Framing the Introduction to Problem-based Learning (PBL)

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Framing the
Introduction to Problem-based Learning (PBL)

Short notes on PBL mindsets, problem design, project design, open problem solving and process analysis

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Introduction

These notes provide a framework for further insight into PBL. Later on, they may also be useful as a brief summary of PBL principles.

It sounds rather easy to work problem-based: "We have a problem and, obviously, we are working in a problem-based way". However, the benefits of the PBL approach will only accrue if there is a change process – a change of mindset, a change of learning strategy and a change in what is valued as the outcome of a learning experience.

We have divided the material into 5 areas.

First, we introduce a PBL mindset and encourage you to construct a mindset of your own, based on your own experiences.

Second, we introduce the problem design process as a careful and scientific approach to the identification, analysis and formulation of a problem. Problem design is crucial, forming the basis for an understanding of the problem and shaping the problem design process.

Third, we turn to project design, as real-life problems often call for collaborative and agile management approaches. Project design provides the necessary frame for PBL processes to collectively work along the same lines and create synergy from individual competences in the project team.

Fourth, we provide notes on open problem solving. Even after the problem has been defined, the problem solving process continues to call for participatory approaches and iterations to make sure that the problem solving process actually solves the problem rather than creating new problems.

Finally, we introduce process analysis and emphasize the need for reflection on the learning process, for analysis of the experiences it entails and for the deployment of this analysis as a platform for improving learning and outcomes in comparable future projects.

The notes have been prepared as part of the SEA-Plastic Edu project funded by the European Union. They can be used to frame an introduction to PBL for students and staff or to initiate reflection on PBL drawing on learning experiences in a variety of educational contexts.

For students, these lecture notes will provide a starting point for further study and for the facilitation of a problem based learning project. They might also serve as a recap of a previous introductory course. The lecture notes are therefore as short as possible, highlighting key terms and providing an overview. They are not intended as stand-alone material; more facilitation is needed if students are to achieve an understanding of the material in relation to the context of use.

The lecture notes have also served as scripts for five video-broadcast, which you can find on the homepage of the Aalborg PBL Centre: ucpbl.net.

Whether you are about to enter a PBL environment or are reflecting on your PBL experiences, we hope that you will find this material useful.

A PBL mindset based on a conceptual platform for learning

Although PBL is solidly grounded in educational theory, it is a concept that has to be situated in a given context – and at more than one level. In other words, PBL can be seen as a conceptual platform for learning.

Factors that need taking into consideration at the societal level include national educational frameworks, regional needs for employability, and broader cultural patterns. At the institutional level, physical frames of learning, resources and curricula demands all affect the way in which PBL is practised. Even in problem based learning projects at the local level, the types of problems addressed, the way the learning is organised and the learning styles of the team-members will influence the PBL approach. With these variations in mind, we set out to define a PBL mindset, while encouraging you to construct your own understanding of PBL. However, let us start by taking a quick look at the theoretical basis of PBL.

PBL is grounded in experiential learning. Just before the 20th century, the American philosopher John Dewey pointed out the experience-based and circular nature of the learning process. In this process, ”stimuli from the environment” affect knowledge, which is re-constructed by judgement in a way that leads to new impulses –new insights (Dewey, 1896).

However, Dewey also pointed out that this so-called learning cycle, a conceptual framework that would later be developed in a variety of ways, is certainly not a closed circle. He thus introduced the concepts of continuity and interaction (Dewey, 1938). *Continuity* refers to the process by which human beings retain experience; reflections on experiences are stored and then carried on into the future. *Interaction* builds upon the notion of continuity and explains how *past experience interacts with the present situation*. This means that because of individual differences, different people experience the same situation in different ways.

In this view, learning is not about repeating knowledge inputs, nor is it about carrying out procedures formulated by others – it is about understanding experiences, combining them with prior formulated insights, and transferring these insights to cope with new yet comparable situations. This can happen when, on the basis of our experiences, we are able to recognize patterns of interaction between humans and their surroundings.

From a social science perspective, Oskar Negt has elaborated on human–context interaction by introducing the concept of exemplary learning (Negt, 1968). According to Negt, learning should exemplify relevant societal, material and social constructs. Drawing on the American sociologist C. Wright Mills (Mills, 1959), he stressed the importance of the sociological imagination for exemplary learning – in other words, we need to think about society in new ways.

Along the same lines, the Brazilian educationist Paulo Freire argued for an empowerment of the learner to engage critically and actively in transforming the world (Freire, 1970). Learners should not only imagine society differently, they should be empowered to engage actively in societal change. Together with Dewey’s constructivist focus on the experience of the learner, this emphasis on empowering the learner underlines the importance of self-directed learning.

PBL has since matured and developed; the focus has shifted from the individual to a social and collaborative approach to learning (Kolmos & Graaff, 2014) in alignment with the increasing complexity and reach of societal problems. Greater reach and complexity call for multiple perspectives that move beyond

the individual, and they require a variety of disciplinary capabilities. Recently, Anette Kolmos has called for more focus on variations in the framing of learning opportunities in a PBL context (Kolmos, 2020), and studies from the Aalborg PBL Centre have made the case for a more hybrid and systemic approach to learning (Jamison et al., 2014; Kolmos et al., 2020).

Meanwhile, a number of actors in the political, corporate and educational arenas have argued that the PBL mindset is exactly what is needed to address current societal challenges. For example, the United Nations Sustainable Development Goals, the so-called SDGs, entail a series of interconnected and rather wicked problems that call for emergent and collective actions.

To summarise, a PBL mindset is likely to have a number of basic characteristics:

1. First and foremost, a PBL mindset primarily directs learning towards **real-life problems**. This means that participants do not just set out to know more; they also want to make a critical assessment of opportunities for change. They are actively engaged, they take responsibility and they strive to make an impact – not only in regard to their own internal learning processes, but also in regard to external processes, products and people.
2. Secondly, a PBL mindset also implies **a constructivist approach**. This means that, like other phenomena, problems are perceived as constructed and continuously re-constructed in the learning process. This means that a problem formulation is never fixed; it is a starting point for an open problem-solving process.
3. Third, a core value of the PBL mindset is **the interaction between theory and practice**, combining the abstract and the contextual. This means that participants focus on understanding the problem by experiencing it at first hand. It also means that they take advantage of theoretical lenses and predefined methods to understand the problem.
4. Fourth, **self-directed leadership** of the learning process is seen as a necessity to navigate in complexity and to adapt to whatever the problem calls for. When it comes to real-life problems, this typically means a focus on inter-disciplinary approaches, collaborative learning and aligned agile management systems that support the learning process.
5. Finally, a PBL mindset emphasizes the **ongoing reflection** necessary for the continuous development of an experience-base and the ability to apply this experience-base across contextual borders to address the variety and uniqueness of real-life problems.

On the basis of such PBL mindsets, researchers and institutions have set out to define principles for PBL. Aalborg University is one of the higher education institutions that have formulated and declared PBL principles (AAU, 2015). If you read these principles, you will see how the PBL mindset introduced above has resulted in principles for PBL practice at university level.

With Dewey in mind, however, you should consider these insights from PBL theories and the prescribed PBL principles as inputs, which, together with your own experience and consideration of the surrounding context, can lead to your own construction of what PBL means for you – on a group or individual level.

We therefore encourage you to develop your own definition of PBL by combining these inputs from theory with your own experiences and a discussion of the alignment with your context of study. The point is that without reflection on your current understanding of PBL, it will be difficult to set the direction for further development of your PBL competences going forward.

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Problem design

Problem design is the identification, analysis and formulation of a problem, where a problem is seen as a social construction.

Real-life problems seldom drop onto university desks by accident – they are brought there, either by staff or by students. Therefore, the first phase in any problem design is problem identification. There are many ways to initiate a problem identification process. For instance, a literature review can reveal existing problems, staff can experience problems in their research practice and engage students to address them, external partners can reach out to the university with a concern, or initial explorative analysis of an organisation or a site can reveal the potential for making a change for the better.

However, to recognise a real-life problem, it takes an understanding of problems as phenomena. In a pragmatic understanding, a problem can be seen as a discrepancy between an actual situation and a desired situation. This understanding involves both a normative aspect and a stakeholder aspect, as someone has to desire a change. This pragmatic understanding is often regarded as most straightforward for engineering and science students. It is like maths: there are negative and positive numbers and between them is the neutral zero. The same can be said of problems. It is a problem in the negative sense if people consider a current situation to be unsatisfactory. It is a problem in the positive sense if there is an unfulfilled potential for making a satisfactory situation even better. Lastly, it is a problem in the neutral sense if we do not know what the risks or potentials are in a given situation. A problem will typically involve all three perspectives, including pains, gains and uncertainties, and, seeing these three dimensions as corners in a field of tension, we can talk about a so-called 'problem triangle'.

However, even though we can typically sketch potential pains, gains and uncertainties by undertaking a quick search, this is not enough to provide a clear picture of the problem. As John Cowan once suggested: If you do not know where you are going, any bus will do. In other words, the problem has to be analysed and validated to make sure that we are not wasting resources on solving pseudo-problems. Five key questions need consideration in the problem design process:

1. Why has this problem attracted attention? Is it an anomaly, a paradox, a contrast or a contradiction (Qvist, 2004)? Seeing the problem from different angles can bring out new perspectives. Who are the stakeholders, who has formulated the problem in this particular way, and why do they argue for a change? On the other hand, who would resist a change? In addition, what validates this particular problem as one that is actually worth solving?

2. What type of problem are we looking at? Jonassen (2011) distinguishes between five characteristics of problems: structuredness, context, complexity, dynamicity and domain specificity. There are a number of related questions. In what context is the problem embedded? Is it a narrow problem within a discipline with few variables, or is it a complex problem moving across disciplines with many variables? Is it an ill-structured problem with multiple solutions and problem solving paths, or a more structured problem where we have a good sense of what to do? How dynamic is the problem – how quickly is it changing?

3. What would it be relevant to consider in analysing the problem? Holgaard et al. (2017) suggest a mapping of the problem using the 5W1H approach, considering the why, what, when, where, who and how of the problem. After this so-called screening, the problem can be narrowed down to a more delimited scope, and focus areas can be selected for problem analysis. Besides relevance

based on stakeholder arguments, there are other areas which should be considered when narrowing down the problem, such as alignment with learning objectives, access to knowledge, the time and resources available for the project and finally the chances of having an impact on the real-life situation.

4. How should the problem analysis be structured, and which theories and methods are needed to address the problem? Holgaard et al. (2013) have identified two different approaches to problem analysis. In a top-down analysis, students start with the sense of something that "can be done" and then go on to elaborate on a potential application. As this is a solution in search of problems, the problem field is relatively open. In the bottom-up approach, by way of contrast, students start with an analysis of an unsatisfactory situation, elaborating on stakeholder needs. As this is a problem in search of solutions, it is the solution space that is relatively open. If both the problem field and the solution space are completely open, we have a so-called 'wicked problem' (Rittel & Webber, 1973). Projects that address 'wicked problems' typically need more semesters and more than one team and discipline.

5. What is the outcome of a problem analysis? In short, the answer is a problem statement, stating the validated and narrowed-down problem, and pointing towards questions to direct the problem solving process.

Overall, we have experienced two typical pitfalls for students in the problem design process. The problem analysis may be too "quick and dirty", in which case the problem solving process becomes a 'blind-shot' based on the ungrounded hope that it might result in undefined impact of some kind. At the other extreme, the group may keep on analysing and analysing, finding new angles all the time and resisting the need to face the fact that their knowledge of the problem will never be absolute. At some point, decisions have to be made if students are to move forward and to make a change. The risk of encountering these pitfalls is particularly high when it comes to problem design related to complex problems. Here, we point to three key areas of concern.

First, greater problem complexity increases the need for an overview of the problem field and of the analytical approach. There are many ways to create an overview, such as mapping the problem field, mapping stakeholder relations, making a flow diagram of the analysis, or mapping areas of concern using a variety of different analytical lenses, such as, for example, psychological, social, environmental, economic, political or cultural approaches. In all cases, diagrams help students to attain and maintain an overview and to structure the handling of complex problems.

Second, complex problems cannot be defined from a single perspective or from the point of view of an individual researcher, actor or student. It is crucial that the students get up from their desks, get out of the university and get a sense of the real-life problem, including the activities, actors, resources, practices, institutions and discourses that constitute the problem. The question is who "owns" the problem – and how the students themselves relate to the problem. The 'people dimension' is central, and students therefore have to be aware of the position of others on the problem - as well as their own.

Third, complex problems need complex decisions about issues such as trade-offs and risks. This means that students have to be able to argue for different paths in the problem analysis, formulate criteria for the decision-making process and make a choice. Whereas the overviews provided represent *potential* paths in

the inquiry process, the problem delimitation presents the path that has actually been chosen. This also relates to ownership. As a student, you embrace the problem with your professional identity, however mature that might be, but at the same time you have to be modest about areas outside your knowledge domains. The way to work around this is to point to network relations and future studies – common sense is unlikely to work because, after all, the common sense we propose is very seldom as common as we believe it to be.

In any case, the more complex a problem, the more interdisciplinary are the theories and methods needed in the problem analysis. This means that further delimitations are needed on rather insecure ground. Consequently, many students find problem analysis challenging. It is tempting to skip this rather diffuse part of the problem based learning process and narrow down to something that you really want to do. However, many students also find that the pleasure of having a real-life impact fully compensates the hard work of problem design.

Einstein once said, 'If I had an hour to solve a problem, I would spend 55 minutes thinking about the problem and five minutes thinking about solutions'. In our experience, working with hundreds of students, year after year in the problem based and project organised learning environment at Aalborg University, we can say that he certainly had a point.

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Project design

A project design is a plan and a specification of the management of the project, including deliberations and decisions on the project type, leadership approach and code of conduct for the team. In this short introduction to project design, we will elaborate on these three topics.

First, the team has to consider the type of project that they are about to work on, as this will influence all other considerations in the project design process. For one thing, the project type depends on the scientific content and problem scoping, which can range from simple problems to complex and interdisciplinary problems (Kolmos et al., 2020). A further important dimension is the size and organization of the project; small projects may only take one semester and involve only one group, whereas larger projects may take several semesters and involve several teams (Kolmos et al., 2020). The more complex the problem, the more iterative the process becomes, and the more agile the project management required. Furthermore, the larger the project, the more complex project management becomes as more activities and actors are included, and this increases the need for a transparent project management scheme to ease communication. Projects with a long timeline require more documentation, as project considerations are more likely to fade from memory. In a problem based learning environment, the ambition is to develop competences to cope with the diversity of the different project types needed to face real-life problems, and as these can range from simple to complex problems, the ability to provide a project design that is appropriate for the project type is crucial.

Secondly, members of the group have to take time to discuss their overall approach to leadership. Typically, in a problem based learning environment, there is no assigned project manager, and the group has to manage the project collectively. It is therefore crucial in the formation phase for the team to engage in a mutual exchange of expectations, to align leadership preferences and to ensure that there is a shared understanding of the aims of the project. This could include a general discussion about the nature of good leadership, about what a good project manager has to take care of, and about how the group will ensure that the individual members develop leadership competences. A collective understanding of the desired leadership approach provides a frame of reference that allows members to experiment with and position their own leadership role during the course of the project. Likewise, this is a useful frame of reference for the evaluation of personal leadership performances for continual development. For inspiration in the discussion of leadership, we recommend the short video “Ten Leadership Theories in Five Minutes” by Professor Michael Zigarelli (Zigarelli, 2013).

Finally, the team members also have to discuss how they want the team to function. We recommend that teams adopt a code of conduct to manage collaboration patterns, resources and daily operations to secure collaborative learning as well as high performance. A real team consists of people with complementary skills and with equal commitment to common goals and working approaches (Katzenbach & Smith, 1993). To become a high performance team, members also have to be committed to each other (Katzenbach & Smith, 1993). Whereas a group can easily agree on the idea of being a high performance team, the process of defining the preconditions for reaching this level is more difficult. We therefore recommend that the group provide a written agreement outlining the code of conduct for the group.

Codes of conduct governing collaboration can be developed by an inquiry focused on a number of questions. Who are we and why are we here? What competences do we have from the outset? What do we wish to do? What are our aims? How far are we willing to go to reach our aims? How should we work together to achieve these aims? How should we work with others to reach these aims? How do we want to

develop? Furthermore, codes of conduct can be specifically formulated to direct collaborative learning, including ongoing peer-learning activities, how decision-making processes will be carried out, how potential conflicts will be managed and how the group will manage to create synergy of personal learning styles and goals in the distribution and organization of work. For the analysis and comparison of personal learning styles, we recommend the Index of Learning Styles (Felder & Soloman, 2020), which is a scientifically validated and free online tool.

In considering the structural side of their project design, the group also have to discuss and select an appropriate resource management scheme. An established method to gain an overview of the relation between activities and resources during the project is to use Gantt charts. The Gantt method is strong on visualizing parallel activities as well as activities that are preconditioned by others. A newer and more agile method for resource management is SCRUM (Sutherland, 2014), which combines product development with project management. SCRUM is typically used in complex development projects.

The project management scheme for student projects is typically based on inspiration from such management schemes as well as consideration of the project type and the chosen approach to leadership. In our experience, therefore, short introduction videos provide very effective inspiration for students who need to develop their project management scheme. For example, we recommend the PROJECTMANAGER.com film (Deen, 2015), in which Content Director Devin Deen introduces the viewer to the history of Gantt charts. A useful presentation of SCRUM is provided by Steve Stedman's 7-minute introduction video (Stedman, 2014). Such videos have inspired many students at Aalborg University to design their own project management schemes and to focus on producing a scheme that makes sense for the group and leaves them fully committed to carrying out any necessary ongoing evaluations, updates and revisions of the plans.

Furthermore, groups typically outline guidelines for daily operations in the team to secure smooth collaboration and continuity in the workflow. Examples of guidelines might include meeting-times, types of meeting and pre-described roles, such as communicating with external contact persons, note-taking, moderating, or even taking turns as project managers. To combine resource management with the everyday activities of the group, such as the management of meetings and files, some student groups at Aalborg University have reported positive experiences with the use of Trello as a support system. Trello provides a common on-line communication platform for the group. If you want to know more, you can look up the introductory videos at Trello.com (Trello, 2015).

Finally, it is also important for the team to outline basic rules for the written collaboration agreement itself. These rules provide for the ongoing evaluation and revision of the agreement and define the consequences of deviating from the agreed code of conduct.

A careful project design process and a detailed agreement prescribing the code of conduct for the team can save valuable resources and time that would otherwise be spent on conflicts or activities that do not really add value to the project. However, it has to make sense for all members, be sufficiently detailed to direct daily operations and be followed up by ongoing evaluations and revisions to align with the iterative nature of problem-based project work.

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Open problem solving

Problem solving is the process that follows the problem design process. It is a premise for the problem solving process that a problem has been identified, analyzed and formulated.

In a problem based learning environment, there can be many types of problems; to be of interest, however, they tend to be somewhat open-ended, and open-ended problems call for open-ended problem solving. The term 'open-ended' refers to the outcome of the work and to whether more than one solution, design or answer is possible (Lock, 1990). By this definition, open-ended problem solving is closely related to complex problem solving, which can be characterised as a process to achieve ill-defined goals that cannot be reached by routine action but instead need creative combinations and a broad set of strategies (Dörner & Funke, 2017).

We draw inspiration from the concept of complex and open-ended problem solving and choose simply to talk about open-problem solving, which we define as a problem solving process with three central characteristics:

1. Iterations and creativity: the dynamic problem design inspires creative thinking in the problem solving process rather than limiting it, and it allows not just one, but a range of potential solutions.
2. Ongoing assessments throughout the problem solving process: not only do ongoing assessments ensure the fulfilment of user needs, but they also move beyond user needs to differentiate the solutions and address their context dependency.
3. Outlook and system thinking: this allows participants to picture the prospects of the proposed contribution in the context of use and in a broader societal context. The goal is to create sustainable solutions for the future.

In the following, we will briefly describe ways in which these three characteristics can be embedded in a problem solving process.

The combination of iterations and creativity means that the criteria stated in the problem formulation for problem solving should be continuously revisited. At the same time, problem solving should be open to new constellations of use, new ideas and new prospects. This involves a delicate balance between being true to the needs presented in the problem analysis phase and being open to new associations which did not initially seem related to the needs presented.

For example, let us say that the problem design process has indicated that when it comes to re-packaging food, consumer behaviour is unsustainable: almost invariably, consumers use plastic bags to store food in the freezer. User behaviour is studied and different ways of storing food are taken into consideration on the basis of user needs. However, in a creative process during the design phase, one of the students starts to wonder, "What if we do not have to store food at all?" The group then rephrase this rather radical idea as a new question: "How can we decrease food storage?" This question does not change the idea of presenting a more sustainable alternative than plastic bags for storing food – it provides another dimension to the solution space to limit the need for packaging.

In terms of open problem solving, the point is that you are gradually working towards a solution – interacting with users and presenting low-fi mock-ups, simulations or prototypes to ensure that the outcome is appropriate to the context of use. There are many different models that can guide developers

through this process; while production managers might use the PLAN-DO-CHECK-ACT Deming cycle (Deming, 1982) for continuous improvements, human interaction designers might adopt the design-thinking process (IDEO, 2018) and computer scientists might refer to the V-MODEL for system engineering (Shamieh, 2012). The most important thing, however, is that these various models all accommodate iterations throughout the problem solving process.

The next central characteristic of open problem solving is ongoing assessment. This does not only mean testing new solutions in different contexts, but also making a comprehensive and ethical assessment of the solutions in different stages of the iteration process. This addresses a central risk of user-centred design: it may focus too strongly on the user. Accordingly, an inquiry process could include important questions: do the users know what they will need in 10 years and do the users know the broader societal consequences of their choices? It is about being aware that a way to solve one problem might involve producing other problems. Ethical-constructive technology assessment (Kiran et al., 2015) and other types of technological assessment which move beyond user needs are therefore recommended as part of an open problem solving process. It is a matter of values and of being aware that openness in the problem solving process does not mean that values should be compromised, whether those values are corporate or personal. If, for example, the problem with re-packaging food in plastic bags is solved by going to the store and buying meat more often and in smaller portions, the amount of plastic ending up in the waste-bin might be just the same.

Finally, outlook and system thinking combine outreach and interconnectivity. Although open problem solving is indeed "open", we also have to be aware that we can hardly avoid the adoption of analytical lenses; this means that no matter how hard we try, we will inevitably fail to embrace all aspects of a problem. We have to narrow down the problem to something with which we can cope. If we keep on analysing *what is*, we will never get to change the situation to *what could be*. Moreover, our attempts to design for the future will always be incomplete in an ever-changing world. Therefore, every open problem solving process should be accompanied by a discussion of the perspectives of the suggested solution. Some of the key questions are

1. What are the preconditions for this solution to work?
2. How does the solution work together with other solutions?
3. Which actors have to be activated – and to what purpose?
4. Which actors will probably resist the change and what would be an appropriate response to such resistance?
5. What gains does this solution offer, and what must be 'traded off' to achieve these gains?
6. How will we validate that the solution has an impact?
7. What are the signs of successful implementation?
8. What do we need to study even more to move ahead?

Furthermore, complex problems very often result in complex and multi-dimensional solutions. Such complex solutions may well address problems that were not even considered in the original scope.

Let us return to the example of the group working to reduce plastic for food-storage. The students could end up creating an app to plan a week's shopping and cooking in a way that reduces meat intake by increasing the vegetables consumed. Furthermore, the app could include suggestions about carrying home and storing food in more sustainable ways, for example in recyclable and re-useable boxes. In the final overall reflections at the end of the project report, the scope could expand to the whole product chain to redirect the food supply and reduce packaging as well as to optimise waste handling systems. Furthermore, a final discussion might address the governmental policy and incentive structures needed to motivate this change.

To sum up, open problem solving is a complex process, balancing divergent and convergent thinking, and balancing present and local needs with future and broader impacts. However, open problem solving is the way to go if we want to make progress and prepare ourselves not only to work within predefined systems but also to change those systems from within.

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Process analysis

When they adopt a problem based approach, students address a real-life problem to motivate a change in the real world "outside the project team"; parallel to this process, however, there is another kind of problem-oriented process in play, focusing on the potential pains, gains and uncertainties involved in developments "inside the project team". The purpose is to optimise team processes in ways that will increase learning potential as well as to improve the project outcome. Such a process relies on what Argyris (1976) has termed "double loop learning"; changing the underlying causes behind the problem demands a high degree of self-awareness.

Exploring the underlying causes of problems within the project group is rather different from addressing external problems. Process analysis is not about analysing stakeholders' behavioural patterns, revealing underlying causes that suggest improvements, and coming to their rescue. On the contrary, process analysis is about analysing your own behavioural patterns, in the group and as a group, and it requires enough self-awareness to point out underlying problems and to find new ways to solve them. Being subject to analysis as well as being the analyst is very challenging, especially because disciplinary knowledge and skills will rarely help you to address process issues such as a malfunctioning project design, a lack of motivation among peers or ongoing team conflicts – just to mention a few examples.

The project design must be as transparent as possible in order to allow assessment of the alignment between the prescribed code of conduct and actual team behaviour. If changes to the code of conduct or behavioural patterns are needed, the group will probably have to move deeper in its analysis of the problem. Sometimes, minor problems can be resolved by a single-loop learning model, but on other occasions, double loop learning is needed.

Let us take an example. Two argumentative and highly vocal group members repeatedly take up valuable group time by doggedly opposing each other in seemingly endless discussions that seldom offer constructive outcomes. The single loop answer would be that the two group members should simply correct their behaviour to limit their discussions. However, if this does not help, what then? In that case, a problem-oriented process has to start. Why do these two people go for each other's throats? When and where does this happen? What do they discuss? Who interferes? How can the group resolve the problem? Moreover, when it comes to the last question, what methods and theories could be of help? The group searches for potential help, talks with the supervisor for guidance and uses prior experience to find potential solutions. Subsequently, the group uses active listening (Rogers & Farson, 2015) around the table, with five minutes for each group member at the beginning of every discussion meeting. They are more careful about having their say, aiming to balance the members' speaking time and secure a group exchange instead of arguments between sub-groups. The group revises the contract, so that if a team member considers a discussion unfruitful, the team-member indicates that there is a problem by leaving the table, thereby using body language to force a time-out instead of the spoken word, which was too much in play in heated situations. Furthermore, the contract specifies that the group will evaluate the experiment after two weeks.

Such a situation calls upon group members to participate in a conscious process of observing, thinking, analysing and reinterpreting actions and situations in which they themselves play a part. In other words, it calls for meta-reflection; participants have to reflect on their own first-hand reflections, which have already proved unable to motivate the necessary change. According to Anette Kolmos and Lise Kofoed (2004), there are three levels of reflection in student projects. On the first level, the focus is on reflection, and

students have to gather the energy to direct their attention towards the process. The second level, the documentation and description of events and emotions, involves reflection on what has happened and what can be done. At the third level of reflection, learning occurs through variation, where, on the one hand, students experience different outcomes when taking different approaches in different situations, and, on the other hand, can point out typical situations where similar approaches would most likely work.

To train students' meta-cognitive skills, we recommend that a project period or a semester should be partly devoted to observing, analysing, evaluating and changing problem based learning practices. A way to do so is to ask for a process analysis in which students move through the following five phases:

Phase 1: Document and argue for the project design at the beginning of the project

The project design includes reflections on the project type and leadership of the group, as well as a specific code of conduct for work practices. As this constitutes a frame of reference for the group's work practices, the arguments and reflections behind the project design should be documented. Furthermore, the group should make clear reference to the sources of inspiration for the particular project design. Our recommendation is that this kind of reflection about what the group wants to do and why they have chosen this approach should constitute the first part of the process analysis.

Phase 2: Ongoing observations and documentation of work practices

In phase 2, the focus is on maintaining attention to work practices, and we typically advise students to report on their work practices in a logbook. Each day, a group member notes down what happened that day. Once a week, the logbook entry is based on a reflection meeting. In this reflection meeting, the group share experiences and develop a collective understanding of the workflow in retrospect, including their collaborative patterns, progress made in relation to the plan, and the smoothness of daily operations.

Phase 3: Mid-term analysis

In their mid-term reflections, students are advised to synthesize the logbook material and analyse their work practices in five areas: problem design, project management, group collaboration, external collaboration and reflections on the learning process. The key questions are what did we do, why did we do it, what were the gains, pains and uncertainties, and what do we want to change? The purpose is to develop and document the ability to reflect on the group's work practices and to analyse them in light of their own experiences as well as useful conceptual frameworks to provide a deeper understanding of underlying causes and potentials for change.

Phase 4: Experiments based on mid-term reflections

In the next phase, the focus is on setting up and carrying out experiments involving the changes called for in the mid-term analysis. For each experiment, students can describe what they have planned to do in the experiment and, on the basis of their ongoing weekly reflections on their progress, use their logbook to report what they actually do. The purpose is to internalise an approach to development based on the experiential cycle of learning, such as the one introduced by David Kolb (1984). In this approach, reflections

on experiences lead to new actions based on a more abstract conceptualisation that includes both prior experience and selected theories and methods. At best, experiments become exemplary instances of double loop learning deployed to develop PBL competences.

Phase 5: Final reflections and recommendations for future projects at the end of the project

In the final stage of the project, or just after finalising the project, students are advised to reflect on the whole project period in retrospect. First and foremost, this entails documenting the results of the experiments – what was the outcome, what lessons were learned, and how can this experiential approach to developing process competences be transferred to similar situations? Furthermore, students are advised to supplement their mid-term analysis by considering overall changes in the work practices and changes in the conditions in the final stage of their project work. The purpose is to develop the ability to evaluate the process in a comprehensive way, summarising the most important changes and lessons learned, and, on that basis, to be able to produce general guidelines for future projects in comparable contexts.

The documentation of these five phases comprises the project design, logbook of work practices, mid-term analysis, experimentation and final reflections; gathered in a portfolio format, they constitute what we call a process analysis.

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Final remarks

At Aalborg University's Faculty of IT and Design and at the Faculty for Engineering and Science, all first semester students take a five ECTS course and consultancy unit to help them develop problem-based learning skills and competences. Throughout their studies, students receive ongoing support to help them fine-tune and develop their PBL competences and to be clear and explicit about this in a personal PBL profile.

Typically, the challenge facing students is to provide the necessary attention to work practices, to make reflections so explicit that they can be used as a basis for development, and to select conceptual frameworks and methods that will develop their practice in a professional way.

PBL competences span problem-oriented and contextual competences, and they include the ability to create a problem design for various types of problem, to take a leadership role, to collaborate effectively inside and outside the group, and to use self-reflection for personal and team development. This huge span of competence domains and of their nuances in various educational contexts clearly implies that the transition to PBL from more traditional educational practices is far from easy.

Consequently, these brief lecture notes are intended to introduce core PBL concepts and frame a facilitated introduction to PBL or to provide students with a recap of the overall principles of PBL.