Chapter 2
Problem-Based Projects, Learning and Interdisciplinarity in Higher Education

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2.1 Introduction

The increasing speed with which knowledge and information are emerging, coupled with the growing complexity of the problems which science is expected to address, mean that the role of higher education today is entirely different from what it was only a few decades ago. In the past knowledge, skills and competencies developed through a university degree ensured a solid foundation for life. However, today students in university degree programmes cannot even be sure that the knowledge and skills gained during the first year of study will be comprehensive on graduation day. Or put differently "*So we are trying to prepare our students for the unknown by using what is known*" (Bowden and Marton 1998: 26). Parallel to, and perhaps as a consequence of, this development, the landscape of tertiary education is becoming increasingly diverse. New student groups are finding their way into university, significantly altering the composition of the student population. This is not least due to the international restructuring of educational systems where, for example, student populations in master's programmes may be both multicultural and composed of students with diverse degree backgrounds. These changes are strongly encouraged through international qualification frameworks as for example the European Qualification Framework emphasising mobility, lifelong learning and transferability of qualifications (The Council of European Union 2017).

The fact that higher education institutions must now educate students in ways that still ensure a sound knowledge base while also offering possibilities to develop

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strong competencies to continue learning beyond graduation and formal education is making the choice of pedagogical approach increasingly important and simultaneously difficult (Miller 2010). These changing conditions of higher education have been referred to as the postmodern condition (Lyotard 1984) constituting a new arena for doing research and offering higher education (Gibbons et al. 1994). Under postmodern conditions for knowledge production, interdisciplinary learning in higher education is centrally positioned as a conceptual framing that can build bridges and fill voids between traditionally irreconcilable disciplines. This has contributed to a new vocabulary of contemporary higher education that is not limited to an exclusive academia behind the university gates.

This chapter will address the complexities of interdisciplinary higher education and will frame some of the unresolved issues that continue to challenge interdisciplinary teaching and learning, as well as the underpinning pedagogies. More specifically, the chapter will, through the case of a specific university, highlight some of the ways in which interdisciplinary learning may be perceived and conceptualised in higher education. In particular, the chapter will discuss the premises of problem-based learning as a pedagogical approach that may offer the potential for opening interdisciplinary learning spaces. Thus the aim of the chapter is to highlight key issues that need to be researched and better understood if the principles of problem-based learning and the intentions of interdisciplinary learning are to be a compatible match.

As a point of departure it is important to emphasise that here we will not offer a precise definition of the concepts of interdisciplinarity or interdisciplinary learning. Rather, we acknowledge that these concepts may have different meanings and uses that vary with the context. As a consequence, with this chapter we wish to contribute to the development of a nuanced and comprehensive vocabulary of interdisciplinary learning that will broaden what we can and cannot think and do in higher education settings and which will allow us to discuss how issues of interdisciplinarity have very real and direct implications on pedagogical and didactical considerations and on students' learning.

2.2 Complexities of Interdisciplinary Learning in Higher Education

The notion of interdisciplinary learning is difficult to grasp, and is given a variety of meanings in literature and research depending on context (DeZure 2010). Somehow research into the field is still relatively limited and, it has been suggested, points in multiple directions (Mansilla 2010). As will be evident through the chapters of this book interdisciplinary learning can be conceptualised in one of two ways; *through the characteristics of the people involved,* or *as the way knowledge is produced and handled* in the learning process. Thus the phrase 'interdisciplinary learning' may signal the complex and diverse characteristics of persons involved in shared

processes of learning. In higher education this condition may arise when students from mixed educational backgrounds, holding varied views on shared problems come together to collaborate and extend their perspectives. This conception of interdisciplinary learning emerges as a consequence of the specific and diverse characteristics of the persons involved. On the other hand, interdisciplinary learning can be conceptualised as the way in which learners construct and produce knowledge. In this conception, interdisciplinary learning is not framed by the characteristics of the persons involved, but rather by the way these persons develop and design their shared learning process to construct new knowledge. In this conception it is the actual interactions within and across disciplines that delimit the boundaries of what can be understood as interdisciplinary learning. Both conceptions are addressed in this book, and both have a place in discussions of higher education, yet each conception make its own contributions to the understanding of interdisciplinary learning in higher education settings.

In higher education settings, the approach to and conception of interdisciplinary learning largely depends on the organisation of the curriculum and actual learning activities. Students may work in a monodisciplinary, multidisciplinary, or interdisciplinary educational environment, and as such it may be the curricular adherence to disciplinary boundaries that implicitly determines the actual scope and nature of interdisciplinary learning. For example, students in a monodisciplinary setting keep well within the boundaries of disciplines when learning. The problems addressed, the methods applied to reach an answer and the theories used are in this setup clearly within the traditions and scientific practices of a particular scientific community and overall paradigm. In contrast, in multidisciplinary learning settings students address issues or phenomena from a multitude of disciplinary perspectives, but do nothing to navigate and explore the intersections of these disciplines. Often such educational settings emerge in interprofessional programmes and courses where students from varied backgrounds come together to illuminate a shared problem from multiple perspectives. An example could be students from psychology, teacher education, social work and nursing bringing together their various perspectives on how to work with children who have experienced domestic violence. Working and creating knowledge from an interdisciplinary perspective, in contrast, calls for the development of processes whereby the intertwining of several disciplines can lead to knowledge and comprehension beyond what any one discipline could offer. In these processes, students may transgress boundaries and contribute to the development of products and professions not yet conceivable or defined. Klein (2012) offers a detailed and elaborate taxonomy of interdisciplinarity characterised by words such as integration, interaction and collaboration.

Whether interdisciplinary learning in higher education programmes is defined according to the backgrounds and competencies of the persons involved or the way processes of knowledge construction are developed and designed, there is no doubt that moving from monodisciplinary to interdisciplinary education adds layers of complexity and requirements to the roles of both student and teacher. However, venturing into interdisciplinary education is also political in the sense that it carries with it a perspective on students and professions that acknowledges the need for

graduates to deal with uncertainty and to have the competencies to construct knowledge not within but across disciplines. As such, offering interdisciplinary higher education emphasises emerging professions rather than contributing to hyper-specialisation.

Regardless of the approach to interdisciplinary learning, higher education institutions offering interdisciplinary programmes are faced with a considerable pedagogical challenge. This challenge is particularly evident when transforming interdisciplinary intentions and learning objectives of curricula into the actual practice of education (Nowacek 2009; Stentoft 2017). To meet this challenge, problem-based, case-based and project-organised learning are often brought forth as pedagogical approaches that can open up spaces for interdisciplinary learning (e.g. Majeski and Stover 2005; Sternberg 2008). Here we will refer to these by the commonly used term 'problem-based learning', or simply PBL.

2.3 Problem-Based Learning in Higher Education

Problem-based learning (PBL) is based on a philosophy of learning that takes complex, ill-defined real-life problems as a point of departure for learning (Dewey 2005). As a pedagogical approach, PBL was first developed and implemented in the 1960s at the medical school of McMaster University, Canada (Servant 2016; Barrows 1996; Savery 2006). The principles of PBL have since gained worldwide recognition in numerous domains, which has led to PBL today being adopted for a variety of models and strategies for learning in higher education settings that are locally adjusted to accommodate educational beliefs, policies and demographic and economic realities.

Since its first implementation, PBL in higher education has developed in response to changing educational and societal conditions and as an attempt to strengthen the interplay between the sciences and the world to which these sciences are meant to positively contribute. Servant (2016) has in her work uncovered the diverse historical contexts of four universities which continue to play significant roles in PBL today, namely McMaster University, Maastricht University, Roskilde University and Aalborg University. These four universities all took a progressive stance towards higher education in the late 1960s and 1970s and continue to offer education based on the principles of PBL today.

The reasons for adopting a problem-based approach in higher education are many, and the approaches and practices arising from the overall principles of PBL are highly diverse (Savin-Baden and Major 2004; Stentoft 2016, 2017). Even within a single institution there may be significant differences in the way problem-based learning is practiced, depending on the field of study and the prospects for students beyond their university education. However, all practices of problem-based learning take their point of departure in real-world problems rather than firmly defined disciplines and well-structured textbooks.

To be more specific about the theoretical underpinnings and practices of PBL, it appears sensible to take a closer look at one higher education institution, which from its establishment has embraced and continued to develop the principles of PBL across the entire institution. This will allow for a discussion of the process of bringing principles into educational practice and of the value of PBL when intended for interdisciplinary learning. It is, however, important to also bear in mind that each institution will have its own contextual setting and characteristics, meaning that no single implementation of PBL can be considered ideal for all.

2.4 Case: Project- and Problem-Based Learning at Aalborg University, Denmark

In Denmark, Roskilde and Aalborg universities were established with an institutionalised PBL approach in 1972 and 1974, respectively. These universities emerged with a specific philosophy of learning and education based on problem orientation and participant-directed project work in groups. This approach was referred to as problem-based learning, and the universities were from the outset considered to be somewhat in opposition to older and larger universities in the country. The Danish education professor Knud Illeris offered considerable insights into the theoretical foundations of problem-oriented project work in a Danish context, initially in his book *Problem orientation and participant direction: An introduction to alternative didactics* (Illeris 1974) and later in numerous books and articles.

The approach to problem-based learning adopted at Aalborg University is based on the following six principles (Askehave et al. 2015):

- The problem as point of departure in the learning process.
- Projects are organised in groups.
- The project is supported by courses.
- Collaboration is essential within the project groups and with supervisors and external partners.
- Problems and projects must be exemplary.
- Students take responsibility for their own learning.

Taking a *problem* as the point of departure for the learning process means that students investigate and study the knowledge, methods and theories relevant to a specific problem rather than focusing on a narrow discipline-bound theme or task. Consequently, interdisciplinary learning is often a prerequisite for fully comprehending the problem. The problem is not predefined by the study programme or by the teachers, so the students themselves are required to find and define the problem they wish to investigate further. In defining the problem, students must argue for its relevance and the context in which it is relevant, thus tying the problem to realities outside academia. Simultaneously, developing a problem-based project is a highly academic and analytical exercise. Students consequently have ‘ownership’ of the

problem and make their own decisions on how to organise their investigations. In other words, the work is *participant-directed*. The students' processes of handling and constructing knowledge relating to the initially ill-defined problem and their deliberations on the relevance of theories and methods for investigating the problem gradually lead to a more profound understanding of the complexity of the problem. When reaching a point where the problem can be stated as a clearly defined research question, students move on to plan their further research into the problem. The curiosity and the challenges experienced in this process, as well as the wish to better comprehend the problem (or to answer the research question), are some of the motivating factors. Often, addressing a problem also involves collaboration with *external partners* (e.g. organisations, companies or public institutions), which further contributes to the engagement of students.

Studying in a problem-based setting at Aalborg University is primarily organised around *projects,* most often one large project per semester, and accounts for approximately 50% of study programmes. The remaining 50% consists of *course work*, lectures, workshops, assignments, etc. Although these study activities may support and inspire students in their project work, they are assessed separately. Students work on one project per semester, which continues through the entire semester. An important aspect of problem-based project work is that it is *group based*. This provides a basis for peer learning, the development of *collaborative* skills and scientific and academic vocabulary proficiency, which the students practice in discussions and the negotiation of meaning as well as in written communication, since the research processes involved in studying the problem and its potential solutions are documented in a project report. The group is thus an important factor in the students' learning as they become responsible for organising and leading both their own and their fellow students' learning processes.

To support the learning processes of the project, the groups are assigned a *supervisor* with whom they discuss how the project is progressing. The supervisor provides formative feedback and comments on their drafts for the chapters of the project report. The role of the supervisor is important as a discussant for the group – asking critical and constructive questions to make the students reflect on their work, their understanding of the problem and their choice of theory and method for further exploring their research question. The supervisor's focus is also on unleashing perspectives to ensure a comprehensive and critical examination of the problem from all angles. Furthermore, the supervisor has the responsibility to ensure that the project falls within the formal, thematic framework of the semester in question and enables the students to fulfil the requirements of the study. The PBL approach applied at Aalborg University is based on the principle of *exemplarity*, which means working from problems that are representative of more general issues, and are realistic and relevant to a future working life and profession. This will enable students to transfer scientific and interpersonal knowledge, skills and competencies developed in one project into future unknown situations involving similar issues.

The members of the project group are jointly responsible for the final project report, which forms the basis for their oral group assessment.

A problem-based project tends to go through the following phases:

- The thematic framework for the semester is presented. In some cases, supervisors present a number of more specific areas or issues to inspire the students to engage in the project work process.
- Project groups are formed. Ideally based on students' shared interests, but they may also be formed administratively based on predefined criteria.
- The groups define a scope for their project within the overall thematic area of the semester in question and they start their first reflections on relevant problems in cooperation with the appointed supervisor. An example of a semester thematic area in sport science could be physical activity in children, and a project group could choose to delimit the project to be about preschool children's activity in kindergarten.
- The project groups start framing the problem they wish to address. This is a dynamic process that continues throughout the project period; as the group becomes more knowledgeable they continuously refine the problem statement/research question. During the initial weeks of the project period, much effort is put into researching the literature and identifying relevant gaps in existing knowledge in order to present a strong and concise argumentation leading to and emphasising the relevance of the actual research question.
- When the research question is established, the groups engage in reflection on methodology and research methods and make decisions on how to design the research process to best address this question.
- Some study programmes include specific peer learning and reflective activities in the form of midterm seminars/status seminars/opponent seminars, the analysis of metacognitive processes and writing of process reports. In seminar activities each group may be assigned an opponent group and an opponent supervisor, who are expected to provide constructive feedback on the project and the progress. Reflective activities are fruitful for the students as they receive valuable feedback, while through their feedback to other groups they simultaneously have an opportunity to reflect on their own work as well as the academic decisions and progress in their own projects.
- Finalising and submission of the project report, which may in some study programmes also contain artefacts such as physical models, pieces of software, prototypes etc.
- Oral examination in groups. The examination takes its point of departure in the project report. Generally, the oral exam is organised into several stages. First there is a round of individual student presentations related to the project and the project report. The presentation is followed by questions from the examiner, who is also the project supervisor. From the questions naturally flow joint discussions between the students and the internal and external examiners. The examination is conducted over an extended period of time, thus providing ample opportunity for the individual assessment of each student.
- Each student is given an individual grade, which is jointly decided by the internal and external examiners. The group is finally offered collective feedback on their project and their learning process.

Although the study programmes at Aalborg University follow these principles, research has shown that there is diversity in the implementation of the principles across the faculties and specific educations offered by the university (Kolmos et al. 2004). Furthermore, the principles of PBL at the university are continuously being developed to respond to the demands of advisory boards, employers and students. They must also meet challenges from governmental regulations (Krogh and Jensen 2013; Jensen and Krogh 2013; Laursen 2013) and international educational policy developments, such as the Bologna Process (Ravn and Jensen 2016; Jensen and Thomassen 2018).

In summary, the PBL principles mentioned create the overall framework for an interdisciplinary learning space. The scope of the curricular 'boundaries' for PBL projects are determined by the individual study programme, and it is then up to the students – supported by their supervisor – to take up the challenge of locating and defining the relevant problems and embark on (inter)disciplinary research processes.

2.5 PBL as a Pathway Towards Interdisciplinary Learning

In light of the demands placed on twenty-first century graduates to develop competencies to address and handle ill-defined problems, and considering the speed with which knowledge is emerging and becoming out-dated again, it seems relevant to investigate in detail whether *interdisciplinary learning* is indeed achieved through problem-based university education, and if so, what role interdisciplinarity might play in learning processes. In other words, we need to understand in greater detail if and how a problem-based setting enables interdisciplinary learning, and whether we need to design learning processes in particular ways to create and optimise interdisciplinary learning spaces.

The need to explore these questions is further reflected in the increasing number of higher education institutions adopting problem-based learning as their principal approach to student learning. The desire to transform pedagogies is often rooted in a desire to bring students in closer contact with 'real-world problems' and professions to enable a comprehensive contextualisation of university studies. In transforming into a PBL university or in adopting a PBL approach in specific study programmes, institutions consequently adopt an approach in which the actual learning processes are considered a strategy for contextualisation. PBL promotes interdisciplinary learning when students identify and delimit problems. It is in this process students must acknowledge the margins of disciplines and develop new vocabularies to adequately address the real world problems identified. Whether they delimit the project to only offer one particular perspective, or whether the problem calls for an interdisciplinary perspective to advance the understanding of the problem further, students need to defend their strategies and demonstrate their relevance. In this way, interdisciplinary learning presents itself as a possible part of many solutions that venture past the disciplinary boundaries of curricula.

As we have discussed, this interdisciplinary learning approach is possible when the identified problems are ill defined and not necessarily situated within a specific scientific paradigm. Instead, problems may be located within a politicised, uncertain, complex and to some extent undefined or unstable aspect of the world, and may be formulated around inputs from commentators, politicians, experts, scientists, citizens, professionals of different kinds etc.

The situated and contextualised character of a problem might initially and intuitively lend itself to a 'traditional' monodisciplinary understanding and solution, but by allowing and encouraging students to frame the problem differently, and by giving them the freedom to choose the theory and methods for investigating their problem, the possibility of innovative and experimental approaches emerges, together with imagination and creativity in dealing with the problem. In this light, a problem-based approach to learning obviously opens up learning spaces conducive for interdisciplinary learning; however, as also becomes clear in the above, this will only happen in so far as students are given both encouragement and opportunity, as problem-based projects may also be defined well within disciplinary boundaries (Stentoft 2017). Consequently, the supervisor comes to play an important role in keeping the problem 'open' for as long as possible by supporting students to remain in the ambiguous and frustrating phase of discovering new perspectives. In order to truly facilitate interdisciplinary learning, the supervisor must therefore also be curious about new framings and unconventional approaches in theory and research methods, and must accept and be able to manage some degree of uncertainty regarding the students' work and the learning outcome of their process.

As an example, we can imagine how a project on planning the construction of a bridge in an engineering programme may entail multiple engineering computations, theories and approaches; however, the problem equally calls for understanding of the law relating to the positioning and dimensioning of the bridge, and of social science research that explains the potential use of the bridge and its impact on surrounding communities. The possibilities for interdisciplinary learning are thus considerable, and making active decisions regarding the approach form a significant part of what is, in PBL, considered learning.

Opening problem-based projects towards interdisciplinary learning can be seen as a particular way of conceiving of science as a toolbox with many different tools, such as methods and theories, which students can make use of. This way of conceiving of the function of interdisciplinarity in PBL as a juxtaposition of scientific domains is determined solely by the framing and definition of the problem to be addressed. Or put in other words, this view of science is clearly a break from discipline-oriented teaching and learning, and it places heavy demands on both students and teachers as they are challenged to distinguish between mono-, multi- and interdisciplinary learning as the various disciplines involved in a problem-based project do not simply work in parallel as separate perspectives. Rather, in order to fully comprehend the problem at hand, disciplines need to be merged and become entangled in ways that lift the knowledge constructed through the project work to new levels of abstraction.

2.6 Concluding Remarks

The discussion above about the educational conditions that support interdisciplinary learning in problem-based higher education has pointed to a number of key issues which need careful consideration. Thus there is a necessity of reflection on the conditions for doing interdisciplinary PBL projects in relation to:

- The complexity and capabilities of diverse and interdisciplinary student groups.
- The different types of audiences that define the logic of what is considered scientifically relevant knowledge.
- The potentially highly ambitious content of the notion of interdisciplinarity in contrast to mono- and multidisciplinary approaches, as exemplified above.
- The assessment criteria of interdisciplinarity in problem-based learning.
- The key role of the supervisor in relation to interdisciplinary processes.
- The challenges and requirements facing students engaging in interdisciplinary and problem-based learning.

The following chapters of the book will address these issues further. We have only highlighted here what we believe are the key areas for further research in order to get a firmer grasp on the role of interdisciplinarity in PBL and to obtain the means for supporting the further development of pedagogies supporting interdisciplinary learning. We started out by describing how interdisciplinary learning, like all other concepts, does not necessarily benefit from tight definitions, but may be understood by tracing its uses, connections and contexts. We do, however, need to develop a more refined vocabulary about what it actually means for students to work in an interdisciplinary manner to produce a fuller picture of what is really at stake when we use the word in relation to PBL.

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