Deliverable 1.1

PBL Analysis

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**Abstract:**

This document presents the analysis of the PBL strategy and its steps. More specifically, this deliverable begins with a description and discussion of the learning principles of PBL. The deliverable also presents the Aalborg PBL Model, which is shaped around problem-orientation, project work, inter-disciplinarily, and participant controlled learning. The nine principles of this model are initially presented and specific implementation details are discussed. Furthermore, the deliverable describes in details the phases and the learning activities taking place in project work in the AAU PBL Model. Such considerations are important for understanding the data generated and the communication taking place during this process. The deliverable concludes with a discussion of learning resources and web tools currently used in the different phases of the Aalborg Model.
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| Problem-Based Learning (PBL), PBL models, Learning Resources and Tools, Assessment in PBL, The Aalborg PBL Model |  |
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List of Abbreviations

The following table presents the acronyms used in the deliverable in alphabetical order.

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<td>LA</td>
<td>Learning Analytics</td>
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<tr>
<td>LS</td>
<td>Learning Semantics</td>
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<tr>
<td>MOOC</td>
<td>Massive Open Online Course</td>
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<tr>
<td>PBL</td>
<td>Problem (or Project) Based Learning</td>
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<td>Work Package</td>
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Executive Summary

The overall aim of the PBL3.0 project is to enhance Problem Based Learning (PBL) with Learning Analytics (LA) and Learning Semantics (LS) in order to produce a new educational paradigm and pilot it to produce relevant policy recommendations.

WP1 is responsible for the needs analysis of the project, providing state-of-the-art input on the PBL strategy as well as the LA field that will guide the cooperation project in finally constructing the PBL3.0 educational approach. In particular, it aims to:

- Identify all educational data that is generated for each step of the PBL strategy.
- Analyse processes and techniques that transform educational data to meaningful, multi-modal information.
- Identify all intervention mechanisms that could be put into practice based on all LA feedback during course design and course execution.
- Construct the PBL_LA educational approach.

The present deliverable is the first deliverable of WP1, D1.1 – PBL Analysis. Its purpose is to present all the work done towards the analysis of PBL and its steps. It also discusses all the derived information to deduce how the PBL strategy can be transformed into a new educational paradigm with combination of LA and LS. Information that is included in this deliverable is valuable to all partners for ensuring the appropriate development of the PBL_LA educational approach and the LA modules that will be employed in the pilots.

More specifically, this deliverable begins with a description and discussion of the learning principles of PBL. However, PBL is a generic pedagogy that can be implemented in many different ways. For this reason, this deliverable presents some PBL models, which can be used for the adaptation of this generic pedagogy in local institutional contexts and for the classification of different degrees of PBL. While discussing these models, the student learning and assessment in PBL are also presented. Moreover, the course and the institutional approach in PBL are defined.

The deliverable also presents the Aalborg PBL Model, which is shaped around problem-orientation, project work, inter-disciplinarily, and participant controlled learning. First of all, the nine principles of this model are presented and specific implementation details are discussed. A broad discussion of the PBL curriculum of this model is provided, in order for the reader to understand project and course student work and process. Special consideration is given to the way learning objectives are described in this model’s curricula and a taxonomy is proposed for classifying such learning objectives. Student and teacher collaboration and student assessment in the Aalborg Model are also discussed.

Furthermore, this deliverable provides a detailed description and discussion of the phases and the learning activities taking place in project work in the AAU PBL Model. Such considerations are important for understanding the data generated and the communication taking place during this
process. This deliverable concludes with a discussion of learning resources and web tools currently used in the different phases of the Aalborg Model.
1 Introduction

The aim of this section is to introduce the background of the work pursued with Task 1.1 “PBL analysis”. The scope and the objective that the current document has set out to achieve are presented in sub-section 1.1. The intended audience for this document is described in sub-section 1.2 while sub-section 1.3 outlines the structure of the rest of the document.

1.1 Scope

The present document is the Deliverable 1.1 “PBL Analysis” (henceforth referred to as D1.1) of the PBL3.0 project. The main objective of D1.1 is to present all the work done towards the analysis of PBL and its steps and to discuss all the derived information to deduce how the PBL strategy can be transformed into a new educational paradigm with combination of LA and LS. These results will feed into the development of the PBL_LA educational approach and will guide the identification, configuration and application of LA tools in the project’s pilots.

1.2 Audience

The intended audience for this document is the PBL3.0 consortium, the European Commission, and the public interested in investigating the PBL domain.

1.3 Structure

The structure of the document is as follows:

- Section 2 discusses the PBL approach and its learning principles of PBL, and presents some PBL models, which can be used for the adaptation of this generic pedagogy in local institutional contexts and for the classification of different degrees of PBL.

- Section 3 presents the Aalborg PBL Model and its nine principles. It also discusses the PBL curriculum of this model, the description of its learning objectives and the differences between courses and project work.

- Section 4 provides a detailed description and discussion of the phases and the learning activities taking place in project work in the AAU PBL Model. It concludes with a discussion of learning resources and web tools currently used in the different phases of the Aalborg Model.

- Section 5 presents other PBL models as identified by the literature review.

- Section 6 presents the adoption of PBL in non-traditional settings.

- Section 7 concludes the document.
2 The Problem-Based Learning Approach

PBL is a student-centred pedagogy in which students learn through the experience of problem solving (Neville, 2009). Learning begins with a problem to be solved, posed in such a way that students need to gain new knowledge before they can solve the problem, and thereby learn both thinking strategies and domain knowledge. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation (Hmelo-Silver, 2004).

PBL represents also a paradigm shift from traditional classroom/lecture teaching. The role of the instructor in PBL (known as the tutor) is to facilitate learning by supporting, guiding, and monitoring the learning process. The tutor must build students' confidence to take on the problem, and encourage the students, while also stretch their understanding. Therefore, the role of the teacher is to guide and challenge the learning process rather than strictly provide knowledge.

PBL supports group work. Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. This procedure enhances content knowledge while simultaneously fosters the development of communication, problem-solving, critical thinking, collaboration, and self-directed learning skills. PBL may position students in a simulated real world working and professional context which involves policy, process, and ethical problems that will need to be understood and resolved to some outcome. By working through a combination of learning strategies to discover the nature of a problem, understanding the constraints and options to its resolution, defining the input variables, and understanding the viewpoints involved, students learn to negotiate the complex sociological nature of the problem and how competing resolutions may inform decision-making.

PBL was first introduced in the medical school program at McMaster University in Hamilton, Ontario, Canada in the late 1960s (Neville, 2009). Since then, various universities and other educational institutes have adopted PBL as a model of teaching and learning. From such local adaptations, various PBL models have arisen. Although the pedagogical models were used in many different subject fields, they have become most famous in the medicine and engineering models (Kolmos, 2008). Therefore, PBL covers presently a wide range of practices, which might sometimes be difficult to compare (Du, de Graaff, & Kolmos, 2009). For example, PBL is also used as an abbreviation for project-based learning that derives from the project-organised and problem-oriented practices in Europe. Therefore, it is important to stress that the notion of PBL represents a learning philosophy rather than organisational details and goes beyond curriculum change. This learning philosophy includes a cultural change and fosters new epistemologies in the creation of knowledge and innovation.

2.1 PBL Learning Principles

As more and more institutions adopted PBL, the cultural dimension became important. Different local institutions, different fields and practical conditions create barriers in transferring PBL models from one institution to another. As an attempt to reflect on the differences between PBL models and
describe PBL independently from local adaptations, Graaff and Kolmos (2007) developed a list of common PBL principles. Although there are differences among concrete PBL models, Graaff and Kolmos found that there are common learning principles that cross such models, which can be captured in three approaches: cognitive learning, contents and social (Figure 2-1).

The cognitive learning approach supports learning organized around problems and carried out in projects. In this approach, a problem constitutes the starting point for the learning process and provides a context for learning. Moreover, it attaches learning to learner’s experience and contributes to increased motivation. In this approach, learning is also project-based, meaning that it involves more complex problem analyses and problem-solving strategies, and that there is a timeframe for completing the project and consequently the learning process.

![Figure 2-1. PBL learning principles - taken from (Kolmos, De Graaff, & Du, 2009)](image)

The contents approach is related with interdisciplinary learning. Such learning may span across traditional subject-related boarders and methods. This approach supports exemplary practice since “...the learning outcome is exemplary to the overall objectives of the curriculum” (Kolmos & De Graaff, 2007). In this approach, theory is used for the analysis of problems and problem-solving methods. Therefore, the learning process involves an analytical process, which combines theory and practice. Learners in this process are furthermore trained in applying various research methodologies.

The social approach concerns team-based learning. In team-based learning, the learning process has social aspects and takes place through dialogue and communication (Kolmos & De Graaff, 2007). Team-based learning also enhances content knowledge while simultaneously fosters the development of communication, problem-solving, critical thinking, collaboration, and self-directed
learning skills. The social approach also contains the concept of participant directed learning, where there is a collective ownership of the learning process and, especially, the formulation of the problem.

These learning principles are generic guidelines that allow for development of different PBL models for different institutions. Such variations may reflect differences in educational, cultural, social, economic or political aspects. However, these learning principles are not detailed enough to lead to specific changes in curriculum level. These changes are normally developed by theoretical understanding, trial and error, and conducting several experiments. On the contrary, the PBL core-learning principles may contribute to the formulation of strategic plans at higher institutional levels.

2.2 Degrees of PBL and PBL Models

Since the PBL learning principles are generic, they cannot be used to distinguish between approaches adopting different degrees of PBL. For example, a teacher may apply PBL in only one of her courses, while PBL can be adopted by an entire university. Such approaches might not fulfill the PBL learning principles to the same degree (Kolmos et al., 2009). Therefore, researchers have developed models or taxonomies that provide an overview of different practices in the PBL domain and increase awareness about variations of PBL.

Barrows (1986) proposed a taxonomy to facilitate awareness of differences in various PBL designs and to help teachers choose a PBL method appropriate for their students. He referred mainly to PBL in medical education and argued that such differences affect quality and the educational objectives that can be achieved. Barrows compiled the following list of the most important educational objectives achieved by PBL methods in medical education:

1. Structuring of knowledge for use in clinical contexts (SCC). Learning in PBL takes place in the context of future (clinical) tasks (solving future practical problems) and therefore contributes to subsequent recall and application of information (Glaser, 1984). As Barrows mentions: “Learning that is driven by challenge of practice and integrated into the reasoning required to evaluate and resolve patient problems promotes structuring of knowledge to support practice” (Barrows, 1986).

2. The development of an effective clinical reasoning process (CRP). PBL may also contribute to the development of clinical reasoning process, since it employs feature problem simulations, where problem-solving skills are developed (Feltovich, Johnson, Moller, & Swanson, 1984).

3. The development of effective self-directed learning skills (SDL). PBL promotes the development of self-assessment skills by introducing students to self-directed learning. This allows students to become sensitive to personal learning needs.

4. Increased motivation for learning (MOT). The relevance of student work with future professional practice and the challenge of solving problems may increase motivation for learning.
Barrows’ taxonomy identified if and to which degree these objectives (SCC, CRP, SDL, MOT) are addressed in the design or the execution of various methods referred to as PBL. Barrows used a score of 0–5 to indicate how much each particular objective is addressed in each PBL method (Figure 2-2). This taxonomy categorizes PBL practice in the following varieties:

- **Lecture-based cases**: When cases are presented by teachers during lectures in order to demonstrate the relevance of the information provided in the lecture. Barrows argued that although this method is referred to as PBL, it does not directly foster any of the objectives.

  ![Figure 2-2. Problem-based learning method varieties as seen in (Barrows, 1986). SCC = Structuring of knowledge for use in clinical contexts, CRP = The developing of an effective clinical reasoning process, SDL = The development of effective self-directed learning skills, MOT = Increased motivation for learning](image)

- **Case-based lectures**: In this method, cases are presented before lectures to highlight material to be covered in the lectures. Barrows mentioned that in case-based lectures there is some clinical reasoning involved but no self-directed learning, unless curious student study other resources to understand the cases better.

- **Case method**: Students have to study a complete case in preparation for subsequent class discussion. These discussions are facilitated by the teacher, who acts more as a tutor. According to Barrows, this method highly contributes to SDL since it combines both student-directed and teacher-directed learning and it increases motivation.

- **Modified case-based**: In this method, problem formats are employed in small tutorial groups and students have to decide on inquiry actions. Barrows mentioned that self-directed learning is addressed directly in this method, which is highly motivating.
Problem-based: This method involves simulation formats that allow for free inquiry (Distlehorst & Barrows, 1982). Students take part in an active, teacher-guided exploration and evaluation of a problem, which directly activates the student's prior knowledge for review and association with new learning.

Closed loop or reiterative problem-based: This is an extension of the problem-based method, where students are asked to reflect on their resources and reconsider their approach to the problem, after an episode of self-directed study is completed. As Barrows notes, these steps further address CRP, SCC and SDL as students go beyond the acquisition of new knowledge and see its value (Barrows, 1994). As a result of this second problem analysis, another round of self-directed learning may be needed.

Barrows taxonomy focuses on how cases from the professional world can be used in education in order to promote reflection and self-directed learning in a PBL context. However, this taxonomy discusses methods on the course level and does not address the institutional level. Moreover, it does not cover approaches where students are allowed to define their own problems (cases) instead of being given predefined ones (Kolmos et al., 2009).

Savin-Baden (2000; 2007) proposed five models of PBL considering six different dimensions, namely the perception of knowledge, learning, problems, students, the teacher roles, and the assessment. These dimensions stress the fact that implementing PBL is not only a change of the learning methodology but instead a combination of a learning methodology, knowledge construction and scientific approach. Therefore, PBL has also an impact on the scientific approach, since student learners are being trained to use research methodologies and question the propositional knowledge derived from academia (Kolmos et al., 2009). While students analyse and solve problems, they combine theories and practice and they develop theoretical and analytical understanding across existing knowledge boundaries.

Savin-Baden’s models of PBL practice start by considering the epistemology of the problem and according to the description in (De Graaff & Kolmos, 2007), they are the following (Figure 2-3):

- Model I: PBL for Epistemological Competence, where knowledge is more or less propositional with a narrow problem scenario.
- Model II: PBL for Professional Action, where knowledge is practical and performance-oriented and the problem scenario is characterized by real life situations.
- Model III: PBL for Interdisciplinary Understanding where knowledge is propositional, performance-oriented, and practical and the problem scenario is centred on a situation in which a combination of theory and practice occurs.
- Model IV: PBL for Trans-disciplinary learning, where the aim is to test given knowledge and the problem scenario is characterized by dilemmas of different kind.
- Model V: PBL for Critical Contestability, where knowledge might be contingent, contextual, and constructed by the learner for given situations, and the problem scenario is open and offers multidimensional possibilities.
As Kolmos et al. (2009) mentioned, Savin-Baden’s models are rather comprehensive and encompass indirectly an alignment of the various elements in the model if we compare them with Barrows taxonomy. These models stress that it is not possible to have for instance open-ended problems that
address knowledge objectives such as propositional knowledge. The learning objectives have thus to be aligned with the correct types of problems, learning processes, as well as facilitator roles and assessments.

In the literature, there are researchers who differentiate between problem-based and project-based learning (Prince & Felder, 2006). Such differentiations are based on the assumption that problem-based learning is defined by open-ended and ill-structured problems that provide a context for learning, while project-based learning is interpreted in terms of an assignment or task that the students have to perform (De Graaff & Kolmos, 2007). However, a project is a complex task requiring more resources than a single person is able to deliver and thus is more than just one task or assignment (Kolmos, 1996). Therefore, it is mainly the context in which the assignment is presented to the students that supports or not the distinction between problem- and project-based learning. Merging the characteristics of PBL and project learning, Graff and Kolmos suggested a different distinction between different approaches to project in PBL, which was based on varying degrees of self-direction by the students (De Graaf & Kolmos, 2003; Kolmos, 1996):

- The Task project is a large task to be solved, since it is characterized by a very high degree of planning and direction on the part of the teacher. Both the problem and the subject-oriented methods are chosen in advance, so that the students’ primary concern is to complete the project according to the guidelines provided.

- The Discipline project is often characterized by a rather high degree of direction from the teacher’s side (study programme requirements), since the disciplines and the subject area are chosen by the teacher. Nevertheless, the students may still be allowed to identify and define the problem formulations within the guidelines contained in the theme descriptions.

- The Problem project, finally, is a full-scale project, where the course of action is not planned in detail by teachers. The problem formulation arises from the problem-oriented theme and directs the choice of disciplines and subject area methods. This means that different students can actually work with widely different disciplines and subject methods.

The aforementioned models discuss different degrees of applying PBL in specific courses and discuss the fact that problem-based and project-based learning may vary to a certain degree. PBL adopters are then invited to develop mixed models for specific local contexts. For facilitating adaptations of PBL in different contexts, Kolmos et al. (2009) have developed a model for PBL alignment, which is presented in the following section.

### 2.3 Course or System Approach in PBL

While discussing Barrows taxonomy in the previous section, we have addressed the difference between the course and the system approach in PBL. Kolmos et al. (2009) have discussed both approaches (Figure 2-4).

As Kolmos et al. (2009) suggested, the course approach is typically used in discipline and teacher-controlled PBL approaches, where there are courses implementing PBL in parallel. In this case, teachers decide on the specific learning objectives, and the teaching and learning methods. This
means that students may participate in several parallel courses, which implement PBL in different degrees, and at the same time attend other traditional courses. The course approach is not coordinated at the system/institutional level, so teachers provide individual PBL guidelines and introductions.

The institutional or system approach involves the formulation of a common vision for the institutional system together with a quality development system that supports the enhancement and efficiency of the PBL curriculum (Kolmos et al., 2009). The system approach is a much more organised approach, since teachers of various courses must coordinate the objectives, the content that is taught, the type of project that the students are working on and the assessment of the courses and the projects. Therefore, a process of change at the systemic level is required in order to get to this level, which involves the training of academic staff (De Graaff & Bouhuijs, 1993; De Graaff & Kolmos, 2007; Kolmos, Du, Dahms, & Qvist, 2008). This approach allows alignment of more student-centred learning.

### 2.4 Student Learning in PBL

Problem-based approaches to learning are inspired by experience-based education, which has been proved to foster both content and thinking strategies among learners. In PBL, student learning starts with a complex problem that does not have a single correct answer. Students collaborate in groups to identify what they need to learn in order to solve a problem. Then, they apply their new
knowledge to the problem and reflect on what they learned and the effectiveness of the strategies they employed. In this context, the teacher acts as the facilitator of the learning process rather than as a tutor.

Researchers have discussed several benefits for students in PBL environments. Hmelo-Silver (2004) mentioned that PBL helps students develop: 1) flexible knowledge, 2) effective problem-solving skills, 3) self-directed learning skills, 4) effective collaboration skills, and 5) intrinsic motivation. She then discussed the nature of learning in PBL and examined the empirical evidence supporting it. She concluded that there is considerable research on the first three goals of PBL but little on the last two and she suggested that PBL is an instructional approach that offers the potential to help students develop flexible understanding and lifelong learning skills.

Neville (2009) reviewed the literature on PBL and discussed positive (Norman & Schmidt, 1992) and negative (Kirschner, Sweller, & Clark, 2006) views on the cognitive foundation of a PBL approach. He summarized the reported cognitive attributes of PBL conducive to improving learning in the following list:

- Knowledge acquired in relevant context is better remembered
- Concepts are acquired in a way that they can be mobilized to solve/view similar problems
- Acquisition over time of ‘prior examples’ facilitates pattern recognition
- Promotion by PBL of prior-knowledge activation facilitates processing of new information
- Elaboration of knowledge occurs at the time of learning
- Provision of similarity of context for knowledge acquisition and subsequent application also facilitates recall

However, Neville reviewed opinions from other researchers, who doubted that the relatively unstructured approach to instruction embodied in PBL adequately takes account of the characteristics of working memory, long-term memory or the intricate relations between them. He compiled the following aspects of PBL argued to be detrimental to learning:

- Problem-based searching (e.g. of a tutorial case) places a load on working memory
- Working memory cannot “problem solve” and be used to learn at the same time
- The process of learning how to practise medicine and actually practising are cognitively different

Neville concluded that there is evidence in the literature that graduates of PBL curricula demonstrate equivalent or superior professional competencies compared with graduates of more traditional curricula.

Kolmos et al. (2009) suggested that students’ attitude, experience and skills in a PBL curriculum are important to address and it is necessary to establish supporting courses on group work, such as collaboration, team work, and project management. Since students have often only experienced individual learning, they do not know how to handle more collective and collaborative knowledge
processes. Therefore, Kolmos et al. proposed that such aspects of learning are addressed in the curriculum, in order to facilitate the learning process and develop awareness of the importance of these types of skills. Otherwise, students, who do not know how to do handle this learning process, might develop a negative attitude or fight to learn.

Furthermore, Kolmos et al. pointed out that part of students’ attitude is also based on their approach to learning. They mention that in one extreme, students may expect to be told what to do by teachers in order to acquire knowledge while in the other extreme students may expect to construct their own collaborative knowledge through a process of innovation (Nielsen, Du, & Kolmos, 2008). In terms of collaboration, on one hand they may collaborate for the purpose of acquiring individual knowledge or on the other hand they may collaborate for the purpose of constructing collective knowledge. They concluded that it is important for PBL curricula to align the elements of students’ learning with the curriculum objectives and notion of knowledge.

2.5 Assessment in PBL

Assessment methods in education must be compatible with the objectives of the learning process (De Graaf & Kolmos, 2003). As De Graaff and Kolmos (2003) suggested, in PBL this means progress testing to establish the individual's knowledge and testing for competence rather than for isolated factual knowledge (Vleuten, Norman, & Graaff, 1991). As we saw in the previous section, different PBL models organise the didactic elements quite differently, allowing for variation within the general framework. However, De Graaf and Kolmos mentioned that there are limits to this flexibility and they added that it is not enough to simply change the educational format within the framework of ordinary class teaching. They highlight that changes in the educational format must be consistent with the form of the examinations or with the principles of material selection. Otherwise, the students will soon figure out the “examination code” and isolate that as a learning goal instead of completing the PBL process (Verwijnen et al., 1982).

PBL promotes learning in groups, which is a process that involves a whole range of activities very much intertwined. Although group work is assumed to have positive effects on student learning, experiences from educational practice indicate that it can also introduce problems for both students and teachers, such as students who only maintain an appearance of being actively involved and students who let others do the work, also called free riders (Salomon & Globerson, 1989). Assessment protocols within PBL curricula have therefore sought to include peer assessment, in which students contribute to the evaluation of each other’s work, in order to match evaluation procedures with the curricular philosophy (Papinczak, Young, & Groves, 2007).

Peer assessment may help to develop the acquisition of self-directed learning skills (a key objective of PBL) as students participate in the assessment experience (Ballantyne, Hughes, & Mylonas, 2002). Papinczak et al. suggested that since PBL emphasizes the development of proficiency in the resolution of problems, the assessment of student skills, processes and attitudes would take place most appropriately within the tutorial setting (Eva, 2001). They mentioned several advantages to employing tutorial-based peer assessment, including: prolonged interaction between peers for provision of constructive feedback based on multiple observations of performance; and opportunity
to assess areas of proficiency (such as communication skills, self-directed learning, and respect for others) not readily evaluated by more traditional forms of assessment.

Their results indicated the existence of six main themes when peer assessment is adopted in a PBL setting, namely:

1) increased responsibility for others,
2) improved learning,
3) lack of relevancy,
4) challenges,
5) discomfort, and
6) effects on the PBL process.

The final theme represented a unique, although not unexpected, finding. Students who participated in this study expressed serious concerns about the negative impact of peer assessment on the cooperative, non-judgmental atmosphere of PBL tutorial groups.

In Du et al. (2009), Holgaard and Kolmos presented results from a research project on comparing individual and group assessments. They pointed out that different assessment methods assess different types of knowledge and skills, and they argued that the assessment methods chosen to assess PBL are drivers for students’ learning among other things. Students’ ownership and participation in the democratic curriculum processes are important and this goes along with students’ participation in curriculum evaluation. Finally, they highlighted that if educators are to encourage students to do innovative and highly integrated team projects, the assessment systems need to match the learning activity.

Hersam et al. (2004) employed peer assessment in a PBL an engineering course. Peer assessment was employed in order to simulate working environments, where professionals are asked to evaluate one another through peer review. Group work was assigned in place of homework and peer assessment was used in order for the students to evaluate group activities and the final project. They found that students engaged in substantial and meaningful peer assessment and they expressed enthusiasm for the assigned group activities, which were evaluated solely by peer assessment.

Gijbels et al. (2005) conducted a meta-analysis, which investigated the influence of assessment on the reported effects of problem-based learning (PBL) by applying Sugrue’s (1995) model of cognitive components of problem solving. They used three levels of the knowledge structure that can be targeted by assessment of problem solving as the main independent variables: 1) understanding of concepts, 2) understanding of the principles that link concepts, and 3) linking of concepts and principles to conditions and procedures for application. Gijbels et al. found that PBL had the most positive effects when the focal constructs being assessed were at the second level of understanding principles that link concepts. The results suggested that the implications of assessment must be considered in examining the effects of problem-based learning and probably in all comparative education research.
One of the greatest potentials for PBL is that it calls for authentic assessment. When projects or problems are well and accurately designed, they target specific skills, knowledge and competencies, which students need to acquire. Continuous assessment throughout a PBL project is also important, since teachers have to ensure their students are getting the content knowledge and skills that they need to complete the project. Therefore, teachers may track and monitor ongoing formative assessments that show work toward the learning objectives (Sadler, 1989). In addition, formative assessments can be used to give meaningful feedback to students and specific ways to improve. Finally, when summative assessments are relevant, inquiry-based and engaging, then formative assessments become relevant to students.
3 The Aalborg PBL Model of Aalborg University, Denmark

3.1 Principles

In Aalborg University, Denmark, all university programs have been based on PBL, also referred to as “PBL - The Aalborg model” (Barge, 2010; Kjærsdam & Enemark, 1994). When establishing the AAU in 1974, a redeveloped approach to the traditional PBL had already emerged, and the ideals in this involved providing students with an active, participative role, and high degree of engagement in the creation of knowledge, both in lectures and as part of group-based project work. The PBL - Aalborg Model has become both nationally and internationally recognized and a trademark for Aalborg University.

Barge (2010) identified and described nine principles that define the combined key dimensions of AAU’s pedagogical model in practice:

1. **Educational vision**. The institution has developed and adopted a systematic framework for the problem and project based approach to education. The systematic framework informs the development of degree requirements, courses and the pedagogical approaches of faculty members.

2. **Curriculum**. The problem and project based centered approach shapes the institution’s program curricula, which provide for student orientation to the pedagogical method, explicitly link theory and practice, are appropriately adapted to disciplinary paradigms, and are anchored by clearly articulated educational objectives.

3. **Students**. Students understand the problem and project based educational model and, through that understanding, are able to successfully engage it in order to achieve the institution’s educational objectives. In their work, students maintain an institutional culture of authentic collaboration, self-motivation, peer-learning, and personal responsibility. The institution supports students in this regard through orientation and the provision of appropriate services.

4. **Faculty**. Faculty members understand and are committed to the problem and project based educational model. The institution ensures that faculty members are appropriately introduced to and understand the model’s theoretical framework and are able to handle the best practices by which it is implemented in the curricula and pedagogically. As supervisors, faculty members are directly involved in the project-related work of the students. Faculty members hold primary responsibility for continuously adapting and developing the model to the institution’s particular educational and disciplinary context, ensuring integrity of implementation, and guiding its development.

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1 Descriptions taken from (Barge, 2010)
5. **Assessment.** The institution is committed to assessing and evaluating both student performance and program effectiveness. Policies and structures are in place to effectively assess individual student performance within the context of the group project work. A parallel set of policies and structures guide the assessment of students’ performance in individual academic work (e.g. study courses). Program effectiveness is subject to formative and summative assessment and evaluation processes that involve faculty members, students and administrators as appropriate. There are clearly demonstrated links between program assessment and efforts to improve existing programs and develop new programs.

6. **Resources.** The institution acquires and deploys resources in ways that consistently support the problem and project based educational approach. In particular, adequate physical space for student project groups is provided. Library and technological resources provide current and comprehensive access to information and systems that enable students to achieve the institution’s educational objectives.

7. **Programme administration.** The institution has adopted an organizational configuration and established administrative structures that facilitate the effective implementation of the problem and project based educational approach.

8. **External relations.** The institution maintains active relationships with key external organizations that support the effective implementation of the problem and project based model. Administrative support is provided to faculty members and students to facilitate and manage their connections with external contacts such as businesses, social agencies, governmental agencies, foundations, and other academic institutions. These external contacts stand as a source for student problem formulations and project work, and the institution’s research and project work benefit from these external organizations.

9. **Educational research.** The institution conducts ongoing educational research into the implementation, adaptation and outcomes of the problem and project based educational model. Linked closely to assessment efforts, this expanding body of research is a means of documenting and disseminating local adaptations and innovations.

The principles of the Aalborg PBL Model are by no means static or contextually isolated but should always be interpreted in the light of the broader context in which the model is to be implemented and applied. Each of the nine principles identifies critical considerations for implementation of the Aalborg PBL Model with regard to key dimensions of the university. The nine principles, though each addressing a distinct dimension of university practice, are necessarily related. As such, an institution’s attention to considerations in one dimension will often link directly to that which addresses another consideration. If other institutions are to adopt the Aalborg PBL Model, it is important to view implementation not as a sequence of requirements to be met but rather as a transformation of the educational paradigm according to these considerations that span nearly all dimensions of the university.
In the following sections, we provide considerations for fulfillment of each principle and provide some concrete implementation examples from a Bachelor study programme at AAU, namely Medialogy.

### 3.2 Educational Vision

In implementing the Aalborg PBL Model, the institution demonstrates an ongoing commitment to its central principles: *problem orientation, project organization, integration of theory and practice, participant direction, a team-based approach, collaboration and feedback* (Barge, 2010):

- **Problem orientation:** Problems/wonderings appropriate to the study program serve as the basis for the learning process.
- **Project organization:** The project stands as both the means through which the students address the problem and the primary means by which students achieve the articulated educational objectives. The project is a multi-faceted and often extended sequence of tasks culminating in a final work product.
- **Integration of theory and practice:** The curriculum, instructional faculty members and project supervisors facilitate for students the process of connecting the specifics of project work to broader theoretical knowledge. Students are able to see how theories and empirical/practical knowledge interrelate.
- **Participant direction:** Students define the problem and make key decisions relevant to the successful completion of their project work.
- **Team-based approach:** A majority of students’ problem/project work is conducted in groups of three or more students.
- **Collaboration and feedback:** Students use peer and supervisor critique to improve their work; and the skills of collaboration, feedback and reflection are an important outcome of the PBL model.

### 3.3 Curriculum

The program curriculum is mapped onto academic terms (e.g. semesters) according to an appropriate progression with regard to depth and breadth of content as well as sophistication of project work. In each term, a theme is selected to serve as the context in which project courses and projects address the learning objectives. Themes may be fixed due to an overall curriculum program or vary from term to term. The theme connects to the overall learning objectives and is articulated in a formal statement that is distributed to students and guides their problem formulation and project work. Within the theme and the overall learning objectives, problems and project proposals

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are to be chosen. Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε. outlines the courses and semester project themes for each of the six semesters of the Medialogy Bachelor.

All programs include first-term credit-bearing academic work that introduces and orients students to the AAU educational model. At Medialogy, this course is called “Problem based learning in Science, Technology and Society” (Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.). This component of the curriculum addresses e.g. learning theory, problem definition, project management, conflict management, and approaches to collaborative work all within the context of the institution’s problem and project based approach. Further, the PBL orientation component provides students with highly-scaffolded project experiences to prepare them for later self-governed group work.

In each term, a number of project courses are offered, linked to the educational objectives and shaped by the term’s theme. Students select project courses according to the courses’ relevance to their term project work (Figure 3-1). Students spend approximately 50% of their time on course work and the other 50% on project work. In some programs, semesters are governed by fixed themes and therefore central theme related courses replace project courses, as for example in the Medialogy curriculum. In this case, courses are more independent and are given five ECTS points each (Kolmos & Holgaard, 2012). This semester distribution can be seen in Figure 3-2 (Buus, 2016). In both cases, the majority of project course credits are offered in the early weeks of the term, in order to facilitate timely support of students’ project work.

![Diagram](null)

*Figure 3-1. Division of a semester in project and courses. Taken from (Kolmos, Krogh, & Fink, 2004)*
### Table 1: Semester themes and courses for the Medialogy Bachelor. Note the “Problem based learning in Science, Technology and Society” course in the 1st semester.

<table>
<thead>
<tr>
<th>Semester 1: Designing from Both Sides of the Screen</th>
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<tbody>
<tr>
<td>1st</td>
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<td>1st</td>
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<td>1st</td>
</tr>
</tbody>
</table>

**Semester 2: Interaction Design – Human Computer Confluence**

| 2nd | Semester Module (15 ECTS) |
| 2nd | Mathematics for Multimedia Applications (5 ECTS) |
| 2nd | Programming for Interaction (5 ECTS) |
| 2nd | Interaction Design (5 ECTS) |

**Semester 3: Visual Computing – Human Perception**

| 3rd | Semester Module (15 ECTS) |
| 3rd | Image Processing (5 ECTS) |
| 3rd | Human Senses and Perception (5 ECTS) |
| 3rd | Programming of Complex Software Systems (5 ECTS) |

**Semester 4: Sound Computing and Sensor Technology**

| 4th | Semester Module (15 ECTS) |
| 4th | Audio Processing (5 ECTS) |
| 4th | Design and Analysis of Experiments (5 ECTS) |
| 4th | Physical Interface Design (5 ECTS) |

**Semester 5: Audio-Visual Experiments**

| 5th | Semester Module (15 ECTS) |
| 5th | Computer Graphics Programming (5 ECTS) |
| 5th | Rendering and Animation Techniques (5 ECTS) |
| 5th | Screen Media (5 ECTS) |

**Semester 6: Interactive Systems Design**

| 6th | Bachelor Project (15 ECTS) |
| 6th | Real-time Interfaces and Interactions (5 ECTS) – elective |
| 6th | Artificial Intelligence Programming (5 ECTS) – elective |
| 6th | Ethnographically Informed Design (5 ECTS) – elective |
| 6th | Theory and Practice of Game Design and Development (5 ECTS) – elective |
| 6th | Technologies for Web and Social Media (5 ECTS) – elective |
D1.1 PBL Analysis

Most literature written about the Aalborg PBL Model discusses the process of student project work (Khalid, Rongbutstsi, & Buus, 2012; Kolmos et al., 2004; Ryberg, Glud, Buus, & Georgsen, 2010). This literature relates little to the course work that also has to build on the PBL approach that underpins the AAU pedagogical model (Buus, 2016). It is actually possible to some extent to include the process of student project work in the courses, but this may be a more teacher-centered process. The ways courses at AAU follow its pedagogical model are very much teacher- and discipline-dependent and vary significantly. Buus (2016) investigated the PBL taking place in courses, and reflected on how the complex landscape of PBL practices can actually be identified.

The curriculum provides adequate means for students to establish connections between the specifics of the project courses and project work and the broader knowledge and skills of the discipline or profession. Students develop skills for management, synthesis, and construction of knowledge such that they are able to navigate, evaluate, integrate and apply knowledge not explicitly included in the curriculum. The learning involved in establishing these connections and skills are further facilitated by peer students, faculty members, supervisors and assessment activities.

3.3.1 Learning objectives

Specific learning objectives are articulated for the program and associated with each term. These objectives include both overall educational objectives linked to the problem and project based pedagogy and the specific objectives of the program. Table 2 shows the learning objectives expressed in knowledge, skills, and competencies for a semester module at the Medialogy bachelor program.
Title: Designing from Both Sides of the Screen

Prerequisites:
The students must have passed the module: Creative Play – Applied Technology

Objectives:
To provide the student with practical experience defining a project within the area of information technology, communication and new media, which includes use of programming, to implement the project by working in groups and to document the solution in a project report.

Students who complete the project module will be able to:

Knowledge
- Explain basic theory, methods and practices used in media technology that relate to the project (understanding)
- Describe basic concepts of problem-based study and the Aalborg model of PO PBL (knowledge)

Skills
- Compose a problem formulation from a larger problem area that can be answered or addressed within the scope of the project (synthesis)
- Understand how the target group from the problem formulation interacts in a real world context of use with similar media products or artifacts, which address the initial problem formulation
- Apply scientific theory and methods in a media technology oriented project and discuss basic reflections on their use in the project (analysis)
- Apply a programming language and implement parts of programs or small programs in order to solve a specific problem
- Carry out a basic evaluation of an artifact with the target user group (ideally not a convenience sample) or domain experts (application)
- Relate findings from the evaluation to a wider context (analysis) and apply knowledge from the field of Science, Technology and Society (STS) to identify relevant contextual perspectives (understanding)
- Organize and communicate the reflections and results of the problem based project work; orally, graphically and in writing – for the latter by applying a provided template or creating their own version of it (understanding)
- Organize and manage a longer-term project considering group and supervisor collaboration (application)
- Analyse the process involved in carrying out the project from a project management point of view and reflect on individual as well as group learning (analysis)

Competencies
- Use proper terminology to discuss the project and Media Technology related aspects thereof (understanding)
- Take responsibility of one’s own learning during a 2-3 month project period and generalize the gained experiences (synthesis)

Table 2. Learning objectives for the 1st semester module at Medialogy Bachelor Program.
The learning objectives in Table 2 are characterized by terms such as knowledge, analysis, synthesis, application etc. Brabrand and Dahl (2009) investigate how the formulation of such intended learning outcomes fit to the SOLO (Structure of the Observed Learning Outcome) Taxonomy (Biggs & Tang, 2007). The SOLO Taxonomy is based on the study of outcomes of academic teaching and operates with five numbered progressive levels of competencies according to the cognitive processes required to obtain them:

SOLO 1: “The Pre-Structural Level” – at this level, the student does not have any kind of understanding but uses irrelevant information and/or misses the point altogether. Scattered pieces of information may have been acquired, but they are unorganized, unstructured, and essentially void of actual content or relation to a topic or problem.

SOLO 2: “The Uni-Structural Level” – at this level, the student can deal with one single aspect and make obvious connections. The student can use terminology, recite (remember things), perform simple instructions/algorithms, paraphrase, identify, name, count, etc.

SOLO 3: “The Multi-Structural Level” - at this level, the student can deal with several aspects but these are considered independently and not in connection. Metaphorically speaking; the student sees the many trees, but not the forest. He is able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, etc.

SOLO 4: “The Relational Level” - at level four, the student may understand relations between several aspects and how they might fit together to form a whole. The understanding forms a structure and now he does see how the many trees form a forest. A student may thus have the competence to compare, relate, analyze, apply theory, explain in terms of cause and effect, etc.

SOLO 5: “The Extended Abstract Level” - at this level, which is the highest, a student may generalize structure beyond what was given, may perceive structure from many different perspectives, and transfer ideas to new areas. He may have the competence to generalize, hypothesize, criticize, theorize, etc.

SOLO describes a hierarchy where each partial construction [level] becomes a foundation on which further learning is built (Biggs, 2003). Moving up the SOLO hierarchy, quantitative improvements take place as the student becomes able to deal with first a single aspect (from 1-2) and then more aspects (from 2-3). Later, qualitative improvements take place (from 3-4) as the details integrate to form a structure. From level 4 to 5, the structure is generalized and the student can deal with information that was not given.

Figure 3-3 lists prototypical competencies from the SOLO Taxonomy. Brabrand and Dahl (2009) classified an extended list of verbs found in intended learning outcomes based on SOLO.

Learning objectives expressed as knowledge, skills, and competencies and found in curricula based on the Aalborg PBL Model can therefore be classified in the SOLO taxonomy according to the terms used in their description. To this aim, the nouns in Table 2 should be converted into verbs. This classification would help create more abstract descriptions of a program’s learning objectives, to

3 Descriptions of SOLO levels from (Brabrand & Dahl, 2009)
control the achievement of such objectives, and to compare curricula from similar studies belonging to different institutions.

### Table 3.4

<table>
<thead>
<tr>
<th>SOLO 2</th>
<th>SOLO 3</th>
<th>SOLO 4</th>
<th>SOLO 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;uni-structural&quot;:</td>
<td>&quot;multi-structural&quot;:</td>
<td>&quot;relational&quot;:</td>
<td>&quot;extended abstract&quot;:</td>
</tr>
<tr>
<td>- paraphrase</td>
<td>- combine</td>
<td>- analyze</td>
<td>- theorize</td>
</tr>
<tr>
<td>- define</td>
<td>- classify</td>
<td>- compare</td>
<td>- generalize</td>
</tr>
<tr>
<td>- identify</td>
<td>- structure</td>
<td>- contrast</td>
<td>- hypothesize</td>
</tr>
<tr>
<td>- count</td>
<td>- describe</td>
<td>- integrate</td>
<td>- predict</td>
</tr>
<tr>
<td>- name</td>
<td>- enumerate</td>
<td>- relate</td>
<td>- judge</td>
</tr>
<tr>
<td>- recite</td>
<td>- do algorithm</td>
<td>- explain causes</td>
<td>- reflect</td>
</tr>
<tr>
<td>- follow (simple) instructions</td>
<td>- apply method</td>
<td>- apply theory</td>
<td>- transfer theory</td>
</tr>
<tr>
<td>- ...</td>
<td>- ...</td>
<td>(to its domain)</td>
<td>(to new domain)</td>
</tr>
</tbody>
</table>

*Figure 3-3. Examples of verbs within SOLO 2-5 based on (Biggs, 2003). Figure taken from (Brabrand & Dahl, 2009)*

### 3.4 Students

In the Aalborg PBL Model, students are trained to identify the ways in which the problem and project based approach shapes their academic work and successfully integrate its components as they achieve the broader institutional learning objectives as well as the objectives for their program. In their work, students normally demonstrate a high level of self-motivation and personal responsibility for learning.

Regarding group project work, students are supported in developing, strong project management skills that enable the timely and successful completion of projects. With appropriate support from the institution, students learn to negotiate and successfully address the inevitable conflicts that arise in collaborative work. These abilities are developed as part of students’ orientation to the problem and project based model and are subsequently supported, as appropriate, by faculty members and administrators. Students contribute to and maintain a strong culture of collaboration, which values active participation in course and project work. Moreover, students show usually a high level of support for one another in their academic work.

### 3.5 Faculty

All faculty members are introduced, through appropriate means (e.g. orientation, staff development activities, training, mentoring, observation, etc.), to the theoretical framework behind problem and project based learning and best practices in its implementation. Introductory programs address both the broader educational goals of the model as well as the specifics of its implementation in the relevant discipline or profession.

Faculty members act as supervisors in project work. Supervisors ensure that students’ problem formulations, through alignment with the term theme and overall objectives, provide a sufficient
context for achieving the learning objectives. Moreover, they provide appropriate levels of direction in the process of advising groups (i.e. not directing student work, yet facilitating students’ progress). Supervisors and the student project group meet in a regularly basis throughout the semester and discuss the progression of the project and other issues the group needs to be solved. They might also assist student project groups in managing challenges due to the group work process, for instance problems with the collaborative process, intra-group conflict, project management, etc.

3.6 Assessment of Students

Assessment of students’ group project work is conducted in a group setting and stands as the main assessment method (Dahl & Kolmos, 2015). All group members are present for an extended examination involving the group’s supervisor, plus additional faculty members from the institution and/or faculty members from other universities, who act as censors. Examiners guiding the group assessment process have to pay careful attention to exploring not only the quality of the project work itself, but also to determining the extent to which, through the project work, students have achieved the broader learning objectives and have developed an understanding of the larger theories, concepts and issues as they transfer them to different applications. Though conducted in a group setting, students receive appropriately differentiated individual grades for their contribution to the project work and their mastery of the stated learning objectives.

Students’ project-related work (i.e. project-courses) is assessed within the context of the project work itself. The problem as formulated by the students and the subsequent project work are used by examiners as a lens for determining those aspects of the project courses that are relevant to assess. Forms of both formative (status seminars, peer evaluation, supervisor feedback, etc.) and summative assessment (portfolio assessment, etc.) may be implemented. The greater portion of assessment activity is dedicated to formative assessments, which are designed to develop students’ abilities to provide feedback to others and assess their own progress. Alignment as well as validity and reliability are to a great extend important goals. Students’ academic work (e.g. study courses) is assessed according to clearly documented policies and procedures and learning objectives. Figure 3-4 presents an excerpt from the Medialogy Bachelor study plan, where the type of assessment (e.g. graded or pass/fail exam, internal or external censors) is clearly defined for every study course and the semester project.

The institution engages students, faculty members and administrators in the assessment and evaluation of study programs. These activities take on a variety of forms (e.g. student course evaluations, group feedback sessions), and are conducted during and at the end of each term. The institution can document the incorporation of study program assessment data in the decision-making processes related to administration and improvement of existing study programs as well as the development of new study programs and procedures in relation to the context of the problem and project based model.
### 3.7 Resources

Each project group is provided with work space and all physical resources (equipment, laboratories, materials etc.) needed for the completion of the project during the academic term. Students have also access to (online) libraries, books, and technological resources. Students are free to choose the materials and resources to use for their project work. Resources and materials for courses are usually proposed by the teachers.
4 Project Work in the Aalborg PBL Model

As we discussed in the previous session, the main pedagogical principles within the Aalborg PBL Model are shaped around problem-orientation, project work, inter-disciplinarily, and self-directed controlled learning. Students dedicate 50% of each semester to an enquiry into scientific and social problems as part of their entire learning process. Students need to develop hypotheses around problems and then they need to understand and find a solution to these problems. Through this process the students go through different stages of systematic investigations: preliminary enquiries, problem formulation, theoretical and methodological considerations, investigations, experimentation and reflection. In the following sections, we present and discuss these stages.

4.1 Phases in The Process of Project Work

The process of project work can be divided in three main phases: problem analysis, problem solving, and project report (Figure 4-1).

Before analysing the problem, students have to come up with an initial problem to solve. In order to do that, they have to choose a problem area relevant for each semester and then identify how a new approach might be relevant. This is the phase where students come up with an ill-defined problem to solve. Students use various strategies to identify the problem area, such as literature review, brainstorming, interviews, etc.

During problem analysis, students conduct research in order to define the state of the art in this domain, relevant existing solutions, and argumentation for the validity of the problem. Moreover, they define the target group for their solution and their needs and they investigate technical or other possibilities, if relevant. After considering all this, they decide on the best strategy for solving the problem (design) and start thinking on an evaluation strategy for testing and reflecting on their solution. In some cases, it is relevant that students also involve their target group during their design process.
During problem solving, students engage in the process of implementing the selected strategy for solving the identified ill-defined problem. After implementing the solution, students conduct an evaluation of their solution that may contain some testing methods. The evaluation concludes with a reflective analysis of the students’ solution(s) to the identified ill-defined problem, based on the teacher’s and peers’ feedback and possibly on their test results.

The final phase is the project report, where students have to document the whole project work process in an academic report. This report covers all the aforementioned phases of students’ work during the semester.

The three main phases of project work according to the Aalborg PBL Model can be also described in terms of learning activities that take place during these phases (Figure 4-2).

Group forming takes place in the beginning of each semester. Students are free to form groups as long as all students belong to a group. The number of students in each group depends on the program and the semester. For group forming, all students in one semester gather in one room together with the semester coordinator (faculty). The students are not allowed to leave this room, until all students have found a group. Students are allowed to make arrangements before group forming but they have to be present on the day of group forming even if they have formed a group with the indicated number of members for the specific semester. Once groups have been formed,
each group sends to the semester coordinator the students belonging to this group. Then the semester coordinator assigns a project supervisor to each group.

Project supervisors are there to guide students through project work. The students are responsible for contacting their supervisor and arranging meetings with her. Communication between the group and the supervisor takes place mainly via emails, while they usually meet physically. The group also sends via email their progress to the supervisor in order to get feedback. The progress can be a description of their current tasks/activities or a preliminary version/individual parts of their project report.

Problem and task formulation take place before the problem analysis, as we discussed in the previous paragraph. The problem formulation is very important since the ill-defined problem guides the students throughout the project. It has to be generic for allowing students to look into different directions for solving it and at the same time it has to allow for some kind of evaluation of the problem solution. In order to come up with a proper problem, students conduct research on the semester theme. The problem has to be approved by the supervisor, before students can proceed in the next phase of their project work.

Often, task formulation includes additionally a workload and possibly role distribution among group members, which are continuously adapted throughout the project. Common roles are the project leader, the chairman and the secretary. The leader is responsible for keeping an overview of the group’s progress and for making sure that agreed meetings and deadlines held. Moreover, the leader is responsible for creating and maintaining a nice atmosphere between members of the group.

Data gathering, analysis and design take place during problem analysis. Firstly, students gather data on the problem they are investigating. This possibly includes reading both scientific and non-scientific publications, conducting interviews, administrating questionnaires/surveys, and examining the state-of-the-art in the specific field. This phase can be challenging for non-experienced students, since they might lose track of time while gathering information. The students have to learn to be efficient and to be able to filter the available information in order to gather only relevant data.

The analysis of the problem is the next phase in PBL project work. During analysis, the students examine the gathered information in order to decide to a direction towards the solution of the problem. The analysis ends with the creation of a list of design requirements – that means requirements for the proposed problem solution. These requirements guide the design, which is the next phase.

During design, students develop the strategy for a solution to the chosen problem. The design activities depend on the specific field. In technical studies, design refers to the engineering design, where a blueprint of the technical implementation is created. In other studies, the design can be service-design, artistic design, etc.

The implementation and evaluation phases belong to the problem solving. During implementation, the students implement the actual solution to the problem. Again, solutions such as designs vary
depending on the program and the semester. The word implementation is used therefore with a broad meaning.

Finally, students evaluate their solution. The strategy for evaluation is defined at the initial phases of the project, since it is dependent on the problem formulation. Evaluation may include technical tests, user experience or usability tests, surveys, field work such as observations, interviews etc. At the end of the evaluation, students have to report their findings and propose paths for improvement and future work.

In the Annex-A, a very short description of the project phases and a plan for carrying out them is presented. This plan was given as a guideline to 1st semester students at the Medialogy Bachelor program at AAU.

4.2 Learning resources in a PBL context

Throughout their project work, various learning resources are available to students (Figure 4-3). Students are free to use any resource they find useful and relevant for analysing and implementing the problem solution. However, they are strongly encouraged to scientific resources as much as possible and always validate their resources. The lectures of project or semester courses guide also the project work, since courses are tuned with the project theme. Finally, students are also encouraged to conduct field work and experiments during investigation and evaluation of the problem solution. Such approaches are used to gather data for deciding on the problem solution or reflecting on it. Learning resources inform learning activities and decisions during project work.

![Figure 4-3. Possible resources during project work in PBL](image-url)
4.3 Web Tools for Supporting PBL Activities

While going through the learning activities of Figure 4-2, students use various technological tools. Khalid et al. (2012) identified the use of Web 2.0-based tools in supporting these kinds of PBL activities among students at AAU. Their work focused on “learning activities” and not “learning design” (Dalziel, 2015), since they focused on the learning outcome and especially on the interaction going on among students themselves and students and teachers (as supervisors). Such learning activities are the building blocks for teacher facilitated activities and collaborative group activities, which are flexible in nature. Therefore, Khalid et al. argued that referring to learning activities, when one investigates use and adoption of web 2.0 tools is simpler than employing the “learning design” context. Their study used data and findings contributed by (Rongbuttsri, Khalid, & Ryberg, 2011).

Khalid et al investigated tools used for PBL activities in project work only. They mapped web tools to support learning and group work collaboration into different learning activities. Then, they looked on both self-subscribed tools and institution-provided tools and compared these with the phases in PBL project work. Figure 4-4 shows mapping of web tools in the different phrases of PBL project work. There are some common activities, which students usually do in most of the phases are shown in Figure 4-5. The PBL phases shown in Figure 4-4 are for a general PBL group workflow.

The lists presented in these figures can be used as a guideline for students to look for tools to support their learning activities. These also can be used for PBL group supervisors and the IT support department to understand phases of PBL group work and tools which can be applied to each activity in each phase. Therefore, it can be a guideline for the supervisors to facilitate their students to pick up appropriated tools for each activity based on PBL work group phases. These lists can also provide a starting point for the employment of Learning Analytics algorithms in the PBL project work process.

We have to mention here that AAU uses a Virtual Learning Environment (Moodle) in all its programs. However, Moodle is currently used for supporting course work and exchange of files and information and not for supporting communication and exchange of information during project work.
<table>
<thead>
<tr>
<th>Phases</th>
<th>Activities</th>
<th>Web tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Forming</td>
<td>Brainstorming</td>
<td>Twitter, Etherpad, Blogger.com, Wordpress</td>
</tr>
<tr>
<td></td>
<td>Group creation</td>
<td>Email, Twitter</td>
</tr>
<tr>
<td>Problem formulation</td>
<td>Brainstorming</td>
<td>Mindmap, vue.tufts.edu, Mindmeister, Google docs, Etherpad</td>
</tr>
<tr>
<td></td>
<td>Literature searching</td>
<td>AAU digital library, Google scholar, Google, Bing</td>
</tr>
<tr>
<td></td>
<td>Literature Storing</td>
<td>Dropbox, Zotero groups, Diigo, Digg, Mendeley</td>
</tr>
<tr>
<td></td>
<td>Referencing</td>
<td>Wiggio, Refworks, Zotero, Mendeley</td>
</tr>
<tr>
<td>Arguement</td>
<td>Table 3: Common activities</td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>Table 3: Common activities</td>
<td></td>
</tr>
<tr>
<td>Presenting</td>
<td>Table 3: Common activities</td>
<td></td>
</tr>
<tr>
<td>Task formulation</td>
<td>Scheduling</td>
<td>Google calendar, Doodle</td>
</tr>
<tr>
<td></td>
<td>Diagramming</td>
<td>Table 3: Common activities</td>
</tr>
<tr>
<td></td>
<td>Resource allocation (tools, spaces, locations, people)</td>
<td>Basecamp, MS project</td>
</tr>
<tr>
<td>Data gathering</td>
<td>Data Collection</td>
<td>surveyexact.dk, Google docs</td>
</tr>
<tr>
<td></td>
<td>Data Transformation</td>
<td>surveyexact.dk, Google docs</td>
</tr>
<tr>
<td></td>
<td>Data Storing</td>
<td>surveyexact.dk, Google docs</td>
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<tr>
<td></td>
<td>Data representation</td>
<td>surveyexact.dk, Google docs</td>
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<tr>
<td>Analysis</td>
<td>Data analysis</td>
<td>surveyexact.dk, MS Office</td>
</tr>
<tr>
<td>Arguement</td>
<td>Table 3: Common activities</td>
<td></td>
</tr>
<tr>
<td>Diagramming</td>
<td>Table 3: Common activities</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>Development/Production / Testing</td>
<td>Etherpad</td>
</tr>
<tr>
<td></td>
<td>Experimenting</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Modeling</td>
<td>Dabbleboard</td>
</tr>
<tr>
<td></td>
<td>Writing</td>
<td>Table 3: Common activities</td>
</tr>
<tr>
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<td>Simulating</td>
<td>SecondLife</td>
</tr>
<tr>
<td></td>
<td>Prototyping</td>
<td>Dabbleboard</td>
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<tr>
<td></td>
<td>Diagramming</td>
<td>Table 3: Common activities</td>
</tr>
<tr>
<td>Reporting</td>
<td>Report writing</td>
<td>Table 3: Common activities</td>
</tr>
<tr>
<td></td>
<td>Report submitting</td>
<td>Email, Google project, AAU project</td>
</tr>
<tr>
<td></td>
<td>Presenting</td>
<td>Table 3: Common activities</td>
</tr>
<tr>
<td></td>
<td>Arguement</td>
<td>Table 3: Common activities</td>
</tr>
<tr>
<td></td>
<td>Publishing</td>
<td>AAU projekt Projekter (Projektbiblioteket)</td>
</tr>
</tbody>
</table>

Figure 4-4. Samples of tools mapped to PBL project work activities taken from (Khalid et al., 2012)
<table>
<thead>
<tr>
<th>Common activities</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharing</td>
<td>Dropbox, Zotero, Diigo, Youtube, Facebook, Flickr, twitter, Blogger, Delicious, Digg, Box.net, Slideshare, LogMeIn, TeamViewer, LogMeIn</td>
</tr>
<tr>
<td>Discussing</td>
<td>Facebook, LinkedIn, Skype, MSN, Yahoo messenger, twitter, Blogger, Doodle, SignAppNow, Mahara, Moodle, Quickr, Adobe Connect, Lectio.dk, Microsoft OneNote, FirstClass</td>
</tr>
<tr>
<td>Reading</td>
<td>Google</td>
</tr>
<tr>
<td>Presenting</td>
<td>Prezi, Google docs</td>
</tr>
<tr>
<td>Writing</td>
<td>Google docs, Typewith.me, MS Office with Dropbox</td>
</tr>
<tr>
<td>Communicating</td>
<td>Facebook, LinkedIn, Youtube, Flickr</td>
</tr>
<tr>
<td>Reflecting</td>
<td>Facebook, LinkedIn, Youtube, Flickr, Skype, MSN, Yahoo messenger, twitter, Blogger, Moodle, Mahara, FirstClass</td>
</tr>
<tr>
<td>Argumenting</td>
<td>Facebook, LinkedIn, Youtube, Flickr, Skype, MSN, Yahoo messenger, twitter, Blogger, Mahara, Email, Microsoft OneNote, FirstClass</td>
</tr>
<tr>
<td>Diagramming</td>
<td>Gliffy, Diagramly, Dabbleboard</td>
</tr>
</tbody>
</table>

**Figure 4-5.** Samples of tools mapped to PBL common activities taken from (Khalid et al., 2012)
5 Other PBL Models

5.1 The Seven-Step Approach on PBL by Maastricht University, the Netherlands

In 1976, Maastricht University implemented a PBL approach for its training of medical students. Medical students were to work on problems together with their peers in small groups (“tutorials”) and under the guidance of an academic staff member (“tutor”) (Maurer & Neuhold, 2012). The number of lectures was restricted to one or two per week, while the starting point for the process of learning were short texts or task descriptions (“assignments”) that had been designed by the academic staff member responsible for the content of the course (“coordinator”). This student-centered approach has been described as promoting collaborative learning on the one hand, while at the same time enhancing the student’s responsibility for the results achieved (Schmidt, Van der Molen, Henk T, Te Winkel, & Wijnen, 2009).

The Maastricht approach is based on three main principles: student-centred, active and collaborative learning. PBL is university-wide the main learning and teaching instruction method, although there are variations in implementation and application, especially between faculties (Maurer & Neuhold, 2012). Yet, what the various faculties have in common is the reliance on an institutionalised way of guiding students through the learning process: the seven-step approach (Figure 5-1).

The seven-step approach, also called “seven jump” approach, was developed at Maastricht University to facilitate and structure students’ learning processes within a PBL framework\(^4\). This approach is applied for each meeting the students have with their tutor. Each tutorial meeting is divided into two parts: The tutorial session starts with the post-discussion of the assignment that students prepared in their self-study before the tutorial, and after a short break the pre-discussion of the next assignment follows that students prepare until the next tutorial meeting. Ideally both parts together should take a bit less than two hours. In the pre-discussion of an assignment students follow the first five steps of the seven-step approach (Figure 5-1). The assignment provides a picture, some quotes, or few text passages outlining the problem or asking for a specific task to complete. In that way, students are confronted with a certain topic. These assignments are developed by scientific staff and are part of the course book, which students receive at the beginning of each module.

Students are supposed to have read and looked at this assignment already before their tutorial (or during the break), so that they can begin immediately with clarifying terms and concepts. This first step guides students mentally into the topic, and by discussing unknown words or concepts it is ensured that all students understand the text as it stands and that the group shares ideas about illustrations that might be part of the assignment. This first step provides a common starting point

\(^4\)The description of the seven steps is taken from (Maurer & Neuhold, 2012).
and leads the group into the topic. In the next step, the whole group agrees on the formulation of the problem statement that frames the whole assignment, provides a title for the session, and makes the group agree on what the general impetus of the assignment is about. Problem statements can take the form of more traditional titles, but are sometimes also formulated as broader research questions or provoking statements.

Figure 5-1. The seven-step PBL process at Maastricht University

The problem statement should trigger the next step of the brainstorm. The rationale behind this step is that students collect potential interests that they might have, activate prior knowledge, and share certain expectations. Everything is allowed during this step, and ideas are collected unquestioned at the whiteboard (i.e. there are no wrong ideas; everyone should be allowed to follow her/his own ideas). Just in case a group member does not understand how a certain intervention of a peer is connected to the problem statement and if the relevant student did not
explain why a certain keyword should be taken into account in regard of the problem statement, clarification questions can be asked by the group. The outcome of the brainstorm is noted on the whiteboard by the secretary that during the next (fourth) step should be categorized and structured by the students.

The fourth is the most challenging step for inexperienced students, but by structuring the brainstorm students categorise keywords that fit together and in this way they find common patterns that in the next step will allow for the formulation of specific questions. As last step of the pre-discussion, students agree on the formulation of common learning objectives, by referring to the brainstorm and the now structured collection of ideas that they have noted on the whiteboard. This way of formulating learning objectives in the ideal case reflects the different approaches to the wider topic that students have agreed to research upon, because they consider them to be the most relevant to the specific topic and because they are interested in exploring exactly these questions. Additionally, by agreeing on common learning objectives in a group, experience showed that students also get acquainted to formulate learning objectives clearly and to the point, as otherwise the post-discussion in the tutorial group goes into too many different directions.

After these five steps of the pre-discussion, students leave the group again to engage in the self-study, which takes a central position in the Maastricht PBL framework and emphasises the self-responsibility of the learner for knowledge acquisition. During this self-study, students should work on their individual answers to the formulated learning objectives. Especially for students in their first year of study the key literature is provided after each assignment, while this should not discourage students to look for additional sources and other literature that they might find interesting. For more advanced students, sometimes just a general reading list for the whole course is provided, and it is up to the students themselves to decide in their self-study, which of the literature provided is relevant for their respective learning objective. Students thereby also learn how to select relevant material and literature in a relatively short period of time. The following tutorial, normally taking place two or three working days later, starts with the post-discussion where students report back, exchange their answers, discuss problems and try to come to common conclusions on how to answer the learning objectives.

While students should be able to come to a common understanding of some relevant factual knowledge during this post-discussion, it is especially the more normative and non-straightforward answers that allow for a more profound discussion and exchange of arguments. By experiencing different perceptions of a question by their peers, by listening to different lines of argumentation, and by being confronted by different perceptions of perhaps the same reading, students are acquainted to report, listen, discuss and debate. While the formal seven step approach ends here, students are in practice often also encouraged by their tutors to reflect in their post-discussion about their selected learning objectives and potential aspects of the topic that they did not cover originally but found interesting while engaging with the literature. It is, however, mostly more experienced students in their second year of study who are able to show that kind of reflexivity in the post-discussion and provide guidance for improving the next pre-discussion. This way of improving the process of learning is, at the same time, identified as one of the most important
aspects of the PBL cycle (Albanese & Mitchell, 1993). Otherwise, students repeat their mistakes and imprecision every time they engage in an assignment. In addition, students are also encouraged, to provide peer-feedback on their performance as chair, participant and secretary. This way they ideally not only advance on the discussed topic, but are also able to improve their learning process and communicative skills.

Students are also in charge of organising their tutorial meetings as much as possible themselves by fulfilling various roles, while the tutor only provides support and facilitates their collaboration. Each assignment session is chaired by a student-chair who is responsible for convening the meeting, keeping track of the post-discussion to cover all learning objectives, engaging all participants in the discussion and making sure of the keeping within a reasonable time-limit. By summarising the discussion from time to time, the student-chair should also facilitate the understanding of the participants and provide concise overviews, especially in case some students get lost in details during the post-discussion. It is important to note that the student-chair her/himself is not supposed to provide the answers to all questions and lecture his colleagues, but the role is mainly aimed at chairing the meeting in an orderly and inspiring manner. The student-chair is supported by the role of the secretary, who takes note on the whiteboard, especially during the pre-discussion. Depending on the prior details of agreement between group members, the secretary can also be asked to post the learning objectives electronically, or to send other collected material around per email. The roles of student-chair and secretary alternate with every assignment, so that as many students of the group as possible get the possibility to try and succeed in these roles. By fulfilling these roles, students also are meant to improve their leadership skills as chairs, as well as their notetaking skills. A skilled secretary can make a huge impact on how the brainstorm takes shape on the whiteboard, and students this way also learn from each other of how to best organise work in a team. The rest of the tutorial group members, are fulfilling the role of active participants, engaging in dialogue to determine the learning objectives, or to respectively exchange answers and arguments in regard of their prior formulated learning objectives during the post-discussion.

Finally, each tutorial group is supported by an academic staff member, called a “tutor” who is meant to facilitate the learning process of the group by asking provocative questions, providing assistance with the seven-step approach, or providing feedback to the chair/secretary or the overall learning process of the group. At no point in time the tutor should lecture the group, but in case of problems, s/he should support the group in identifying what went wrong and what could be improved to get to a more successful learning process in the next assignment. However, when tutoring PBL-inexperienced students the tutor should react to potentially distracting group dynamics and stop the group in case they are “going off the track”.

Researchers from Maastricht University have argued that this way of learning becomes an “active and constructive process” (Gijselaers, 1996), especially when compared to the more receptive nature of the traditional learning when passively listening to lectures. While following the seven step approach, students mimic the normal process of academic research by elaborating on a problem and developing a research plan and formulating clear research questions for each assignment. Their results have shown that the advantage of this approach is that students feel ownership for their own
learning, and by being able to select themselves how exactly they want to approach certain problems, they show a higher interest and more engagement in their learning process.

**5.2 PBL at the University of Manchester**

PBL was first introduced at University of Manchester in 1994 for both medical and dental students (Ferguson & Rutishauser, 1997). The University of Manchester was the first school in the UK to introduce PBL as its major learning strategy. The specific aims were to develop:

1. Clinically focused knowledge and understanding of the biological, behavioural and social sciences relevant to the practice of dentistry and medicine, resulting in: (a) awareness of their experimental and theoretical basis, (b) fluency in the languages of these sciences and (c) capability in using that knowledge and understanding.
2. Skills in self-directed learning, problem solving, use of technical resources (library, computers, interpersonal communication).
3. Awareness of ethical dimensions in medicine and scientific research.

In Manchester, PBL is used throughout the first and second years of the study programme. The PBL method is interdisciplinary and there are no subject boundaries. Students work in groups of between ten and fifteen, facilitated by a tutor, to research topics and share information in a mutually supportive environment. Each week a different problem forms the focus for learning.

The years are divided into two semesters. Originally, from 1994 to 2000, teaching in year 2 returned to a more didactic mode with lectures and practical experience focusing on individual subjects. However, in 2000, PBL was also extended into year 2. The clinical problems are central to the learning forming the focus for the syllabus and ‘jumping off point’ for the student’s own research and learning (O’Neil, Metcalfe, & David, 1999). The University of Manchester has produced a list of “Index Clinical Situations” (ICSS), for which a newly graduated doctor must have a required level of competence. Using repeated consultation with consultants and general practitioners involved in medical education, a list of 215 ICSSs was agreed. Specialists and generalists were then asked to identify the components of the knowledge base and the performance (skills) base for each ICS. The knowledge base was divided into technical (biomedical facts/concepts) and contextual (effect/management of disease within the individual, family and society) domains. The performance base was divided into intellectual (problem solving and decision making) and interpersonal (history, examination, communication and procedural skills) domains. The defined ICSSs are used in the design of the trigger material for the weekly problem-based learning sessions, with many being revisited at several points in the curriculum. Besides the ICSSs, the students also receive a maximum of four lectures per week, an informatics component that includes computing and statistical elements, laboratory sessions during which skills are acquired and resources to support learning can be accessed and also a clinic-based course that varies in each semester.

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5 The description of the Manchester PBL approach is taken from (Hoad-Reddick & Theaker, 2003)
Student groups follow a seven-step process of group work, similar to the Maastricht PBL approach (David & Patel, 1995) (Figure 5-2). The problems are clinical cases, presented to the students on Thursdays so that they can discuss as a group and then follow up individual avenues of study/research over the weekend. The students are encouraged to first identify their study agenda by outlining the knowledge and skills required to understand the problem. They then actively seek out the information using the available resources, for example libraries, the Internet, laboratory facilities, anatomical images and specimens. Finally, they are able to share and compare findings with other members of their group, discussing the issues involved and drawing their own conclusions. For any one problem, this cycle may be repeated several times but takes place on a formal tutor-facilitated basis twice for each problem (Monday and Wednesday following the previous Friday’s initial group session). Therefore, the Manchester model employs closed-loop or reiterative PBL.

Figure 5-2. The seven-step process of group work at University of Manchester
Students are encouraged not only to seek out the basic medical background but also to consider social and psychological considerations relevant to each case using materials from the library – textbooks and journals – as well as information from the Internet. Thus, students learn to discriminate between peer-reviewed and unsupported research information. During each semester, an in-course assessment of group work is made by each group’s facilitator. This mark is combined with marks from case-based, knowledge-based, publication-based, and skills-based assessments to yield a summative assessment of each student’s performance (Ferguson & Rutishauser, 1997). In the second semester, each student undertakes a special study module (SSM) – a library or laboratory-based project supervised by a member of staff on a one-to-one basis. Students generate an SSM report that is assessed by their supervisor and a second marker yielding a mark that is included in their second-semester summative assessment.

The failure rate in the first set of examinations (shared by both dental and medical students) was higher than expected, with dental students performing less well than medical students (Ferguson & Rutishauser, 1997). In 1998, prior to the examinations, operational interviews were organized with all first year dental students in an effort to provide good support and guidance and help the students in the most supportive way. These have been continued annually and have highlighted the fact that many of the students found adaptation to PBL difficult. The average time taken to get used to the system was four weeks but some students took considerably longer.

The University of Manchester has taken several measures to facilitate the process of adaptation to PBL (Hoad-Reddick & Theaker, 2003). Changes have been made in the areas of recruitment, preadmission interviewing, induction (development of an induction booklet and communication skills module), and tutorial support (overhaul of personal tutor system and introduction of peer-assisted study (PAS) and personal and academic development programmes (PADPs)). Feedback on these changes has been positive and continues to be central to the processes of development in these areas.
6 PBL in Online Learning Environments

6.1 Classroom-based vs. online asynchronous PBL

So far, we have discussed PBL as a learning strategy taking place in institutions and combing course and project work containing at least some face-to-face sessions. In the literature, it has argued that courses with content declarative in nature should not be taught using PBL approaches. For instance, Bland (2004) pointed out that problem-based learning has not been used extensively for the teaching of statistics content within the biomedical sciences for this reason. As a consequence, the module had historically been taught using traditional didactic teaching methods—primarily in the form of face-to-face lectures and practical exercises using the SPSS software package.

In order to investigate such argumentations and in view of advances in knowledge about the cognitive and motivational effect of PBL in small groups (Dolmans & Schmidt, 2006), de Jong et al. from the Maastricht University designed a case-study to compare outcomes from a traditional classroom-based, face-to-face statistics module for students undertaking a Public Health Master’s degree with a parallel asynchronous online variant delivered at the same point during the academic year (De Jong, Verstegen, Tan, & O’connor, 2013). The classroom module used the Maastricht University’s ‘seven-step’ PBL approach (Figure 5-1). In particular, it was believed that input from a problem-based learning group tutor, who was also a core member of the statistics teaching team would help students synthesize the many difficult concepts addressed within the module and help them to consolidate learning acquired from more didactic components such as lectures (De Jong et al., 2013).

The faculty responsible for statistics education within the MSc Public Health programme developed a problem-based module according to the university’s standard module development. However, it was quickly observed that part-time students in full-time employment experienced difficulty attending problem-based learning tutorials in addition to other compulsory modules during their limited study time. In response to student feedback on the proposals, de Jong et al. decided to develop and pilot an online variant of the new module which could be undertaken independently by part-time students in full-time employment in order to better accommodate their work, study and family commitments. During the course of four meetings, the module content was reviewed and the problems adapted slightly so that they better suited the online learning environment. Notwithstanding differences in the means of its delivery, the espoused content of both module variants remained exactly the same, with students accessing the same reading materials and lectures (either face to face within the classroom setting or via a recording of the same lecture in the online variant). However, given the differential nature of the part-time students’ work commitments, it was decided that the online variant would be delivered asynchronously for the most part allowing them to access the materials and contribute to PBL activities at the time, which best suited them. The sample size for the unmatched cohort case-study was intentionally restricted to two groups tutored by the same member of the module teaching team in order to reduce ‘teacher effect’ as a possible source of bias.
This study was one of the few that tried to implement PBL in online learning and teaching environments. The researchers administered a validated student motivation questionnaire to both groups of students at the start of the study and a second questionnaire at the end of the module. This elicited data about student satisfaction with the module content, teaching and learning methods, and tutor feedback. They also interviewed the module coordinator and problem-based learning tutor about their experience of delivering the experimental online variant and asked them to evaluate its success in relation to student attainment of the module’s learning outcomes. Furthermore, they compared student examination results between the two groups. Asynchronous online teaching and learning methods proved to be an acceptable alternative to classroom-based teaching for both students and staff. Educational outcomes were similar for both groups, but importantly, there was no evidence that the asynchronous online delivery of module content disadvantaged part-time students in comparison to their full-time counterparts. Therefore, this study provided evidence that PBL can also be applied successfully in online environments.

6.2 PBL in MOOCs

Massive Open Online Courses (MOOCs) are rapidly increasing in popularity. However, as they’re aimed at attracting large numbers of participants, interaction with the teacher(s) is often limited (Ross, Sinclair, Knox, & Macleod, 2014). Furthermore, many MOOCs are criticized for lacking sound instructional design and often struggle with drop-out rates of up to 95% (Yang, Sinha, Adamson, & Rose, 2013). Trying to apply alternative ideas stressing learner participation and engagement in MOOCs, Maastricht University is currently combining the small-group collaborative learning ideas from PBL with the openness and flexibility of a MOOC. They have therefore created an experimental MOOC on PBL\(^6\), where participants can learn about PBL by practicing PBL in a MOOC. This MOOC is an eight-week course, where participants study four relevant PBL problems with examples from different domains. In small online groups, they discuss what they learned and how they can apply it in their own educational setting. This course also aims at innovating PBL by stretching it to its limits and applying it in new ways. For the time being, Maastricht University has not published any results on their PBL implementation in a MOOC.

\(^6\) https://moocs.maastrichtuniversity.nl/
7 Conclusion

The purpose of this deliverable was to present all the work done towards the analysis of PBL and its steps. In this context, this deliverable has discussed:

- The PBL learning principles and how these principles can be interpreted and applied to produced different PBL implementations. Such implementations, also called PBL models, may be applied in different levels (course, program, institutional) and they may engage PBL in different degrees. Therefore, there is not a unique definition for a PBL model, but various models interpreting in different ways and adhering at different levels to the generic PBL principles.

- Specific PBL models, namely the Aalborg PBL Model, the seven-step PBL approach of Maastricht University and the PBL model of the University of Manchester. The Aalborg PBL Model has been extensively described in terms of its principles, its approach to PBL project work, learning resources and tools used during the PBL process. It has been shown that the PBL steps in project work contain different learning activities and employment of various learning resources.

- The SOLO taxonomy, which has been used for analysing learning objectives when characterized by terms such as knowledge, analysis, synthesis, application etc. The SOLO Taxonomy is based on the study of outcomes of academic teaching and operates with five numbered progressive levels of competencies according to the cognitive processes required to obtain them. Therefore, it could be used to formulate learning objectives in a PBL process.

- Implementations of PBL in online environments. Since this project aims at incorporating PBL, LA and LS in different contexts, this deliverable presented PBL application in MOOCs and asynchronous online learning. Research has shown that PBL can be successfully applied in such settings. Therefore, this is a direction, which the project can further investigate.

Overall, this document has analysed PBL as a learning strategy and as a local implementation and has elaborated on project work in the AAU PBL Model. From this analysis, it became obvious that LA and LS can greatly contribute to better monitor student learning and attainment and teacher performance in this process, which is not adequately monitored by automatic and digital means.
References


Dalziel, J. (2015). Reflections on the art and science of learning design and the larnaca declaration. The art & science of learning design (pp. 3-14) Springer.


Annex A - Plan for project work given to 1st semester students at the Bachelor program of Medialogy, AAU

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT-Introduction</td>
<td>Oct 6th</td>
</tr>
<tr>
<td>Choice of theme + Inspirational Sheet (10 things you are inspired by - initial ideas/ sketches, inspiration projects/ photos/pictures, research papers)</td>
<td>Oct 12th</td>
</tr>
<tr>
<td>Send introduction + initial problem statement + analysis outline to supervisor</td>
<td>Oct 16th</td>
</tr>
<tr>
<td>Draft of Final Problem Statement + Analysis sent to supervisor</td>
<td>Nov 2nd</td>
</tr>
<tr>
<td>Analysis done! Final Problem Statement + Requirements for design</td>
<td>Nov 9th</td>
</tr>
<tr>
<td>Initial Design done! - begin implementation</td>
<td>Nov 13th</td>
</tr>
<tr>
<td>Final Design done! - still implementing</td>
<td>Nov 25th</td>
</tr>
<tr>
<td>Design/Implementation done! - ready for test</td>
<td>Dec 1st</td>
</tr>
<tr>
<td>Test Design finished?!</td>
<td>Dec 3rd</td>
</tr>
<tr>
<td>Test done!</td>
<td>Dec 9th</td>
</tr>
<tr>
<td>Complete report done! (including re-design)</td>
<td>Dec 12th</td>
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<tr>
<td>Conclusion</td>
<td></td>
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<tr>
<td>Final hand-in!</td>
<td>Dec 17th</td>
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<tr>
<td>Process Analysis Hand-in!</td>
<td>Dec 21st</td>
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