The success of Problem Based Learning and Project Organised learning (PBL) as an educational method in the field of Higher Engineering Education is clear and beyond any doubt. An increasing number of Universities of Technology all over the world applies PBL in their curriculum. There are many sound arguments for changing to PBL, such as enhancing students’ motivation, integration of practice oriented competences, improved retention of students, augmenting the quality of education, collaboration with industry.

More and more educational research is supplying evidence to sustain these arguments. Engineers create innovations to improve the quality of our life. It just makes sense that the institutes of Higher Engineering Education want to know what educational innovations contribute to the quality of engineering education.

To promote research on PBL the UNESCO chair in Problem Based Learning in Engineering Education (UCPBL) organised the first Research Symposium on Problem Based Learning in Engineering and Science Education, June 30th-July 1st, 2008 at Aalborg University. This book contains a selection of papers from this research symposium, which have been reviewed and further developed.
Research on PBL Practice in Engineering Education

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The UNESCO chair in Problem Based Learning in Engineering Education (UCPBL) held the first Research Symposium on Problem Based Learning in Engineering and Science Education, June 30th-July 1st, 2008 at Aalborg University. The objectives of this first research symposium were:
- to create a community of researchers within PBL and engineering
- to present research projects
- whether in an early stage or finalized projects on the effects of PBL in engineering educations
- to initiate new research projects

Establishing a network among researchers is a very important task for the UNESCO Chair in Problem Based Learning at Aalborg University. There are many good arguments for changing to problem based and project based learning (PBL) such as creating institutional profiles, emphasise students’ learning and motivation, new competences, enhancing the quality of education, decrease drop out rates, better duration rates, better collaboration with industry, etc. But do we have evidence for these arguments? Are students getting more motivated for learning? Can we find lower drop out rates or higher retention rates? Are PBL institutions collaborating more with industry? Are students achieving new types of skills and knowledge like innovation, collaborative skills etc.

There are many more questions – but do we have answers to these questions? Do PBL institutions research on their own students? Do we have comparable data from traditional and PBL institutions to indicate some of the effect of the established changes?

The answer to this is both yes and no. Institutions that have established PBL curricula during the 80 and 90’ties have not been very efficient at documenting the effect of PBL. However, there is a growing awareness that we cannot go on changing education based beliefs and random experiences. In order to document the effect of PBL systems, we do need to get much more organised in collecting and analysing data. We need to develop theories and new concepts for analysing new types of practice of creating knowledge. Therefore the implementation processes goes hand in hand with research.

This first research symposium attracted more than 100 participants from more than 32 different countries from all world regions. There were 27 paper presentations and 18 poster sessions. This book contains selected papers from this first research symposium, which have been further reviewed and developed.

January 2009
Anette Kolmos, Xiangyun Du and Erik de Graaff
Problem-Based learning emerged at the end of the sixties of the last century at McMaster's University in Canada. In line with pedagogical traditions, Don Woods introduced his ideas on the shift from teaching to learning as a vision rooted in practical experiences (Woods, 1994). Since then Problem-Based Learning has proven to be a successful educational strategy in many different study domains all over the world. Evidently these practices differ from each other.

Presently, PBL covers a wide range of practices which might sometimes be difficult to compare. Today it is also an abbreviation for project-based learning. It is important to stress that the new notion of PBL represents a learning philosophy rather than the details in the organisation of the curriculum and goes far beyond a narrow curriculum change. This learning philosophy encompasses both problem-based and project-based learning. Furthermore, PBL includes a cultural change and fosters new epistemologies in the creation of knowledge and innovation.

Since the beginning, a lot has been published about various aspects of PBL. At first, most publications were in the form of descriptions of developmental work and case studies. However, as PBL became well established and widely recognised over the last 40 years, the research issues and research methodologies have developed. During the 1970’s the first empirical studies started to appear together with descriptions and conceptualisations of new practices (Illeris, 1976; Neufeld and Barrows, 1974; Schmidt, 1983; Barrows and Tamblyn, 1980). The research at this stage can be characterized as descriptive, normative and conceptual research. Often, the normative dimension of research is undervalued and by some research traditions it is not accepted as true scientific research. However, in the pedagogic tradition, descriptive research plays an important part in the development of ideas as it contributes to the understanding and creation of an analytical framework for new innovative practice. This dimension is very important in a process of change.

During the 1980’s and 1990’s a growing number of studies were published which aimed to evaluate the effects of PBL and investigate its basic learning principles (Boud, 1985; Boud and Feletti, 1991; Graaff and Bouhuijs, 1993; Bouhuijs et al., 1993; Chen and Cowdroy, 1994; Woods, 1994; Kjerdams and Enemark, 1994; Kolmos and Rasmussen, 1994; Wilkerson and Gijseelaers, 1996). The methodologies used are quite diverse due to the nature of the research topics. Establishing a new educational practice requires not only an understanding of new learning principles, but also understanding content-based curriculum issues,
students’ collaborative-learning process, and the development of new concepts of PBL knowledge while establishing new organisational and institutional practices.

The methodologies used for the study of PBL range from conceptual studies to empirical studies using both quantitative and qualitative methods. The studies indicate a broad range of research issues such as:

– New notion of knowledge
– New types of competencies and skills
– The students’ learning process and motivation
– New type of curriculum structure and content
– New roles for academic staff
– Institutional change and how to lead change

During the 1990’s, large scale studies on the effects of PBL were published, which reflected the results of extensive research projects. Many of these institutional studies were carried out at Maastricht University and Aalborg University. In Belgium, a study on a comparison of a traditional curriculum in engineering with a PBL curriculum was carried out at the School of Engineering of the Université Catholique de Louvain since 2000 (Faland and Frenay, 2006). This study focuses on the motivations for the adoption of project- and problem-based learning. The results of this study indicate that the new PBL curriculum had no negative effect on engineering student knowledge and skill development. On the contrary, it indicates that students studying under the PBL curriculum have improved skill levels compared to students from the previous lecture-based curriculum. These results confirm the outcomes of previous studies on PBL – especially in medicine: the knowledge level remains more or less at the same level, but, skill development is significantly increased in PBL curricula.

However in general, the research landscape has been dominated by small scale studies funded by the institution itself as part of the existing resource structure. An advantage of these small-scale studies is that there is extensive use of qualitative research methods which attempt to gain understanding on the effectiveness of didactic principles at close range. A disadvantage is that it may be difficult to draw conclusions across different studies since they are studies with diverse practices that use diverse research methodologies. However, there have been several articles that have reviewed these small-scale studies and summed up their results. Many of these reviews indicate that student-skill development has improved immensely and that as for their knowledge there seems to be no difference (Schmidt and Moust, 2000, Dochy et al., 2003, Thomas, 2000).

In order to analyse the advantages and disadvantages of PBL, the most beneficial situation would be to have both small-scale studies that provide details and large-scale studies that aim for representativeness. It would also be beneficial to have cross-institutional studies at both the national and international levels. However, most contributions in this book belong to the category of small-scale studies, which can be regarded as a more explorative phase of the study of PBL.
CONTRIBUTIONS

We have clustered the papers in this book around three themes: Variation and arguments for introducing PBL, research methods for the study of PBL and various case studies of PBL practice.

In chapter 2, Anette Kolmos, Erik de Graaff, and Xiangyun Du explore on the one side what unifies problem-based and project-based learning at the level of a learning philosophy and learning principles. On the other side, they develop a framework for analysing and developing PBL curricula since the PBL abbreviation has become a very broad term that covers diverse practices. The point in this article is that there has to be alignment among all the curriculum components.

The arguments behind introducing PBL still must be investigated. If we cannot provide any form of documentation that PBL makes a difference in the intended change, then there would be no reason for making all the effort. The first reason for changing to PBL is analysed in chapter 3. Lars Bo Henriksen analyses engineering knowledge from a philosophical perspective and compares that to ‘instrumental realism’. By doing so, it is argued that in order to educate a complete engineer who can handle the complexity of engineering in practice, one must ensure that the student masters more than engineering theories. It demands fundamental changes in the engineering curricula which can provide engineering knowledge as well as practice. This is exemplified through a case study on a PBL environment at Aalborg University, Denmark and illustrates how these types of competencies can be achieved. The important research question in this paper concerns the notion of a new type of knowledge. Theoretical knowledge is no longer enough – students have to learn to relate the theoretical knowledge to practice.

In chapter 4, Angela van Barneveld and Johannes Strobel summarize a rich body of literature on effectiveness of PBL by a meta-synthesis. They use a qualitative methodology that employs both qualitative and quantitative studies for data generation and analysis. This paves a basis for the author’s argument for a shift of attention on the research agenda of PBL studies, that is, from focusing on the effectiveness of PBL, to the value of PBL. To support this proposal, the authors also present their initial analysis of drivers of PBL such as the need for new skills and increased retention rates. But the authors indicate that there are challenges to the implementation of PBL.

The second theme for this book is the research methodologies in the study of PBL. In this book, a variety of methodologies are used in the studies depending on the research issues that are addressed. However, quantitative research methods are dominant.

In chapter 5, Sandra Fernandes, Maria Assunção Flores, and Rui M. Lima present ongoing research on the impact assessment of Project Led Education (PLE) at Minho University, Portugal. Methodologically, an evaluation model of CIPP (context, input, process, product) was employed in order to give a broader view of the evaluation. This analytic instrument covers data generation from both qualitative and quantitative methods including document analysis, questionnaires,
interviews and observation. Primary results are reported and discussed in this paper.

In chapter 6, Jette E. Holgaard and Anette Kolmos discuss relevant assessment methods for core PBL competencies. They stress that the method of assessment is essential for aligning learning goals, contents and outcomes within PBL contexts. Empirically, this paper draws upon an empirical research project in the Danish context that compares individual and group-based assessment by the use of quantitative methods.

In chapter 7, Mingyi Gao, Peter Willmot, and Peter Demian study the teaching effectiveness of design projects in the context of the U.K. A quantitative parameter which is rooted in self-regulated learning theory is employed to build a route-map model of effectiveness of PBL teaching methods. Four aspects are addressed in the analysis and initial results are reported upon: the PBL model, student time allocation, student improvement and satisfaction.

In chapter 8, Christel Heylen, Herman Buelens, and Jos Vander Sloten examine one specific aspect of competence development in terms of student learning – Socio-Emotional Quality (EMQ) - in the context of K.U. Leuven University, Belgium, where PBL practices are well established. A questionnaire-based survey was used in this study, drawing upon the assumption that collaborative project work encourages the improvement of students’ EMQ together with their complex engineering problem-solving skills. However, the quantitative results illustrate a different picture from those expected. This thus shows a complexity for PBL studies.

Alex Stojcevski and Xiangyun Du further investigate the topic of assessment and PBL in chapter 9 by drawing upon the experiences of Victoria University, Australia, where portfolios have been used as the major method of evaluating group projects done by engineering students. Through the analysis of 75 portfolios and questionnaire responses (which investigated the students’ opinions of the PBL curriculum as well as the assessment methods), this study identified a lack of alignment in experimental practice at the initial stage of institutional implementation of PBL. The authors argue that to maximize the effectiveness of PBL, it is essential to consider the alignment between factors such as learning principles of PBL practice, curriculum design, assessment methods and learning outcomes.

The third theme is cases which can provide a platform for learning and inspiration from examples of PBL from all over the world. It is quite amazing how many institutions are actually practicing some type of PBL curriculum – even if it is with a teacher-centred approach in a minor course. This indicates the seriousness and dedication by which academic staff all over the world invest in the education of engineers.

In chapter 10, Hayrettin Arisoy and Alex Stojcevski from Faculty of Health, Engineering and Science, Vitoria University, Australia discuss the role of technical support staff, a topic which remains a less addressed topic in PBL studies. An important message that can be gained from this paper is that in order to maximize
the effect of PBL on both students’ learning and institutional change, it is essential to facilitate the changing role of technical support staff. Once used merely as resources for equipment and components for lab work, in a PBL setting, the technical support staff should also be a facilitator whom students can discuss their project work with. This can benefit not only student learning, but also the alignment of curriculum development as well as staff development in the change process towards PBL.

Kati M. Vilonen and A. Outi I. Krause introduce in chapter 11 a practice of using the Problem-Based Learning method in team-based laboratory courses in industrial chemistry at a university in Finland. Achievements from this practice are positively visible: higher level of teaching and learning motivation, as well as improved students skills on collaboration and report writing skills. The authors also discuss their concerns with the challenges they have confronted such as formulating problems in an appropriate way and the difficulty of assessing individual performance in team work. In general, from an organizational point of view, this practice has been regarded as a successful experiment which paves the way to the further implementation for the whole curriculum in a broader sense.

In chapter 12, Javier Garcia and Jorge Perez from Spain introduced how Project-Based Learning has been employed as one of the major national strategies for improving university education and how it has been used as a teaching methodology at different levels – from single subject, group subject and masters. Specifically, this paper elaborates on how the Project-Based Learning method has been practiced in a course on Real Time System in Computer Science. Projects are initially designed by lecturers and further developed by students before they are carried out by student teams. The portfolio is used as a way of documenting the students’ learning process throughout the project. This practice in general witnessed no lower level of theoretical performance in terms of learning outcome than when compared with previous methods that did not include project work. In addition, higher levels of learning motivation and no course dropout rates were visible positive effects.

In chapter 13, Marcos Azevedo da Silveira, José Alberto Reis Parise, Reinaldo Calixto de Campos, Luiz Carlos Scavarda do Carmo, and Nival Nunes de Almeida give a cultural description of educational change towards Project-Based Learning in Brazil. Based on a review of the historical development of engineering education over the past decades and the philosophical discussion of pedagogical change, the authors explain why engineering education in Brazil should be transformed into PBL and how this transformation can take place successfully. However, in practice, the process of change has been restricted due to culturally related barriers such as the difficulty in changing from a teaching-centred to a learning-centred approach, the teacher-student relationship, as well as the shortage of financial resources, along with other factors. Appropriate strategies are suggested to solve the culturally-related issues in the process of implementing PBL.

In chapter 14, Yoshio Tozawa from Japan introduces how Project-Based Learning has been used as a pedagogical method in a Master’s Program on IT Strategy and Business Process Re-engineering for continued education in Japan.
Students of the program, who are daytime workers in a company, are expected to carry out a real industry project during the second year of their study (half way through the whole program). This implementation has been observed to successfully bridge both educational and industrial demands, although the challenge remains in regard to teaching how client value can be maximized. This PBL practice can also be regarded as an illustration of an interdisciplinary project in sustainable thinking which covers not only the technical aspect of IT, but also takes business strategies into consideration.

In chapter 15, Sabina Jeschke, Lars Knipping, Nicole Natho, Ursula Vollmer, and Marc Wilke provide another way of using Project-Based Learning and teamwork as method to design IT-Service curriculum at the University of Stuttgart, Germany. The multidisciplinarity of the projects that design and construct robots and the teamwork-based organization have been successful in recruiting students and increasing the diversity of engineering studies within the university. It does not only attract students from different technical fields such as computer science, electrical engineering, mechanical engineering, physics, math, cybernetics, etc (among them 25% are female), but it also helps them to improve their confidence and ability to work in some traditional ‘hard-core’ engineering fields.

In chapter 16, Cagil Ozansoy and Alex Stojcevski give an introduction to how Problem-Based and Project-Based Learning have been implemented at the Faculty of Health, Engineering and Science, Vitoria University, Australia. It provides an overview along with detailed information on different aspects of the implementation at the institutional level. It discusses background, curriculum model, the project design, the changing role of teaching and assessment.

Finally in chapter 17, Benoît Raucnet, Anne Hernandez and Geneviève Moore discuss staff development in PBL by bringing in the experiences of tutor training in Belgium. Based on the practice of a 5-module tutor training activity in PBL, the paper reflects on the challenges facing staff development from a perspective of the trainers. It is not difficult for the trainees to understand PBL teaching techniques; however, the main challenge lies in changing their perceptions of learning and shifting their teaching focus from products to learning process. Another difficulty for such activities is how to facilitate the trainees’ self assessment with the agreed upon success criteria. Their experiences call for more attention to be paid to developing new ideas for staff development in the process of organizational change towards PBL.

Enjoy the book.

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CHAPTER 2
DIVERSITY OF PBL
– PBL LEARNING PRINCIPLES AND MODELS

ABSTRACT
Over the last ten years, PBL has become an abbreviation for both Problem-Based and Project-Based Learning as it was known from the reform universities that established these pedagogic approaches. There are many reasons for unifying problem-based and project-based learning at a level of learning principles. Especially when implementing PBL in various education systems it calls for a flexible and more abstract definition in order to allow adjustment to the subject area, institutional culture and national educational framework. But along with the more abstract and unified notion of PBL, there is a growing diversity in the implementation of PBL curricula and therefore an increased need for conceptualisation of diverse practices. This article will present the unifying learning principles along with taxonomies and models for framing the diversity of PBL.

Keywords: PBL learning principles, PBL models, PBL alignment, diversity

1. INTRODUCTION
Nowadays, PBL is an abbreviation for both Problem-Based Learning and Project-Based Learning and it has proven to be a successful educational strategy in higher education. Historically, the term PBL as Problem-Based Learning was coined at the end of the sixties at McMasters University in Canada and many schools have used this label to identify (parts of) their curriculum (Savin-Baden, 2000; Boud, 1991; Bouhuijs et al., 1993; Evensen and Hmelo, 2000; Dutch et al., 2001). Today, PBL also covers the project-based practice that derives from the project-organised and problem-oriented practices in Europe. Evidently these practices differ and the question arises as to how we should define PBL. Should we refer to specific practices or rather to common learning principles? What are the advantages of a narrow definition versus a more general definition?

In a sense, it is surprising that the relatively new educational concept of PBL has been developed within higher education. Usually, higher education and especially universities of technology adhere to very traditional approaches to learning and curriculum development. The ruling conviction is that research qualifications
include the ability to teach students. However, the new innovative universities that were established in several parts of the world in the late 1960’s and early 1970’s exhibit a clear trend to try out new educational models. Examples include the problem-based approach in medicine at McMaster, Maastricht, and Newcastle in Australia along with the problem oriented and project organised (this later became known as problem based and project based) approach at Bremen University in Germany and at Roskilde and Aalborg University in Denmark. There were close links between McMaster and Maastricht on the one side and Bremen, Roskilde and Aalborg on the other side. Although the pedagogical models were used in many different subject fields, they have become most famous in the medicine and engineering models (Kolmos, 2008).

During the 1980’s and the 1990’s the two types of PBL universities in Europe became aware of each other’s existence and their diverse practices. In Europe, a new network was established among Maastricht, Twente, Linkoping, Roskilde and Aalborg University called UNISCENE (University Student Centred Network). During the 1990’s, this network held several conferences and produced newsletters, but faded out after a few years due to a lack of commitment for – at that time – such a specific educational network for the PBL institutions. However, for the involved partners the UNISCENE network created an understanding of the core learning principles and learning theories that were beyond the common educational models at that time as well as the variations in their concrete practices.

As both types of PBL models began to spread to other universities and more institutions, practitioners and researchers became involved, and there was a clear trend to separate the two models and distinguish between the problem-based learning and project-based learning models. Most of these definitions attempted to narrow down the conceptual understanding of PBL and define them solely through one particular practice, subject area or cultural setting.

However, as more and more institutions go in the direction of more student-centred learning, the cultural dimension become important. A specific model developed in Canada or the Netherlands, in a specific subject area such as medicine, cannot easily be transferred to engineering in Asia or South America. In engineering, the practical conditions are quite different from those in the health sciences and the cultural values in Asia or South America result in different communication patterns and decision strategies on teams. As a consequence, it is not possible for Asian or South American universities to copy a western curriculum and learning approach. If it is to be successful, the organisation of learning has to be developed from the cultural practices that are known to students and staff.

Graaff and Kolmos (2007) address this global and cultural challenge and reflect upon the differences between the two PBL models as well as subjects leading to the development of common PBL-learning principles. The PBL-learning principles are based on an analysis of the learning principles beyond the two PBL models and based on the learning theories that form the basis of both PBL-models such as Dewey, Kolb and Schön (Graaff and Kolmos, 2007; Graaff and Kolmos, 2003). In this book we want to present the learning principles together with a new framework for modelling and analysing PBL at the concrete level.
DIVERSITY OF PBL–PBL LEARNING PRINCIPLES AND MODELS

2. PBL-LEARNING PRINCIPLES

Although there are differences at the concrete model level, Graaff and Kolmos (2003; 2007) found that there are common learning principles that cross PBL models and that can be captured in three approaches: learning, contents and social.

- **Cognitive learning:**
  - Problem
  - Project
  - Experience
  - Context

- **Collaborative learning:**
  - Teams
  - Participant directed

- **Contents:**
  - Interdisciplinary
  - Exemplary
  - Theory and practice including research methodologies

![Figure 1. PBL learning principles](image)

The cognitive learning approach means that learning is organized around problems and will be carried out in projects. It is a central principle for the development of motivation. A problem (a wonder, an anomaly, contradiction, needs, etc.) makes the starting point for the learning processes, places learning in context, and bases learning on the learner’s experience. The fact that it is also project based means that it is a unique task involving more complex problem analyses and problem-solving strategies and that there is a timeframe to consider such as a deadline.

The contents approach especially concerns interdisciplinary learning, which may span across traditional subject-related boundaries and methods. It is an exemplary practice in the sense that the learning outcome is exemplary to the overall objectives of the curriculum. Normally, the problem approach supports the relationship between theory and practice by the fact that the learning process involves an analytical approach by using theory in the analysis of problems and problem-solving methods. Furthermore, this is a training of research methodologies.

The social approach is team-based learning. The team-learning aspect underpins the learning process as a social act where learning takes place through dialogue and communication. Furthermore, the students are not only learning from each other, but they also learn to share knowledge and organize for themselves the process of
collaborative learning. The social approach also covers the concept of participant-directed learning, which indicates a collective ownership of the learning process and, especially, the formulation of the problem.

Defining PBL as PBL learning principles allows variation in the development of PBL models and allows them to be adjusted to a given institution. Special considerations should also be made in terms of educational goals, social, cultural, political and economic traditions, as well as educational and institutional cultures. What is going on at Aalborg University, Delft University of Technology or any of the other universities can never be copied, but the concrete model can give inspiration for curriculum development in other parts of the world.

However, there is no logical deduction from the theories to the model level – on the contrary, history shows that the models have been developed by ideas, trial and error, theoretical understanding and new experiments. Therefore, formulation of core-learning principles can only lead at the strategically curriculum level and there is a need for more concrete tools at the curriculum level.

3. PBL MODELS

The learning principles unify the problem-based and project-based approaches and create a risk of not being able to distinguish degrees of PBL. If PBL is one single course assigned a few credit points it might be hard to compare it to an entire university practising PBL. In each case, every practice might not fulfil the PBL learning principle to the same degree. Therefore, there is a need for PBL models to graduate the specific practice. It might not be possible to develop PBL models or taxonomies that cover the full picture of PBL since PBL has many variables and layers throughout the educational system, however, by giving an overview, awareness of the PBL practices might be increased. Therefore, it is beneficial to develop taxonomies for diverse PBL practices – or at least to conceptualise the dimensions for variation.

4. TAXONOMY FOR PBL IN COURSES

As early as 1986, Barrows developed a taxonomy identifying different varieties of PBL. He wrote:

“The increasingly popular term ‘problem-based learning’ does not refer to a specific educational method. It can have many different meanings depending on the design of the educational method employed and the skills of the teacher.”

He developed the following taxonomy for categorising PBL practice – especially in medicine:
- Lecture-based cases: cases used to demonstrate the relevance of information provided by lectures
- Case-based lectures: cases are used to highlight material that will be covered in the subsequent lecture
DIVERSITY OF PBL—PBL LEARNING PRINCIPLES AND MODELS

- Case method: cases are studied in preparation for class discussion
- Modified case-based method: cases provide opportunities for deciding between a limited number of options
- Problem-based learning: cases are used in a problem simulation format that encourages free inquiry
- Closed loop, or reiterative, problem-based learning: a reflective phase complements the problem-based format

This taxonomy range shows how cases can illustrate points on one end to a more open and reflective PBL approach on the other end—so it is a question of teacher control versus student control. But it is also important to stress that this taxonomy only addresses the course/unit level and does not address the programme/educational/institutional level. So it is a taxonomy developed for analysing and developing cases in the classroom. It does illustrate the range of cases that can be used and the variation in how to use these cases as part of the students’ learning process and the lecture’s teaching process. There is quite a difference between using cases as illustrations for some predefined points and letting the students define their own problem.

5. FIVE PBL MODELS

Savin-Baden proposes different models of PBL covering the objective of PBL, and include the perception of knowledge, learning, problems, students, the teacher roles, and the assessment, (see Figure 2). These modes conceptualise five different aligned models of PBL practice, although the starting point is clearly the epistemology of the problem. Savin-Baden’s five PBL modes are: attainment of knowledge, PBL for professional work, PBL for interdisciplinary understanding, PBL for cross-discipline learning and PBL for critical competencies (Savin-Baden, 2000; Savin-Baden, 2007).

Compared to Barrows (1986), Savin-Baden’s models are rather comprehensive and encompass indirectly an alignment of the various elements in the model. They stress that it is not possible to have, for example, open-ended problems that address knowledge objectives such as propositional knowledge. The learning objectives have to be aligned with the correct types of problems, learning processes, as well as facilitator roles and assessments.

The six dimensions in the five models stress the important point, that implementing PBL is not only a change of learning methodology—but indeed a combination of learning methodology, knowledge construction and scientific approach. Therefore, a change to a full-scale PBL has an impact on scientific approach, mostly in the sense that student learners are being trained to use research methodologies and question the propositional knowledge derived from academia. Analysing problems and solving problems involves pragmatism in the relationship between theories and practice, as well as in the development of creating theoretical and analytical understanding across existing knowledge boundaries.
| Model I Problem-based learning for epistemological competence | Knowledge: Propositional knowledge  
Learning: use of propositional knowledge  
Problem scenario: limited problems with known solutions  
Students: are receivers of propositional knowledge  
Facilitators: guide to understand the correct knowledge  
Assessment: test of knowledge according to objectives |
|---|---|
| Model II Problem-based learning for professional action | Knowledge: know-how  
Learning: skills for workplace  
Problem scenario: real life  
Students: learning to solve real problems in order to undertake practical action  
Facilitators: demonstrator of practical skills  
Assessment: test of skills for the workplace and supporting knowledge |
| Model III Problem-based learning for interdisciplinary understanding | Knowledge: a cross between know-how and know-what  
Learning: knowledge and skills across discipline boundaries  
Problem scenario: centred around knowledge with action  
Students: integrators across boundaries  
Facilitators: coordinator of skills and knowledge across boundaries  
Assessment: skills and knowledge in a relevant context. |
| Model IV Problem-based learning for trans-disciplinary learning | Knowledge: to understand existing boundaries  
Learning: critical thinking and understanding discipline borders  
Problem scenario: dilemmas  
Students: independent thinkers with a critical stance  
Facilitators: flexible  
Assessment: opportunity to demonstrate integration across disciplines |
| Model V Problem-based learning for critical contestability | Knowledge: contingent, contextual and constructed  
Learning: interrogation of frameworks  
Problem scenario: multidimensional, offering alternative ways of understanding  
Students: explorers of underlying structures and beliefs and developing new hypotheses and knowledge  
Facilitators: commentator, challenger and decoder of cultures, disciplines and traditions  
Assessment: open-ended and flexible |

Figure 2. Models of Problem-Based Learning. (Based on both Savin-Baden, 2000 and Savin-Baden 2007)
6. MODEL FOR PROBLEM AND PROJECT BASED ALIGNMENT

With inspiration from Savin-Baden’s five models, we have developed the following model for the elements that must be aligned in a problem and project-based curriculum. This approach is much more comprehensive since students on teams collaborate on a common project. Therefore, the nature of the problem plays an important role along with how the projects and teams are organised.

Figure 3 illustrates a model which gives an overview of the various elements that are important and which are to be found in the articles in this book. We have identified the following seven elements: objectives and knowledge, types of problems and projects, progression and size, students’ learning, academic staff and facilitation, space and organisation and, finally, assessment and evaluation. All these elements are elementary in a curriculum and all elements must be aligned.

The principle of alignment is based on a holistic understanding. If there is a change in one element it will effect change in all the other elements as well. However, with Savin-Baden’s five models in mind, there will be a spectrum of possibilities for each element. Each of these spectra can be helpful in clarifying the specific PBL practice. Many of the practices will be in between the extreme points – but if the practice reflects a zigzag line through all the elements, it symbolises a missing alignment in the specific PBL model.

Figure 3. PBL Alignment of elements in the curriculum
The left side of the following list expresses the open-problem based and learner-centred approach, whereas the right side represents the teacher-controlled approach.

<table>
<thead>
<tr>
<th>Curriculum element</th>
<th>Discipline and Teacher-controlled approach</th>
<th>Innovative and learner-centred approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives and knowledge</strong></td>
<td>Traditional discipline objectives</td>
<td>PBL and methodological objectives</td>
</tr>
<tr>
<td></td>
<td>Disciplinary knowledge</td>
<td>Interdisciplinary knowledge</td>
</tr>
<tr>
<td><strong>Type of problems and projects</strong></td>
<td>Narrow</td>
<td>Open</td>
</tr>
<tr>
<td></td>
<td>Well-defined problems</td>
<td>Ill-defined problems</td>
</tr>
<tr>
<td></td>
<td>Disciplined projects</td>
<td>Problem projects</td>
</tr>
<tr>
<td></td>
<td>Study projects</td>
<td>Innovation projects</td>
</tr>
<tr>
<td></td>
<td>Lectures determine the project</td>
<td>Lectures to support the project</td>
</tr>
<tr>
<td><strong>Progression, size and duration</strong></td>
<td>No visible progression</td>
<td>Visible and clear progression</td>
</tr>
<tr>
<td></td>
<td>Minor part of the curriculum</td>
<td>Major part of course/curriculum</td>
</tr>
<tr>
<td><strong>Students’ learning</strong></td>
<td>No supporting courses</td>
<td>Supporting courses</td>
</tr>
<tr>
<td></td>
<td>Acquisition of knowledge</td>
<td>Construction of knowledge</td>
</tr>
<tr>
<td></td>
<td>Collaboration for individual learning</td>
<td>Collaboration for innovation</td>
</tr>
<tr>
<td><strong>Academic staff and facilitation</strong></td>
<td>No training</td>
<td>Training courses</td>
</tr>
<tr>
<td></td>
<td>Teacher-controlled supervision</td>
<td>Facilitator/ process guide</td>
</tr>
<tr>
<td><strong>Space and organisation</strong></td>
<td>Administration from traditional course and lecture-based curriculum</td>
<td>Administration supports PBL curriculum</td>
</tr>
<tr>
<td></td>
<td>Traditional library structure</td>
<td>Library to support PBL</td>
</tr>
<tr>
<td></td>
<td>Lecture rooms</td>
<td>Physical space to facilitate teamwork</td>
</tr>
<tr>
<td><strong>Assessment and evaluation</strong></td>
<td>Individual assessment</td>
<td>Group assessment</td>
</tr>
<tr>
<td></td>
<td>Summative course evaluation</td>
<td>Formative evaluation</td>
</tr>
</tbody>
</table>

Figure 4. Spectra of PBL curriculum elements

In figure 4, the extremes are defined as discipline. The teacher-controlled approach is on one hand and the innovative and learner-centred approach is on the other hand. In between each extreme of the dimension there are many points – and there might even be many more dimensions combined with each curriculum element. The intention is not to cover the PBL practices completely, but to indicate that there is a lot to consider in a PBL implementation process and a lot of variation in PBL practices.

6.1 Objectives and Knowledge

Savin-Baden (2000; 2007) addresses the variation in knowledge as an important element in defining the five models. In her models, the extremes are propositional
knowledge and contingent, contextual and constructed knowledge. The dimensions that we have chosen for this element are more or less the same, however, phrased differently by disciplinary objectives and knowledge and methodological objectives together with interdisciplinary knowledge (Christensen et al., 2006). From an engineering perspective, the disciplinary and interdisciplinary perspectives play important roles since most innovation is based on cross disciplinary, interdisciplinary and collaborative knowledge.

6.2 Type of Problems and Projects

Graaff and Kolmos (2003) define various problem definitions and project types. On the one side, there are the better defined problems – often within a discipline and with well defined answers – and discipline projects. On the other side, there are the open and ill defined problems along with the more interdisciplinary approach as well as more open-problem projects where the answer and solution are unknown to either the facilitator or the students.

Discipline projects can be regarded as study projects – with clear subject objectives – and the learning objectives are that the students learn the predefined scientific knowledge. In the opposite extreme, there are the problem projects based on open-ended problems without solutions. These can be seen as kind of innovation projects (Nielsen et al., 2008). Innovation projects are based on collaborative and interdisciplinary knowledge.

Lecturing is still part of PBL curriculum – no matter at which point on the PBL scale. However, there is a clear difference; in one the objectives are defined based on the content of the lectures and the project is more or less a question of applying the taught knowledge, and in the other the lectures support the projects. If the project is on developing some new innovation based on cross disciplinary knowledge, the lectures have to support the projects. This means that the curriculum objectives are formulated as more general methodological objectives that address the learning in problem/innovation projects and supporting lectures.

6.3 Progression, Size and Duration

Savin-Baden and Major (2004) has formulated five different modes of progression which are examples of either parallel PBL curriculum to traditional curriculum, as elements spread out all over the curriculum or as learning objectives and PBL models becoming more and more interdisciplinary and complex during the study. Indeed, there are many ways of formulating the progression – the point is not to point at one particular strategy, but to an awareness in the system of the progression in order to plan for efficient student learning.

Part of the progression is also the amount of time allocated to PBL – is it 20% to 80%? Students’ learning outcomes will depend on this factor due to the fact that learning takes time.
6.4 Students’ Learning

Students’ attitude, experience and skills are important to address and it is necessary to establish supporting courses on collaboration, team work, project management, etc. Normally, students have only experienced individual learning and they do not know how to handle more collective and collaborative knowledge processes. When students do not know how to do things, a natural reaction is either to develop a negative attitude or to fight to learn. However, to facilitate the learning process and develop awareness of the importance of these types of skills, it should be addressed in the curriculum.

Part of students’ attitude is also based on the approach to learning. Do they expect to be told by academic staff and acquire knowledge or do they expect to construct their own collaborative knowledge through a process of innovation (Nielsen et al., 2008)? Do they collaborate for the purpose of acquiring individual knowledge or do they collaborate for the purpose of constructing collective knowledge? In PBL curricula, there are many dimensions of this – and it is important to align the elements of students’ learning with the curriculum objectives and notion of knowledge.

6.5 Academic Staff and Facilitation

In any educational change process, academic staff may be the most critical component, and it is important to provide training for the staff. A core element in the training of staff will be the supervision/facilitator role (Kolmos et al., 2008a; Kolmos et al., 2008b) and how to handle interaction with the students. What should be done when there are conflicts in the group? When the students want to kick someone out? Etc. All of these issues have to be discussed and academic staff need to learn new skills in order to handle issues like these.

6.6 Space and Organisation

Graaff and Kolmos (2007) point out that the organisation has to support the curriculum and that space is an issue for facilitating PBL teams in their work. However, space and organisation can be organised in many different ways. Space can be organised in a big lecture room with movable walls and maybe in combination with virtual space. Organisations do not have to change completely from the traditional system, but the access to expertise knowledge and re-organisation of resources are important issues.

6.7 Assessment and Evaluation

In chapter 6 in this book, Holgaard and Kolmos present results from a research project on comparing individual and group assessments. They point out that different assessment methods assess different types of knowledge and skills. 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.

7. COURSE OR SYSTEM APPROACH

Finally, it is important to address the difference between the course and the system levels. In principle, the course level could be related to the more left side of figure 3 and the system level to the right side with its more learner-centred approach. Especially for many of the extremes on the right side in figure 3, it might be very difficult to practice these in a more narrow course design, however, it is not given that this relationship will always exist.

The course approach is typically used in the traditional system where there are parallel courses. The lecture decides on the specific learning objectives and the teaching and learning methods. This means that students in principle can participate in three PBL courses in parallel or a mix of traditional and PBL courses. The course approach is not coordinated at the system level and all the PBL introductions might be taught several times or not at all.

Figure 5: Course or system approach to PBL

The system approach is a much more organised approach where the lectures from the 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. A system level also 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. To get to this level involves a process of change at the systemic level (Graaff and Bouhuijs, 1993; Graaff and Kolmos, 2007; Conway and Williams, 1999) involving the training of academic staff (Kolmos et al., 2008). The system level allows alignment of more student-centred learning.

8. CONCLUSION

In this article we have pointed out the necessity of both unifying abstract learning principles on the one hand and taxonomies and models for addressing the concrete curriculum on the other. As globalisation develops and especially as higher education is oriented towards new innovative learning methods, there is a need for transformation and adjustment to cultural and institutional needs. The only way to transfer ideas from one culture or institution to another is by extracting the core learning principles. This has been done by defining the PBL learning principles.

But along with a definition of learning principles, there is a growing need for conceptualising the variation in the curriculum design in order to be able to develop adequate curricula, to analyse diversity in the existing PBL curricula and, not at least, to be able to compare research results based on PBL curricula.

Therefore, this article both has presented the core learning principles and a PBL alignment curriculum model based on seven curriculum elements each with a number of dimensions. Each dimension is formulated on a spectrum with two extremes. The main message is that according to educational theory, it is important that the PBL curriculum encompass an alignment among all the curriculum elements. This could be a theoretical starting point for most PBL research in order to identify the coherence among curriculum elements in the PBL practice and especially to study the impact of a chosen practice on students’ learning and students’ outcomes. In order to improve and develop the existing PBL practice and knowledge on the impact of PBL curricula, these research questions are important to study.

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DIVERSITY OF PBL—PBL LEARNING PRINCIPLES AND MODELS


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