Problem Based Learning in Engineering Education

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Abstract

Problem based learning (PBL) has gained widespread approval as a student centered and student activating approach to teaching and learning. At Aalborg University this approach has been applied since the foundation of the university in 1974 and the so called Aalborg model has to some extent been developed through 'learning by doing'. In recognition of the long experience with PBL the university was in 2007 granted a UNESCO Chair in Problem Based Learning in Engineering Education (UCPBL) one of the aims of which is to disseminate information about PBL worldwide.The hands-on session at ALE 2014 is aiming towards fulfilling this aim.

Keywords – Educational change; problem based learning; interdisciplinarity; generic competences.

1 Introduction

Problem based learning (PBL) has gained widespread approval as a student centered and student activating approach to teaching and learning. The learning process in a PBL environment takes its point of departure in an ill-structured real-life problem – and this approach has a very strong motivational impact on students' learning processes. One of the recognized strengths of PBL is that, apart from professional engineering competences, students also develop methodological competences in areas such as project management, team work, negotiation, communication, problem solving etc.

The process of change from a traditional learning environment that is teacher centered and teacher controlled to a PBL learning environment that is student centered and (at least partly) student controlled is a process that incorporates a number of elements, such as curriculum development, staff development and institutional development. It is a time consuming and complex process which, if carried out appropriately, can, however, lead to great benefits for all stakeholders in engineering education: students, teachers, institutions, companies and society at large. Therefore, in this paper I will discuss the change process and go into details with some of the elements of change

The first section of the paper is this introductory part. In the second section the change process at large is described and important aspects of the process are discussed. The third section goes into details with the most important element of change, the development of a new curriculum based on PBL. In the fourth section four different models of PBL are described in some detail, while the fifth section discusses the change seen from a teacher's perspective. In the sixth and last section a short conclusion is found, together with recommendations for change to PBL.

2 The Change Process

In this section the process of change from a traditional learning environment to a PBL learning environment will be discussed. Included in the discussion are different aspects of the change process, such as reasons for change, elements of change, strategies for change, factors influencing change and patterns of change.

2.1 Reasons for Change

When discussing educational change it is worthwhile to reflect on reasons for introducing change in engineering education. Reasons that are found in many institutions worldwide are, f.ex.:

- High demand from industry and society in general for engineering graduates with new professional competences in areas such as project management, team work, intercultural communication etc.
- (Too) low employability of engineering graduates due to lack of above mentioned competences and irrelevant curricula being taught in the educational institutions
- Lack of motivation among students, leading to
- High drop-out rates and thus inefficiency in the educational system

While some of the reasons for undertaking an educational change process do vary from institution to institution and from country to country, the growing demand for engineering graduates that are capable of handling the major technological and ecological challenges, taking into consideration the accompanying social and economic challenges, is one major reason for educational change that should be common to all engineering institutions throughout the world.

2.2 Elements of Change

An educational change process should by necessity include at least the following three elements:

- Curriculum development
- Staff development
- Institutional development.

To the above elements may be added a process of 'student development', i.e. preparing students for the change of role of all parties involved in the educational process, including the students themselves. Figure 1 illustrates the different elements of the change process.

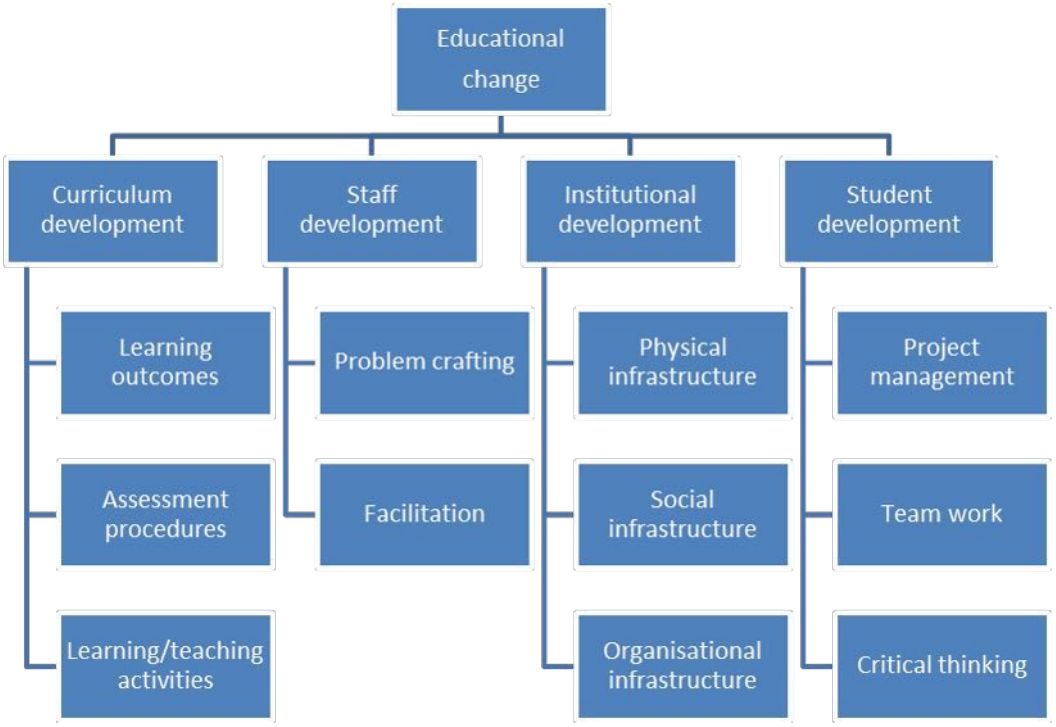

Figure 1: Elements of an educational change process

The curriculum development process consists of developing the new curriculum, including learning outcomes, assessment and learning and teaching activities. The staff development process has as its main focus to prepare teachers, emotionally as well as cognitively, for the changes that take place in their roles as teachers when shifting from a traditional teacher controlled educational approach to an approach that is student centered and (to varying degrees) participant controlled. Included in the institutional development are processes of change in, f.ex. the lay-out and use of physical infrastructure of the institution, the social infrastructure in the form of student support systems and students' access to learning resources etc. Student development may include, among others, training in project management, team work, critical thinking etc.

2.3 Strategies for Change

When observing educational change processes around the world, one can see that in some places the strategy applied is a top-down strategy where management decides to introduce PBL without much involvement of staff in discussions, decision-making and training. In other places a bottom-up strategy is applied where one or a few very committed staff members may decide to introduce PBL within their own teaching, without any support from top management. Neither strategy is recommendable if the change is to be sustainable.

The top-down strategy has the advantage that change is indeed introduced, but with a reluctant and hesitant staff who has received (too) little training in preparation for the change, the chances are that 'resistance to change' takes over

and the actual teaching delivered is not in accordance with what was envisioned by management. The bottom-up strategy has the advantage that a change, true to the spirit of PBL, may indeed be introduced, but because it is very dependent upon few people the change may often fade out and teaching may return to the traditional approach when the committed staff member(s) eventually gives up, either due to change of position or due to fatigue.

The recommendable strategy is a combination of top-down and bottom-up: The top-down managerial support for the change and the existence of committed and dedicated staff members who with the support of management can initiate sustainable change from the bottom-up. The change process may possibly start within one department and then eventually spread to other departments, once the results start proving the value of the change.

2.4 Factors Influencing Change

According to Thousand and Villa (1995) the following 6 factors should be present in order to achieve successful change: Visions; consensus; skills; incentives; resources; action plan.

Within the institution that is aiming to undertake an educational change process, top management are responsible for formulating the **visions** and for creating the **consensus** among staff and managers at all levels, while middle level management may be in charge of formulating an **action plan** together with committed staff members who are keen to be part of the change process.

While awareness raising workshops and seminars about the change process should be arranged for all personal, management and teachers alike, those staff members interested in being directly involved in the teaching of the new curriculum should be more intensively trained in order for them to achieve the **skills** necessary to function effectively in a PBL environment. **Incentives** should be provided to participating staff, whether teachers or management, in a format suitable for the particular institution and department. Of course the **resources** needed to prepare for the change should be in place which is a joint responsibility of top and middle level management.

2.5 Patterns of Change

Very few existing institutions are in a situation where they can ‘wipe the board clean’ and start planning a complete curriculum from scratch. Therefore, in most cases change has to be a gradual process, starting on a small scale and gradually spreading from course to department to institution. Thus, one way of getting started with the change to PBL is by introducing a short problem oriented project or case as a student activity at the end of an already existing course. If the professional contents of the course is sufficiently broad it may be possible to identify a suitable real-life problem, the solution of which can be worked out by mainly drawing upon the theories and methods from within the one course, i.e. a disciplinary project or case.

A better approach is to draw upon professional contents from two or more courses from within the same or related fields of engineering for the solution of an identified real-life problem, i.e. introduce an interdisciplinary problem. The reason why the interdisciplinary problem is to be preferred over the disciplinary problem is that real-life problems by nature are interdisciplinary – disciplines exist in academia but not in real life.

This interdisciplinary approach does, however, often present a difficulty in many institutions where teachers are used to consider teaching a ‘private’ activity which is not shared or discussed to any significant degree with colleagues. Thus, for interdisciplinary teaching to occur teachers have to collaborate across disciplinary borders and jointly identify suitable real-life problems drawing upon theories and methods from disciplines involved - and possibly also upon theories and methods from other disciplines that students may have to study on their own.

Given that one of the main reasons for changing to PBL is the motivational impact that PBL has on students, the introduction of real-life interdisciplinary problems should preferably take place at the very beginning of the study and the teaching period. In this way the students’ motivation and interest will be aroused from the beginning, (s)he will pay more attention to what is being taught and (s)he will learn better because the purpose of the learning is known: the solving of the problem.

2.6 Summary

In this section the process of educational change from a traditional teacher-centered and teacher-controlled environment to a PBL environment has been discussed. Reasons for change, elements of change, strategies for change, factors influencing change and patterns of change have been discussed. In the ALE 2014 hands-on session one of the topics presented will be educational change and participants will discuss potentials and barriers for change within their own institutions.

In the next section one of the important elements of change: Curriculum development for PBL will be discussed in more detail.

3 Curriculum Development for PBL

In this section the important process of curriculum development, i.e. designing a new PBL curriculum, including formulation of learning outcomes, design of assessment procedures and planning of learning and teaching activities to support students in achieving the learning outcomes, will be described and discussed. The curriculum development model described will automatically lead to achievement of constructive alignment, a principle applied in high quality curriculum development that will also be discussed in this section.

3.1 The Logical Curriculum Development Model

According to Cowan (2003) most often a traditional 'input-oriented' curriculum development process is a chronological process, proceeding from a definition of teaching aims to planning the teaching activities which are then delivered and eventually the assessment of students follows at the end of the teaching. In contrast to this chronological model the curriculum development model presented here is a cyclical and logical model developed by Cowan and Harding (Cowan, 2003).

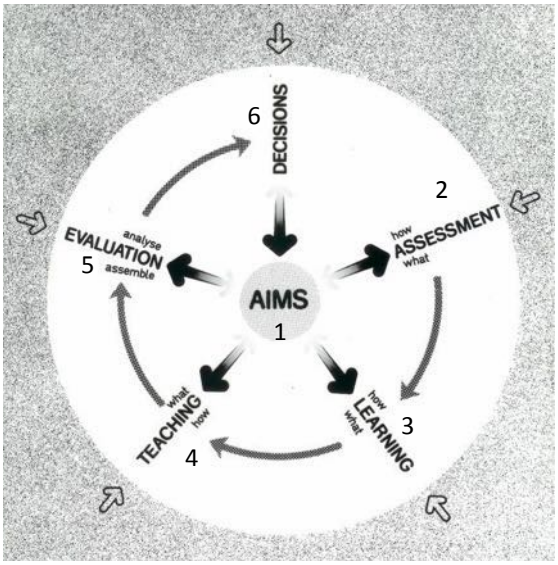

Figure 2: The logical curriculum development model by Cowan and Harding (Cowan, 2003)

According to this model which is shown in Figure 2, curriculum development is a process with six steps:

1) The first and most important step is to formulate the aims, i.e. the teaching objectives and the intended learning outcomes, in clear and specific language and communicate these to the students
2) Second step is to design the assessment, including the form of assessment as well as the contents
3) The third step in the process is to identify students' learning needs, either by anticipating such needs or by responding to students' expressed needs
4) Only after having carried through the first three steps comes the fourth step of planning of teaching activities directed towards fulfilling students' learning needs
5) The fifth step is evaluation, formative and summative, of the teaching and of students' learning experiences, by collecting data from students, peers, examiners etc.
6) The sixth and final step in this cyclical curriculum development process is to make decisions about revision of the curriculum, based on the data collected through the evaluation.

The curriculum development model described above is not specifically related to a PBL setting. It is, however, specific to an outcomes-based or competence-based educational approach, such as PBL, in so far as the (learning) outcomes which are identical to the competences that students are expected to achieve as a result of the teaching process, are in focus throughout the curriculum development process. As such it is a model with focus on student learning rather than on teaching.

In the situation where any one of the intended learning outcomes deals with students' competences to identify, formulate and solve complex and real-life problems, the same curriculum development model should of course be applied and processes of designing assessment, identifying learning needs and designing teaching activities that will enable students to achieve such a learning outcome would be part of the curriculum development process.

3.2 The Principle of Constructive Alignment

Applying the logical curriculum development model by Cowan will automatically lead to fulfilling the important principle of constructive alignment (Biggs, 2003), ie. alignment between learning outcomes, assessment procedures and contents and the actual learning and teaching activities carried out by students and teachers. This important principle which – if adhered to – secures high quality teaching, is illustrated in Figure 3.

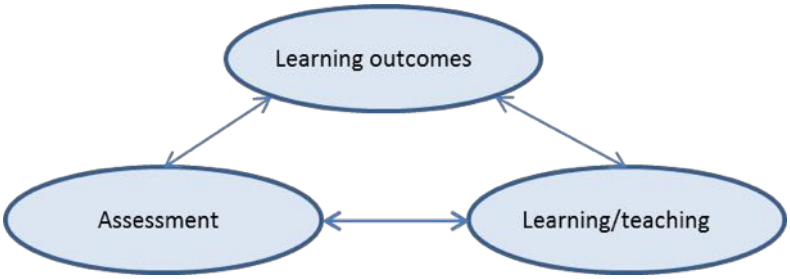

Figure 3: The principle of constructive alignment (after Biggs, 2003)

An interesting discussion in connection with the principle of constructive alignment is to which extent there is a conflict between this principle, according to which intended learning outcomes are formulated by the teacher, and the learning theory of constructivism which states that learning is the individual student's process of constructing knowledge based on information inputs. Another interesting discussion is to which extent there is a potential conflict between the teacher-controlled intended learning outcomes and the procedures in a student centered, participatory learning environment where students have a determining influence on the topic of learning, such as is the case, f.ex., in a problem oriented project or case. Neither of these discussions will, however, be taken up in this paper.

In the ALE 2014 hands-on session one of the topics presented will be curriculum development according to the logical model by Cowan and participants will be discussing the use of the model within their own institutions. Another topic presented will be assessment, more specifically assessment of higher level competences selected by participants among a range of competences.

3.3 Summary

The most important element in a process of educational change to PBL is the development of a new curriculum which is student-centered and focuses on students' learning processes. This curriculum development process should be carried out in accordance with the logical curriculum development model presented in this section. In the process the learning outcomes are at the center of the efforts, securing that the principle of constructive alignment is adhered to.

The next section presents four different PBL models applied in four different institutions throughout the world.

4 PBL Models in Practice

PBL is not a certain prescribed method of teaching and learning. Many universities around the world are practicing one or another model of PBL and no university can claim that their PBL model is the 'right' or the 'best' way of practicing PBL; any educational approach, including PBL, is contextual and depends upon the given university and its context. In this section four different models of PBL will be presented: The PBL model implemented in University of Brasilia; the Republic Polytechnic model with 'one problem per day', the Maastricht model with 'one problem per week' and the Aalborg model with 'one problem per semester'. The models will be described and compared.

4.1 University of Brasilia, Brazil

In Brazil the University of Brasilia may well have been the first university in the world that applied a PBL teaching and learning approach. The university was established in 1960 and started teaching in 1962. The two main aims of the university were: 1) To help solve developmental problems of Brazilian society and 2) to counteract the scientific dependency upon the West. Some of the main characteristics of the university were as follows:

- Problem solving
- Interdisciplinarity
- Experimentation
- Integration of research and teaching
- Critical, incl. self-critical approach to teaching and research
- Collaboration with society

Unfortunately, the university was closed down after the military coup in 1964 and the university population of dedicated and committed teachers and students were killed, jailed, dismissed or fled into exile. Some of the exiled teachers came to Bremen in Germany and here they were assisting in founding a new university that applied PBL. When the two Danish PBL universities (Roskilde University and Aalborg University) were established in 1972, resp. 1974, study tours to Bremen University were part of the preparation and planning.

4.2 University of Maastrict, the Netherlands

In the Netherlands the University of Maastricht (UM) is probably the most famous of the PBL universities. It has been applying PBL since its founding in the early 1970ties. The Maastricht model described below is from the Medical School. Some of the main characteristics of the Maastricht model are:

- Learning based on problems and case studies (= real patient records)
- Integration of disciplines and skills
- Interdisciplinarity secured via interdisciplinary teams of teachers responsible for thematic blocks.

The structure of the curriculum is based on interdisciplinary thematic blocks of 6 weeks duration. Each block contains 6 cases or problems, i.e. one problem per week, with all 6 problems being related to the theme of the block. The students collaborate in tutorial groups of between 8 and 10 students per group. They meet regularly in their tutorial groups, to discuss the problem within the group and with their non-expert tutor who guides the group process, asks facilitating questions, shares his/her knowledge and generally supports the students in the learning process.

One of the well-known elements of the Maastricht model is the so-called seven-step model that describes students' work processes in the tutorial group:

1) Clarifying terms and concepts not readily understood
2) Defining the problem
3) Analysing the problem
4) Summarising the various explanations of the problem into a coherent model
5) Formulating learning outcomes
6) Studying individually
7) Reporting and synthesizing the newly acquired information.

Steps 1 – 5 serve as a preparatory phase within the tutorial group for the individual self-study in step 6. After being presented with the problem or case, in steps 1 to 3 the students are expected to elaborate on their prior knowledge in order to come to understand the problem to such an extent that they are able to summarize explanations of the problem in step 4. In the course of this process the students come to realize what they already know and what important information about the problem they still need to acquire and thus they are able to formulate learning outcomes in step 5. These learning outcomes are then guiding the information pursued during the self-study in step 6. The newly acquired insights from the self-study are presented in the next tutorial group meeting, i.e. in step 7, and the seven-step model may be applied a second time around.

A high degree of self-directed learning takes place and skills training and practice oriented sessions are also included in the curriculum. By the end of a thematic block individual examinations are carried out and also individual progress examinations are being held regularly.

4.3 Republic Polytechnic, Singapore

Republic Polytechnic (RP) in Singapore was established in 2002 and was the first institution in Singapore to deliver PBL throughout all its educational diploma programmes. The visions of RP are that their graduates should be:

- Knowledgeable (understand, share, apply)
- Inquirers and thinkers with ability to reason
- Open minded, risk takers and decision makers

- Communicators and negotiators,
- Teamworkers
- Caring and tolerant individuals with a balanced outlook and good values
- Learning-enabled

The RP portfolio includes a total of 7 diploma programmes, each with a duration of 3 years or 6 semesters. Each programme consists of 30 modules. One semester lasts 16 weeks, with 5 modules per semester.

The students in a given programme are divided into classes of 25 students per class, subdivided into 5 teams of 5 students. A facilitator is assigned for the day to each class and a problem is presented by the facilitator in the class in the morning. Since each week contains 5 studying days, this gives a total of 5 different but related problems per week. The schematic for a student's day in RP is shown in figure 4.

Sessions	**Activities and actors: f=facilitator, s=students**
First meeting (1 hr)	Presents problem trigger + scaffolding (f) Analyse problem (f + s) Identify known – unknown - learning needs (f +s) Assign research duties (s)
First break out (1 hr)	Search, select, structure information (s) Make meaning (s)
Second meeting (1 hr)	Discuss progress and difficulties (s + f) Helps develop learning strategies (f)
Second break out (2 hr)	Review resource materials (2) Peer teach each other (s) Prepare presentations (s)
Final meeting (1 hr)	Present outcomes – discuss, justify, defend (s) Presents 'the sixth outcome' (f)
Assessment (½ hr)	Do an individual written quiz (self assessment, s) Write in personal reflective learning journal (s)

Figure 4: The daily procedure for students in Republic Polytechnic, Singapore.

There are similarities between the RP model and the UM seven-step model, for example, in the identification of known and unknown and the formulation of learning needs and learning outcomes.

In terms of assessment in RP, a written self-assessment quiz is made by each student by the end of each day and a total of 4 'understanding tests' per module and per semester are carried out during the semester.

4.4 Aalborg University, Denmark

Aalborg University (AAU) was established in 1974 and has been applying the problem oriented and project organized team work approach in engineering education since the beginning. The present organization of the study programmes within the Faculty of Engineering and Science is as follows:

One semester lasts 20 weeks, of which 15 weeks are scheduled teaching and studying time while the remaining 5 weeks are time for self-study and preparation for examinations. One semester is credited with 30 ECTS (European Credit Transfer Systems points), with 1 ESCT being approximately equal to 30 hours of study time for an average student, i.e. one semester is equivalent to a total of approximately 900 study hours. Half of this time, i.e. 450 hours is spent on the problem oriented project work that students carry out in groups of between 6 – 7 students in the beginning of the programme and 1 – 3 students by the end of the programme.

The other half of the study time is spent on course work, with three courses of 5 ECTS, each consisting of lectures and related assignments. The courses in a semester are normally designed so as to support the project work, but this is not a requirement. Project work and course work is scheduled so that the majority of course work is concentrated in the beginning of the semester, while at the end of the semester the project work is dominating the weekly schedule. The project is, however, introduced to the students from the very beginning of the semester.

Concerning projects there are several possible ways of formulating projects. In some study programmes the facilitators prepare a project catalogue and students' groups choose one of the proposed projects. Most often facilitators are also open to proposals from students themselves. In other programmes the students are responsible for formulating the projects after a period of initial introduction to the theme of the semester.

In terms of examination there is a group based oral project examination by the end of the semester, based on the written project report that the students have jointly prepared within the group. Examinations in the courses are also carried out, according to different models in different programmes and courses.

4.5 Summary

In this section four different PBL models have been described. In figure 6 an attempt has been made to compare the three existing PBL models, i.e. RP, UM and AAU while the University of Brasilia model has been left out due to lack of information. The models are compared on a range of different parameters. As illustrated in the figure there are remarkable differences between the three models. However, when listening to students from, for example, RP tell about their daily study and about the competences they gain from this study form, the similarities to statements from f.ex. AAU students about their study and their competences, are striking.

	RP	**UM**	**AAU**
No. of stud.	5	8 – 10	2 – 7
Lectures - problem work	No lectures (?)	Few lectures	½ lectures ½ project
Length of problem work	One day	One week	One semester
Pre-structure of problem	High	Medium	Low
'Teacher' direction	High	Low	Low to medium
Outcome	Presentation learning	Learning	Report, product, presentation learning
Assessment	Individual Daily+'understand'	Individual Block+progress	Group based Courses + proj.

Figure 6: Comparison of three different PBL models.

The main point is that PBL is not one prescribed way of teaching and learning – each PBL model is unique to the institution and to the context in which the institution is operating. No institution can claim to have developed the 'right' or the 'best' PBL model – models are simply different and as long as they follow the principles of PBL they may lead to impressive performance of students. In the ALE 2014 hands-on session one of the topics presented will be different PBL models and participants will discuss suitable models of PBL for their own institution.

5 Staff Development

The role of teachers changes rather dramatically once a change from a traditional to a PBL learning environment has taken place. This section will discuss the process of change seen from the teacher's perspective. Two of the most important tasks of teachers in a PBL environment are crafting of problems that can form the point of departure for the students' learning processes and facilitation of the students' learning processes. These two tasks will be described and discussed in this section.

5.1 Change of Teacher's Role

Seen from a teacher's perspective one aspect of the change process is a change from a teacher controlled teaching situation based on a behavioristic learning theory to a student centered learning situation based on a social constructivist learning theory that states that learning is the student's individual process of constructing knowledge by processing information received from different sources of information and in social interaction with others, such as peers, teachers, experts, stakeholders etc. While it may be easy to intellectually state a belief in the constructivist learning theory, it often turns out to be considerably more difficult to act out this belief in the actual teaching situation.

Assuming that all good teachers genuinely care about their students' learning, the process of letting go of what may be thought to be control of the learning process and handing over this control to the students can by many teachers be perceived as letting go of their professional responsibility in the teaching situation and this loss of control can be mentally demanding and difficult for good teachers. The snag here is that if we truly believe in constructivism we have to realize that as teachers we are never in control of the learning process – only the students themselves can be and are in control here. We have to move away from the psychological mistake about learning:

> *"We pretend that there is co-incidence between what is being taught and what is being learned" (Illeris, 2006, page 245; own translation).*

One way of assisting teachers to take on the role of being a teacher in a PBL environment is to provide adequate skills training and tools to be used in the new environment. Furthermore, based on experience with change processes at Aalborg University, it is recommended to start by directly involving only staff members who are interested in participating in the PBL approach to learning and teaching. In other words, do not try to force any staff members into roles of teaching that they are not confident with and not happy to undertake.

5.2 Problem Crafting for PBL

As mentioned above, two main tasks of teachers in a PBL environment are to craft problems and to facilitate group work. The task of problem crafting will of course depend upon the specific PBL model applied; thus, there is quite some difference between crafting a problem that can be solved within a day and crafting a problem that students will be working with for a semester. In RP, for example, a good part of a teacher's daily work is to craft problems that are suitable for the 'one problem per day' approach applied here, while in AAU problem crafting is a teacher activity that takes place once per semester, and there is a fair degree of re-use of problems, since the students differ from year to year. Another difference between the two institutions is that while in RP the problem is presented to the students together with a so-called scaffolding, i.e. a series of increasingly more open and complex questions that may eventually lead to the solution of the problem, in AAU this work of formulating sub-questions to the overall problem is taken care of by the students themselves. In the ALE 2014 hands-on session one of the topics presented will be problem crafting for PBL and participants will try to craft problems for two different PBL models.

5.3 Facilitation in PBL

Concerning the task of facilitation there are also differences in the functions of the facilitator, depending upon the PBL model applied. The daily tasks of the facilitator in RP can be seen from figure 4. In AAU the tasks of a facilitator vary over the semester, from focus on problem formulation and –analysis in the beginning to focus on the technical solution and the end product in the form of a report and (most often) a technical device later in the project. In order to leave the responsibility for learning with the students, a good facilitator will mainly ask facilitating questions and give

constructive feedback and advise to students' work, but will not attempt to control or direct the flow of work in the project group. Tools that are useful for facilitators in AAU are, for example:

- A contract of cooperation with the students, explicating mutual expectations to the cooperation
- Regular meetings between students' group and facilitator
- Joint formulation of project learning outcomes
- A process analysis at the end of the semester

Armed with such tools the task of being a facilitator in a PBL environment can be eased and chances are that after a short while the teacher will realize the truth of the following quote:

> *"Once anyone is involved as PBL-tutor working with students and has the opportunity of seeing what the students can do* ***when given the permission to think and learn on their own****, he or she usually becomes a convert."* (Barrows, 1996, page 9; emphasis added)

In the ALE 2014 hands-on session one of the topics presented will be facilitation of project work in a PBL environment where participants will perform role plays as students' groups and facilitators, trying out different tools for facilitation.

5.4 Summary

The main point in this section is that for staff to feel confident about a change to a PBL environment and to function well in this environment, adequate training is needed. This training should take place well in advance before the educational change takes place and time should be set aside for staff to discuss and become familiar with their new tasks in the PBL environment. A well-functioning teaching staff is a prerequisite for a successful educational change.

6 Conclusion

The overall topic of this paper was educational change within engineering education. A change to problem based learning may be an expensive and time consuming endeavor but given visionary and supportive management and well-trained, committed and dedicated staff, the change may lead to results in terms of student competences that are worth the effort.

A summary of recommendations made throughout the paper is given here:

- The strategy for change should be a combination of top-down managerial support and bottom-up initiative from dedicated and committed teachers.
- Interdisciplinary collaboration among teachers should be secured in order to provide interdisciplinary real-life problems for students to work with.
- Real-life problems should be introduced early on in the study programme, when the motivational factor is the greatest.
- The logical curriculum development model presented in the paper should be applied for curriculum development for PBL. Using this model automatically assures that the principle of constructive alignment is satisfied.
- A unique PBL model should be developed, suitable for the institution and for the particular context in which this institution is situated, whether cultural, social, economic or otherwise.
- Teaching staff to be involved in teaching the new PBL curriculum should be provided with ample opportunities for discussions and deliberations leading to mental comfort about the change, as well as ample training leading to cognitive skills in mastering the PBL teaching tasks, such as problem crafting and facilitation.
- Only teaching staff who are interested in participating in the delivery of the PBL curriculum should be involved in the first phases of the change – forcing staff to take on teaching tasks that they are not comfortable with does not lead to sustainable change.

Any questions or comments to this paper are very welcome at: mona@plan.aau.dk.

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