester requires a very concerted and integrated effort, as Bertel and Kristensen (2018) illustrated. (They provided examples of initiatives where the teacher or teacher teams had greater leverage in and responsibility for the entire flipped initiative.) The original and radical vision of the flipped semester involved rethinking courses as less stable entities and collaborative sensemaking as a learning community or network of students and lecturers (Figure 5).

Figure 5
Conceptualisation of a Flipped Semester



While this particular configuration has not been realised and experimented with during the project, external trends are starting to push forward and introduce themselves into higher education. As was mentioned in Chapter 1, the merging of ideas around personalisation, individualisation, learning trajecto-

ries, MOOCs, and micro-credentials are starting to circulate and shape educational provision. A pressing question, from a short-term perspective, is how to appropriate these external trends into the AAU PBL model; how do we maintain, or rather what central values and ideas of PBL should we maintain in responding to such external pushes? How can we take a more flexible approach to the individual student while collaborating on problems and challenges that are not solvable at the individual level (and might require even more than a small group)? We foresee that such challenges will be on the agenda in the immediate future when the development of PBL at AAU is being discussed.

Final Remarks

In Chapter 1, we outlined some contemporary challenges in the field of PBL. Some of these stem from external pressures or trends such as flexibility, individualisation, and personalised learning trajectories. These are in many ways tightly interwoven with particular understandings and visions of digitalisation. Other challenges or agendas stem from a more intrinsic perspective, such as a wish to align with a sustainability agenda (e.g., sustainable development goals) and to increase the focus on interdisciplinarity and external collaboration. In Chapter 2, we introduced and discussed three overarching principles that we have returned to in the present chapter, namely variation, reflection, and hybridisation and digitalisation. In Chapters 3 to 8, we highlighted different aspects of PBL that have emerged from the work on the PBL Future project: participant direction, complexity and interdisciplinarity, new forms of collaboration, reflection, competences, and coherence.

Each of these concepts was represented in different ways in the four scenarios in the present chapter. Participant direction is a central value in the AAU PBL and goes beyond terms such as student-centred or active learning. Participant direction transcends being involved or *active* in class; it includes selecting, researching, and engaging with complex problems, methods, and theories. We have also suggested that participant direction itself might be challenged – students could work in larger groups on problems specified by others and receive input from collaborators across the globe. This relates to the principle of variation; students need to experience problems that differ in terms of type, scale, and complexity and engage with them accordingly (Chapter 4). They should also reflect on their differences and similarities (Chapter 6). In so doing, they will develop the relevant competences (Chapter 7).

To facilitate variation and support reflection, it is important to think differently about coherence within and across semesters (horizontal and vertical; Chapter 8) and work with differently organised curricula (e.g., the four scenarios in the present chapter). The intention behind this book and the PBL Future project is not to develop a new AAU PBL model. Rather, we wish to suggest that PBL can and should be enacted in many different ways across semesters and there are multiple ways we can challenge the three-courses-one-project structure or the idea that the small group is the only possible collaborative form. We have pointed out how digitalisation and hybridisation can help new curricular designs and forms of collaboration that might otherwise be difficult or impossible to implement blossom and grow. At the same time, it is important to keep in mind that future PBL models should be firmly grounded in existing principles such as participant direction (as was discussed in Chapter 3).

References

Bertel, L. B., & Kristensen, N. S. (2018). Student engagement and study intensity in flipped PBL curriculum and blended learning activities. In Wang, S., Kolmos, A., Guerra, A. & Qiao, W. (Eds.), *7th International Research Symposium on PBL: Innovation, PBL, and competences in engineering education* (pp. 116–125). Aalborg Universitetsforlag https://vbn.aau.dk/da/publications/student-engagement-and-study-intensity-in-flipped-pbl-curriculum-

Davidsen, J., Ryberg, T., & Bernhard, J. (2020). "Everything comes together": Students' collaborative development of a professional dialogic practice in architecture and design education. *Thinking Skills and Creativity*, 100678. https://doi.org/10.1016/j.tsc.2020.100678

Holgaard, J. E., Guerra, A. Kolmos, A., & Petersen, L. S. (2017). Getting a hold on the problem in a problem-based learning environment. *International Journal of Engineering Education*, 33(3), 1070-1085.

Kolmos, A., Bertel, L. B., Holgaard, J. E., & Routhe, H. W. (2020). Project types and complex problem-solving competences: Towards a conceptual framework. *Educate for the future: PBL, sustainability and digitalization 2020*, 56-65. Aalborg Universitetsforlag**.**

Kosow, H., & Gaßner, R. (2008). Methods of future and scenario analysis. DIE.

Ryberg, T., Davidsen, J., & Hodgson, V. (2018). Understanding nomadic collaborative learning groups: Nomadic collaborative learning groups. *British Journal of Educational Technology*, 49(2), 235–247. https://doi.org/10.1111/bjet.12584

Ryberg, T., Sørensen, M. T., & Davidsen, J. (2018). Student groups as "adhocracies" − challenging our understanding of PBL, collaboration and technology use. In Wang, S, Kolmos, A., Guerra, A. & Qiao, W. (Eds.), *7th International Research Symposium on PBL: Innovation, PBL, and competences in engineering education* (pp. 106–115). Aalborg Universitetsforlag. https://vbn.aau.dk/da/publications/student-engagement-and-study-intensity-in-flipped-pbl-curriculum-

Snowden, D. (2000). Cynefin: A sense of time and space, the social ecology of knowledge management. In C. Despres & D. Chauvel (Eds.) *Knowledge horizons: The present and the promise of knowledge management* (pp. 237). Butterworth Heinemann.

Svarre Kristensen, N., Busk Kofoed, L., Bruun-Pedersen, J. R., & Andreasen, L. B. (2020). Flipped learning in a PBL environment – an explorative case study on motivation. *The European Journal of Social & Behavioural Sciences*, *1*. https://doi.org/10.15405/ejsbs.268

AALBORG UNIVERSITY PRESS

PBL in a Digital Age

In 2017, the PBL Future research project was initiated at Aalborg University, bringing together PBL researchers from all faculties in a common research project exploring the future direction of problem-based learning. The overall goal for this research project was to develop research-based directions for problem- and project-based learning (PBL) in a digital age. The project set out to re-conceptualise how PBL could operate in new formats, based on the core principles of PBL, while exploring and developing new approaches that operate in and open for new hybrid PBL learning models.

The PBL Future project was split into 5 subprojects, focusing on both the current practice and how PBL can be transformed to fit a learning landscape which is increasingly becoming more digital.

The book *PBL in a Digital Age* seeks to summarise the findings of the PBL Future research project and to provide an answer to the overall questions *how can the Aalborg PBL model adapt to contemporary challenges and is PBL still the answer*?