Education for complex problem solving

Is problem-based learning one answer to today's higher education challenges? Case study: a Danish university

Chapter 2

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"Problem-based learning is both pedagogical approach and curriculum design methodology. Simultaneously it develops higher order thinking and disciplinary knowledge bases and skills. It places students in the active role of problem-solvers (practitioners) and confronts students with real-world situations (…)" (Barrows, 1986, p 481).

1. Introduction

The problem-based learning (PBL) model as it is practised at Aalborg University grew out of expectations for future graduates in the 1970s. Many changes and developments have taken place since then in the ways the principles and methodologies are practised, due to changes in society and governmental regulations. However, the basic educational principles and methodologies are still the same and seem to meet expectations from society and academic workplaces today, as documented by surveys and research carried out on a regular basis. (see, for instance, Krogh, 2013).

Aalborg University, located in northern Denmark, has more than 40 years of experience using PBL methodologies. The aim of this chapter is to take a closer look at why and how a PBL approach may be a relevant educational approach for higher education today in meeting current challenges. The core principles and methodologies of the PBL approach at Aalborg University will be discussed by way of various experiences (possibilities and challenges).

One of the key points is that the principles and the methodologies – including the aspect of inter-disciplinarity – generally support both students' acquisition of academic knowledge, skills and competencies for the academic labour market and simultaneously correspond to research methodologies. By applying this approach throughout their education, students actually acquire competencies that are relevant for both university-based careers and non-university academic careers.

> *"What you specifically learn at university is difficult to tell somebody, for instance, being able to build a radio or something similar. This is something you have to learn later on but you have found your way. What matters is the way in which you learn at Aalborg University. It makes up 80% of the way in which we work. It is crucial because more than the exact knowledge has been put into their heads."*

(Director at a large firm, see Krogh, 2013)

Arguments for applying PBL principles and methodologies

Societal changes have had an impact on labour markets with regard to types of jobs, production technologies, company structures and industrial dynamics. Workplaces have become more complex and unpredictable, technologically and in terms of knowledge, qualifications, competencies, values and attitudes among employers and employees. It has been explained as a shift from the industrial society to the information society, the knowledge society, and even to the learning economy and

society (Lundvall, 2008).

These tendencies influence what is required of academics in terms of professional, general and personal skills. Regardless of discipline, we see a demand for abilities in development, planning, communication, knowledge, creativity, collaboration, theoretical reflection, problem solving, ethics, action and accountability. These abilities are often referred to as 21st-century skills (e.g., Crockett, 2016). Specific requirements obviously vary considerably depending on the kind of job – academics work in universities, public administrations, consulting firms or other types of knowledge organisations. Generally speaking, so-called 21st-century skills and competencies are in high demand. As a result, higher education institutions have begun revising their teaching strategies to prepare students to meet labour market and societal demands. Referring to Bowden and Marton (1998), students must develop skills designed for a society, which develops in yet unknown directions. Based on an understanding of the role of universities, the research community, teachers and students possess the capabilities that are necessary in building up sustainable solutions for the future world's challenges.

Universities are key players and partners in the diffusion of new knowledge to society by means of research and well-educated candidates.

Understanding the relationship between universities and society is connected to the social dynamics described within the concept of the knowledge or the learning society (Lundvall, 2008). All types of jobs and other social functions within this concept must be dealt with more dynamically by individuals within a specific social context. Words such as flexibility, dynamics, human resources, quality, collaboration skills, individual and organisational learning carry particular weight. What does this mean to university education? Universities are increasingly forced to operate within the context of new management forms and new economic models. At the same time universities have to diffuse knowledge within the context of the university, characterised by significant diversity among students. The challenge is finding education strategies that will support the diversity of students in developing the relevant academic skills and competencies.

Creating and using PBL principles and methodologies at Aalborg University

Problem-based learning, project work, etc. are widely-used concepts with different meanings, integrated into varying educational designs and with different instructional goals. The original idea and theoretical foundation of the problem-oriented project work in a Danish context was formulated by Danish researcher Knud Illeris (1974) in his seminal book, *Problem orientation and participant direction: An introduction to alternative didactics*. The PBL teaching strategies at Aalborg University were developed from these original principles. Exemplarity, open curriculum, interdisciplinary and experience-based learning, peer learning, and collaborative learning in groups were important concepts (Aarup Jensen and Krogh, 2013). These concepts characterise the PBL model today at Aalborg University. They will be expanded on in the following pages.

Illeris was central to implementing PBL strategies in Denmark from the 1970s. He lists three categories of qualifications which seemed necessary for the development of society at that time: (i) skills that can be defined in direct relation to a given task or work process, (ii) general, adaptable qualifications with behaviour-based characteristics (e.g., diligence, perseverance, vigilance etc.) – combined with a willingness to apply these characteristics to work and existing work processes, (iii) creative/innovative qualifications that may be divided into qualifications for scientific, innovative work and qualifications for continuous renewal and the ability to collaborate (Illeris, pp. 32–35). Referring to Piaget's theory of learning, Illeris explains accommodative learning processes as a prerequisite for creativity. From this point of departure, he describes an expedient learning process

that allows for the development of skills, adaptive ability and creativity in a process that alternates between accommodative processes (the creation of new cognitive structures) and assimilative processes (the incorporation of new material in an individual's existing structures). Such alternating processes are a precondition of a student's ability to acquire holistic competencies that comprise skills, an adaptive ability and creative qualifications, which according to Illeris' analysis were needed by society at that time, and still are (Illeris, pp. 76-77).

Illeris developed these ideas further to an alternative didactic concept – problem-oriented project work, characterised by the following principles:

- **Problem orientation**, which means that the point of departure for the students is the subject-related knowledge, methods and theories relevant to the specific problem rather than a narrow discipline-bound theme or task. Consequently, inter-disciplinarity becomes a core principle.

- **Participant direction**, which means that the students define the problems (the research questions) and choose the work methods.

These are important principles setting out accommodative learning processes, which are necessary for developing creativity and flexibility. However, if teachers or the educational system determine which problems should be the point of departure and how students are supposed to work with problems, traditional borders between disciplines may be crossed, but new political agendas delineate and constrict in the same way as old ones and hinder students' accommodative learning processes (Illeris, 1982).

The chosen research questions must and should be experienced by the individual student to ensure accommodative learning processes occur, which depend on commitment. Accommodative learning processes are demanding and will only happen when an individual student takes ownership of a situation and feels they have something at stake. Otherwise, the student will either dismiss the problem or simply assimilate it, i.e., integrate it into already established cognitive structures. (Illeris, pp. 82-83). The principles are:

- Exemplarity: This means working with the important and representative aspects, exemplifying the area of the discipline in question. Transferable skills will be developed.

- Group work: Students collaborate in groups on problem solving to learn the difficult art of collaboration and project leadership.

The work process in practice

Ideally, problem-based project work will go through the following phases:

- Selection of the theme and initial problem raising

- Project development (the term 'problem formulation' is often used in PBL terminology)

- Methodological reflections and decisions on how to solve the questions raised in the problem formulation

- Project work (i.e., theoretical and empirical work, perhaps involving experiments and field work)

- Production (of a project report), which sometimes involves descriptions of work processes

- Product assessment (group exam), and if necessary, product adjustment

Formative assessment and feedback from supervisors and fellow students during the semester provide valuable input in the working process. This may take place as a part of the continuous work processes and feedback from fellow students and supervisors. It can also be more formalised in debate-type seminars held on a regular basis throughout the semester.

Problem-oriented problem-based project work may be interpreted and implemented in a number of different ways depending on the educational institution, discipline, subject and learning goals. There may be varying degrees of free choice regarding the specific problem, subject area and methods, and the project work may differ in size (ECTS[1] points), i.e., the students' workload per semester. Furthermore, there may be vast differences in resources allocated to the project work in terms of hours of teacher supervision as well as study facilities (rooms) for the groups to work in.

Although the facilities and resources for project work may vary, the following model illustrates the elements which generally form part of problem-oriented project work at Aalborg University (see Fig. 2.1).
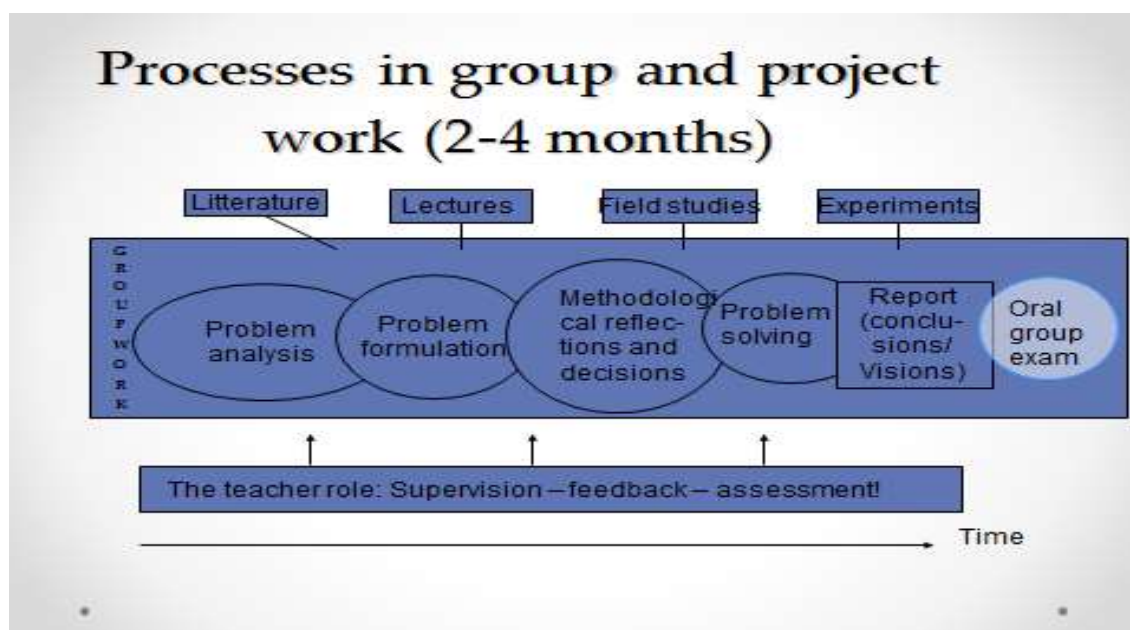

Figure 2.1. Processes and resources available for the problem-based project work at Aalborg University.

Project work is combined with lectures, seminars or laboratory work on relevant subject matters. How the study programme is actually organised depends on the learning goals, the reason for using problem-oriented project work, and recommendations put forward by a study board and professors. The aim is for all sources and methodologies to support the students in their working processes and in developing the relevant knowledge and skills. Students' work is facilitated by the university professors who supervise them and their project work. Generally, students are expected to work in groups of three to six people during the first year of study, although in later years they may work in groups of two to three. Individual project study is accepted, but students are told that this minimises opportunities for peer learning and getting feedback from supervisors.

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[1] European Credit Transfer System

Fig. 2.2 shows the distribution of project work and other course activities.
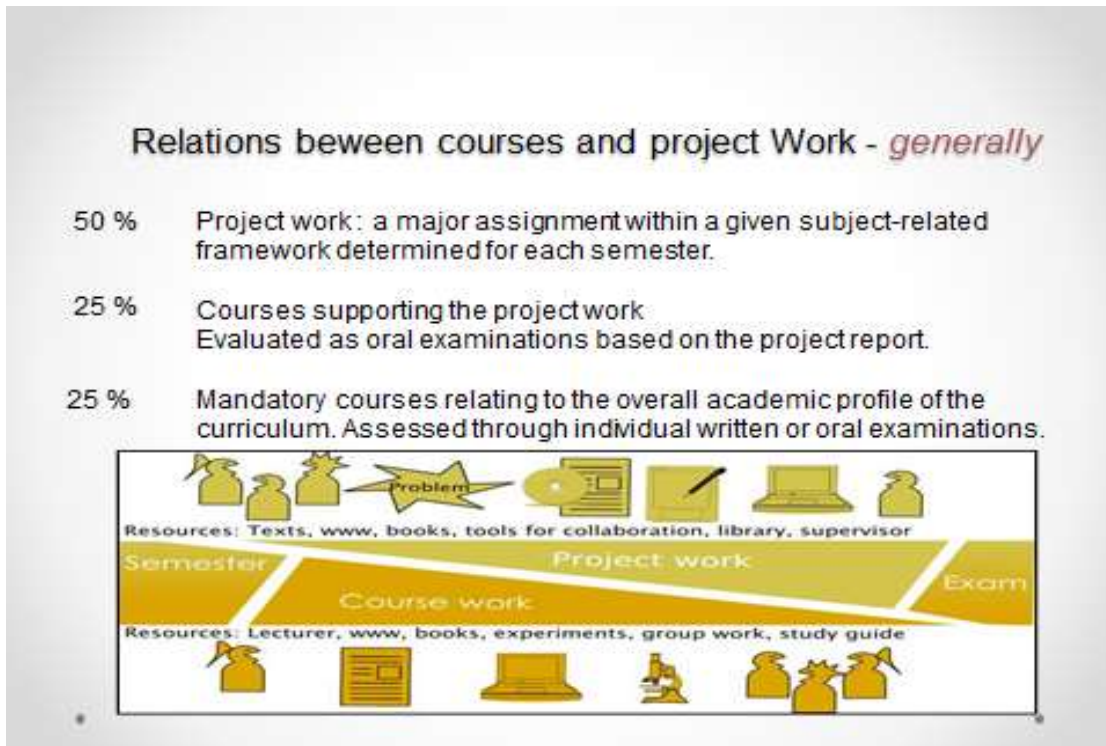

Figure 2.2. General distribution of project work and other course activities.

Project work can take a number of forms based on the different disciplines, needs and practices; however, they all share the core PBL principles such as problem orientation, student direction, exemplarity, group work, interdisciplinary cooperation, a group exam and professors as supervisor/facilitator.

At the end of a semester, students finalise their project work with an oral group exam, where all students are present and with the supervisor (professor) and an external censor as discussants. During the exam the students present the problems they have been working, their results and the theories and methodologies they applied. The students are assessed individually based on the joint product and their behaviour during the exam. The more students in the group, the longer the assessment time must be. Because of the duration of the exam, the students have an opportunity to document extensive and complex knowledge in depth within the professional field in question. The assessment is based on a written project the student group worked on during the two to three prior months. During the work process, students regularly receive formative feedback from their supervisor and fellow students.

The professor as supervisor and examiner

As mentioned previously, each group is assigned a supervisor who helps, challenges, supervises, advises and discusses the work with the students before assessing them. The supervisor's assistance is, however, particularly important at certain times, such as when selecting and formulating problems, supporting methodological reflections and decisions, and facilitating and providing formative feedback during the working process. Finally, the supervisor must be knowledgeable about the formal requirements and explain to the students how exams will take place to ensure valid assessments of each individual student.

Documentation of the relevance of a PBL approach

Aalborg University has for many years produced research to describe, evaluate and explore the PBL-principles and methodology, (e.g., Adolphsen & Quist, 1995; Jæger, 1992; Kolmos & Rasmussen, 1994; Olsen, 1995). Some of the more recent work includes two substantial surveys conducted in 2003 and 2009 involving graduates and employers and investigating the connections between the Aalborg PBL model, students' development of qualifications and competencies and expectations from national and international workplaces (www.cand.aau.dk, Krogh, 2013). Overall, the studies showed that the candidates generally meet future employers' expectations in terms of skills.

The experience at Aalborg University is a reflection of what is going on in society as well as new expectations for a more highly educated population and how universities can support people's aspirations and hopes for the future. A changing perception that universities are no longer just for the intellectual elite has had significant consequences. The so-called 'mass university' came with large student numbers from diverse backgrounds (socially and culturally), putting high demands on increased supervision and guidance from professors. There is a need for more physical space, while cultural challenges and special needs for international students must be considered. As international mobility increases, universities must also understand the needs of foreign academic staff. For a university like Aalborg University, this means explaining and teaching them how to apply PBL methodologies to university teaching.

The international society and the Danish government place expectations on universities regarding practices related to internationalisation and the Bologna process. A framework for qualifications,

described as employability, mobility and lifelong learning is being implemented (http://ec.europa.eu/education/policy/higher-education/bologna-process_en). This framework outlines expectations on flexibility and transparency in all aspects of educational programmes, which has made it necessary to focus more on leaders' and teachers' abilities in handling challenges. We see students from a range of backgrounds with various ambitions in terms of their studies. In fact, the challenge lies in creating learning environments and methods that meet and match expectations from society and workplaces with students' backgrounds and expectations. Documentation from surveys and experience sharing over the years has shown that the principles and methodologies, as reflected in the Aalborg PBL methodology, could be a successful way to handle many of these challenges.

Conclusions

Developing and implementing PBL principles and methodologies at Danish universities has not been an easy process. Traditional thinking and existing teaching ideologies within the university culture and society have been both platforms and drivers for changes. However, this does not mean that teaching has not changed at the universities over the years – on the contrary there is considerable development underway within many Danish universities.

The reason PBL principles and methodologies were implemented at Aalborg University is that the development took place as a new university, without a history, was established, with new buildings, new staff and new researchers. They strongly believed in problem-oriented methodologies as ways of initiating and supporting the development of academics who would be a part of the future society and workplaces. It should be emphasised that the university was formed and specifically built on the principles of problem-orientation and group work and with professors functioning in new roles – as supervisors.

The way the problem-oriented approach works at the university is very much based on values and understandings of Danish society and its expectations. If PBL principles and methodologies are to be implemented in another educational culture, the specific educational context must be taken into consideration, as well as the possibilities and the challenges that may lie deep within cultures in the different subject areas. The process takes time, and each university must develop their own approach based on the basic PBL principles.

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