

## Problem Based Learning in Engineering Education

### *a Development Option for Africa?*

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*Publication date:*  
2008

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

#### *Citation for published version (APA):*

Dahms, M.-L., & Stentoft, D. (2008). *Problem Based Learning in Engineering Education: a Development Option for Africa?*. Paper presented at The 4th African Regional Conference on Engineering Education (ARCE-2008): 'Capacity Building in Engineering Education for Sustainable Development', Dar es Salaam, Tanzania, United Republic of. <http://www.coet.udsm.ac.tz/arcee2008/>

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# Problem Based Learning in Engineering Education – a Development Option for Africa?

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## Abstract

Increasingly, consensus on the importance of higher education and research for development has occurred among the broad range of stakeholders in the 'development' arena, whether donor governments and organisations or recipient governments, organisations and institutions. Similarly, there is consensus that innovation, especially in the areas of science, engineering and technology are of crucial importance in this endeavour. This recognition should, however, go hand in hand with the recognition of the necessity of curriculum reforms in higher education.

In this paper we will argue that Problem Based Learning (PBL) in higher education is a powerful tool to achieve sustainable development in African countries. With PBL local developmental problems can be brought into the educational sphere thus ensuring that students during their study efforts contribute to local development. Furthermore, PBL increases the creativity and innovativeness of students, thus enhancing the role of universities in national systems of innovation.

**Keywords:** Problem Based Learning;; engineering education; developmental university; curriculum reform

## 1 INTRODUCTION

Recent years have seen a growing awareness that higher education and research in general (WB 2000; Bloom et. al. 2006; DFID 2005) and within science and technology specifically (NEPAD 2001; Utz 2006; AIST 2008) plays an important role in poverty alleviation and in the efforts of poor countries to catch up and become equal partners in the global knowledge economy.

A stream of this discourse on development in the global knowledge economy is centred on the importance of innovation and of the existence of so-called 'national systems of innovation' for development (Masinda 1998). A recent study by the Danish Association of Engineers (IDA) found that in almost 80% of small and medium sized companies in Denmark innovation is spearheaded by engineers (IDA 2004), thus confirming the importance of engineering, science and technology for innovation and technological development. Another study made for the Danish Agency for Science, Technology and Innovation showed that the innovative capacity of small and medium sized companies is greatly enhanced if the company staff is diverse in terms of education, gender and ethnicity (FIST 2007). The study documented that the probability of innovation of a small or medium sized company would increase by 110% if the proportion of women was increased from 25% to 40%, and similarly the innovation probability would increase by 30%, given an increase in ethnicity from 5% to 30% (FIST 2007). Given the fact that African societies in general are far more

diverse than Western societies in terms of ethnicity, African institutions and companies in general and African universities specifically could capitalise on this diversity to enhance and harness the creative and innovative potential of African youth.

One way of enhancing the innovative competences of engineering students, while at the same time harnessing this innovativeness for local development, is to introduce the problem based learning approach proposed in this paper. This approach to teaching and learning has documented its strength as far as innovation and creativity is concerned. Furthermore, it holds a strong motivational factor for students, not only attracting more students than traditional approaches to higher education but also securing lower drop out rates and better performance of so-called 'poor' students. While collaborating on solving an identified problem the students learn to enter into dialogue, to discuss, negotiate and eventually reach consensus and to handle disagreements and solve conflicts in a peaceful way. In a PBL environment there is room to embrace the diversity of African student bodies while still making the education oriented towards the main results: The learning outcomes in form of students' competences and the solutions to developmental problems. Rather than being a specific method of teaching PBL is a philosophical idea based on a certain conceptual perception of learning and a set of core principles. As such PBL is adaptable to almost any context and any level of education.

In September 2007 the United Nations Educational, Scientific and Cultural Organisation (UNESCO) granted to the Faculty of Engineering and Science at Aalborg University, the UNESCO Chair in Problem Based Learning in Engineering Education (UCPBL), in recognition of the longstanding tradition at this university of applying problem based learning. One of the aims of the UCPBL is to promote and support PBL in engineering education worldwide and this paper and the conference presentation is part of efforts to fulfil this aim.

After this introductory section the next section of the paper will attempt to answer the question '*What is PBL?*' by looking at the underlying learning theory and by describing the fundamental principles common to most implementations of PBL. Some of the main claims of PBL proponents focus on the ability of a PBL curriculum to provide more efficient education while at the same time meeting the needs of students as well as of industry. In section three these claims will be discussed and documented, in an attempt to answer the question '*Why introduce PBL?*' Given the multitude of diverse methods of implementation of the PBL approach it would be an impossible task to give a thorough description of all PBL methods. Still, the question of '*How to implement PBL?*' begs an answer which will be provided in section 4 by describing in some detail the Aalborg PBL model, along with one very recent example of a different PBL implementation in a different context. In the generation of relevant and meaningful knowledge a problem based learning approach inevitably leads to closer links between university and society, including issues of social, economic and technological development. In the final section this relationship between PBL and development will be discussed by first discussing the main challenges to higher education in Africa and then relating the advantages of PBL to these challenges specifically and to 'development' in general.

## **2 PRINCIPLES OF PROBLEM BASED LEARNING**

The widespread use of Problem Based Learning (PBL) had led to a proliferation of diverse practices in different educational institutions and within different study programmes throughout the world. Therefore, the question '*What is PBL?*' cannot be unanimously answered. There is,

however, a certain agreement on the core principles of PBL. These core principles will be presented shortly in this section, as will the underlying theory of learning, the so-called 'constructivism'. But first follows a few quotes by educational researchers to illustrate one of the main characteristics of PBL:

**"PBL reflects the way people learn in real life;** they simply get on with solving the problems life puts before them with whatever resources are to hand." (Biggs 2003; emphasis added)

**".... problem-based learning helps students to see that learning and life take place in contexts,** contexts that affect the kinds of solutions that are available and possible." (Savin-Baden 2003; emphasis added)

Thus, one of the most common characteristics of the many diverse practices of PBL is the real-life perspective, illustrated in the above quotes.

Problem based learning represents a radical shift in educational thinking from a teacher-centered approach to teaching to a student-centered approach to learning, i.e. the focus is shifted from the teacher teaching to the students learning. This student-centered learning approach is supported by the learning theory known as 'constructivism' which emphasizes that 'learning' is an individual process of constructing knowledge and meaning, based on individual transformation of experiences. Thus, knowledge is not an objective quantity which can be passed on from one person to another; rather, it is the result of an ongoing individual process of construction, taking place in and through social interaction, negotiation and discussion with peers and with teachers. A crucial quality of the PBL approach is that creation of knowledge does not respect hierarchy or position; instead, the emphasis is on equity in the knowledge creation process. Inputs to the learning processes come from a wide range of different sources of learning, such as books, articles, the Internet, lectures, field studies, data collection, laboratory experiments etc. Given this perception of learning, 'teaching' becomes a task of supporting students in their learning efforts; in other words, teaching is the "setting up of a situation from which a motivated learner cannot escape without having learned" (Cowan 2003).

Concerning the fundamental principles of PBL, de Graff and Kolmos have summarized the literature on PBL and extracted the core principles, categorized under three headings: Cognitive learning; collaborative learning; content (Graaff and Kolmos 200). Supplementing their summary with the principles of critical enquiry, dialogue and democracy (Qvist 2008) the core principles of PBL may be described as follows:

*Cognitive learning:* The learning process takes its point of departure in an identified local *problem* and is often organised as a *project*, i.e. the students work on a unique and complex task limited in time and resources and resulting in an end product in the form of a proposed solution to the problem. Working with real life problems increases the motivation of students and ensures a high degree of student engagement and activity. It furthermore places the learning in a relevant *context*. Students draw upon and integrate their own *experiences* from previous studies and life and they actively work to solve the problem, i.e. the learning is *action-oriented*.

*Collaborative learning:* Since in most PBL practices the students work in groups, collaborative and social learning take place within the *team*. i.e. in accordance with the constructivist learning theory knowledge is constructed in and through social interaction with peers as well as with teachers. During the team work students participate in *dialogue* among themselves and with the teacher, whereby they learn to discuss, negotiate and handle conflicts and disagreements in a *democratic* manner. Furthermore, the students have a high degree of control of their work, since they may either formulate the problem to work with themselves or may choose from a list of proposed problems, i.e. the learning is *participant-directed*, which secures a strong sense of student ownership, thus increasing motivation.

*Content:* While working on identification and analysis of the problem and in order to come up with a viable solution, students have to take into consideration the given problem *context*, including all stakeholders to the problem. This contextualised approach to problem solving necessitates a fair degree of *interdisciplinarity* as well as the ability for *critical enquiry, analysis* and *thinking*. Also, a close relation between *theory and practice* is demonstrated in the project work where students apply theoretical models and methods to develop practical solutions. Furthermore, the project is *exemplary*, i.e. the methodological skills and knowledge acquired by the students during the learning process can be transferred to and applied in other problem solving situations.

Although there is a high degree of consensus on these main principles of PBL the diversity of approaches to putting the principles into practice when implementing PBL is astounding. Before moving on to describing models of implementing PBL we will, however, in the next section attempt to answer the question ‘*Why introduce PBL?*’ One part of the answer deals with the competences developed by students studying in a PBL environment. Another aspect of the answer deals with efficiency of education seen from an institutional perspective while employability of graduates seen from an industrial employer’s perspective is yet another aspect.

### **3 ADVANTAGES OF INTRODUCING PBL**

The advantages of introducing PBL into higher education in general and into engineering education specifically can be seen from the perspectives of different educational stakeholders some of whom are: the students; the faculty; the institutions; the employers; the government. This section will discuss the advantages seen from the perspectives of the first four stakeholders, while advantages seen from a governmental and national perspective will be discussed in the concluding section 5 on PBL for development.

#### **3.1 A Student Perspective**

Students’ main interests in their education are twofold: To have an interesting and motivating time while studying and to acquire competences which will allow them to be able to get a meaningful and rewarding job after graduation. Working with real life problems of importance to people outside the university enhances students’ motivation for studying and makes the learning meaningful. Furthermore, working in groups enhances the learning, because the group is a framework for social interaction, negotiation and discussion, in accordance with the constructivist learning theory and at the same time it decreases drop-out rate. Four statements by students at Aalborg University serve to illustrate these claims:

"When working on a problem, I am strongly motivated and attracted. We need to solve this problem."

"This way of learning is much better than only attending lectures, because I have to know why I need to learn this. When I know the objective clearly, I learn much better."

"I think that it becomes easier when you learn technical matters in groups. Normally we use the blackboard to discuss things.

"Working in groups we get mental support from each other; it is also a responsibility so that we won't drop out easily." (Du 2006)

Furthermore, studying in a PBL environment develops the students' analytical, methodological and social competences, such as: ability for critical thinking and analysis; problem solving skills; project management skills; communication, negotiation and conflict resolution skills; life long learning skills. Such competences are in demand in industry and are related to getting a meaningful job, an issue which will be touched upon later.

### 3.2 A Faculty Perspective

One of the main advantages of PBL seen from a faculty perspective is a closer linkage between research and teaching, i.e. students may work on projects which are derived from the faculty member's own research, thus allowing students to become familiar with research even from an early stage of study. Another advantage is illustrated in this 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, p. xx; emphasis added)

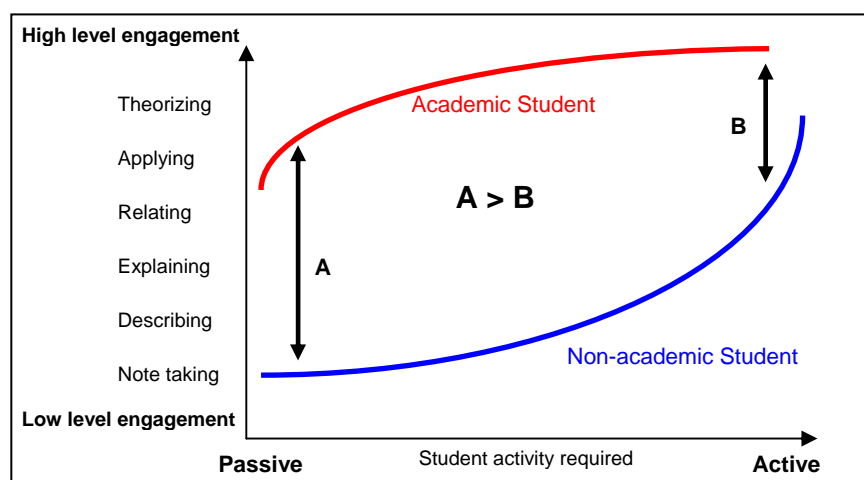
A final advantage to be mentioned is, that if Faculty members themselves are true to the lifelong learning concept - which we should be as researchers and which we often try to encourage our students to be - the chances of learning together with one's students rather than just repeating the same old lecture year by year should be tempting.

### 3.3 An Institutional Perspective

Seen from an institutional perspective one of the most obvious advantages of introducing PBL is more efficient education. Students being more motivated leads to decreased drop-out rates and shorter completion times, thus, less money wasted on unsuccessful students. In a statistical survey performed by Universities Denmark it was found that in the year 2005 the % completion rate, i.e. completing in scheduled time plus 1 year, for engineering students at Aalborg University (AAU) was 70% against 45% in the Technical University of Denmark (DtU), an institution with a more traditional approach to teaching and learning. Drop-out rates in 2005 at the two institutions were 21% and 33%, respectively (Universities Denmark 2008). These figures are quite stunning, although the differences may not be attributed solely to the different approaches to learning and teaching, since the two institutions differ also in other respects. Another advantage is that institutional introduction of PBL necessitates improved interdisciplinary staff collaboration around education - and thus enhances the potential for interdisciplinary problem based research as well.

The real life characteristic of the PBL approach means that the problems forming the point of departure for the learning process may be solicited from industry, even in the early years of study, thus enhancing the collaboration between university and industry. Also, the graduates acquire relevant and useful competences, leading to a better match between the competence profile of graduates and the needs of industry, as will be shown shortly.

Another advantage of PBL is that shifting the focus from teaching to learning, i.e. shifting to student-activating forms of teaching, 'forces' non-academic students to engage with the material to be mastered in an active manner and as a result they learn better, thereby acquiring better competences and increasing their chances of completing the study. This effect is illustrated in figure 1.



**Figure 1:** Student engagement as a function of activity required (Biggs 2003, p. 4).

The same effect was demonstrated in a study performed at City University of Hong Kong. First year students within the same field of engineering were divided into two groups: One group (group A) consisting of students with high entry qualifications for university (the 'academic' students) and another group (group B) with low entry qualifications (the 'non-academic' students). The two groups were to learn the same subject matter material, but through different methods of delivery: Group A was exposed to a traditional method of delivery, i.e. lecture-based teaching, while group B was taught according to a completely problem-based learning approach. After 15 months of study the 'non-academic' students in group B showed considerable improvements (on average 27%) in meta-cognitive competences of planning, monitoring and evaluating their own learning, while there was hardly any change in these competences for the matched group A of 'academic' students (Downing 2007).

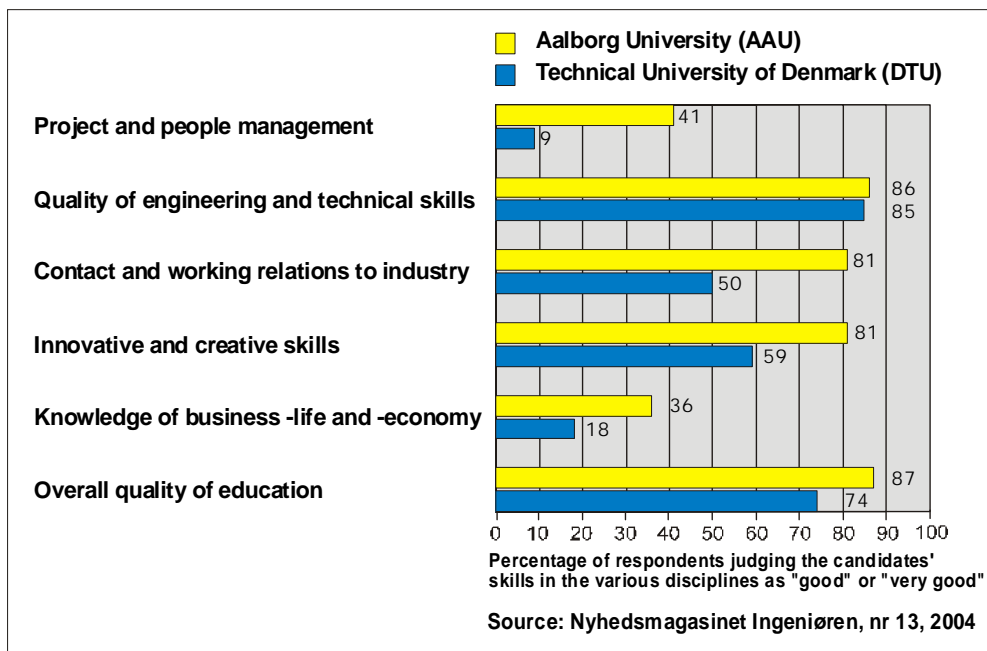
### 3.4 An Industry Perspective

From an industry perspective the main advantage of PBL is that PBL graduates possess some of the important competences which industry is looking for in new employees, more so than other graduates. This was documented in a study examining employer satisfaction with university graduates (Kandidat 2002). Out of the respondents 57% of private employers preferred graduates

from Aalborg University (AAU) to graduates from a more traditional university within the same region of Denmark. The reasons stated by the employers for this preference were that the AAU candidates possess: Project management skills; methodological and structured way of working; good skills in team work; innovation skills; ability to acquire new knowledge and skills. One respondent in the survey said:

“The ones [i.e. the graduates] coming from, for example, Aalborg University, go in and work in projects from the start.” (Kandidat 2002, p. 33)

Another survey on employer's satisfaction with competences of graduates was performed for the Danish weekly "The Engineer" (Danish: Ingeniøren) by Institute for Opinion Analysis (Ingeniøren 2004). In the survey human resources persons in 125 of the largest engineering companies in Denmark were asked to rate the competences of the new graduates from the more traditional engineering education at Technical University of Denmark (DtU) and from Aalborg University (AAU) with its PBL approach.



**Figure 2:** Competences of PBL and non-PBL Engineers in Denmark (Ingeniøren 2004)

In figure 2 is shown the percentage of respondents in the survey who answered 'Good' or 'Very good' when asked about the quality of competences of graduates within the areas indicated in the figure. From the results can be seen that a considerable majority (> 80 %) of companies are satisfied with the competences of the PBL graduates from AAU in the areas of 'quality of engineering and technical skills', 'contact and working relations to industry' and 'innovative and creative skills'. Furthermore, it can be seen that the employers assess competences of AAU graduates as considerably better than those of DtU graduates in the areas of 'project and people management', 'contact and working relations to industry' and 'innovative and creative skills'. Thus, it can be concluded that seen from an industry perspective the competences of AAU graduates are in



accordance with what is needed and presently AAU graduates do not find it difficult to obtain meaningful jobs in industry.

Having discussed at some length the advantages of introducing a PBL approach to teaching and learning in engineering education seen from different stakeholder perspectives, in the next section we will describe two specific and very different models of implementing PBL, both of which, however, take their point of departure in the PBL principles described in section 2.

## 4 PROBLEM BASED PRACTICES

A discussion of the multitude of different approaches to implementation of PBL would be beyond the scope of this article. Suffice to say that each educational institution will need to develop its own model of implementation of PBL, based on local contextual conditions and circumstances. In this section two examples of PBL implementation will be described. Since both of the authors are employees of Aalborg University this first example will be described in some detail. The second example concerns a rather young institution, Republic Polytechnic in Singapore, which has implemented its own unique model of PBL.

### 4.1 Aalborg University, Denmark

Aalborg University Centre (AUC, later Aalborg University, AAU) was established in 1974 as the fifth university in Denmark, and was to be a so-called 'developmental university', i.e. part of the explicit mission of the university was to partake in the social and economic development of Northern Jutland, a region of Denmark which has consistently been poorer than the rest of the country (Müller 2006). The close collaboration between the university and the local society was emphasized through the enthusiastic involvement of a group of influential local politicians, business people and educationalists who for a decade had been lobbying for the establishment of a university in the region (Du et. al. 2007).

From the outset the study form was characterised by the five key words: problem orientation, interdisciplinarity, participant control, project organisation and team work, all of which form part of the PBL principles discussed in section 2.

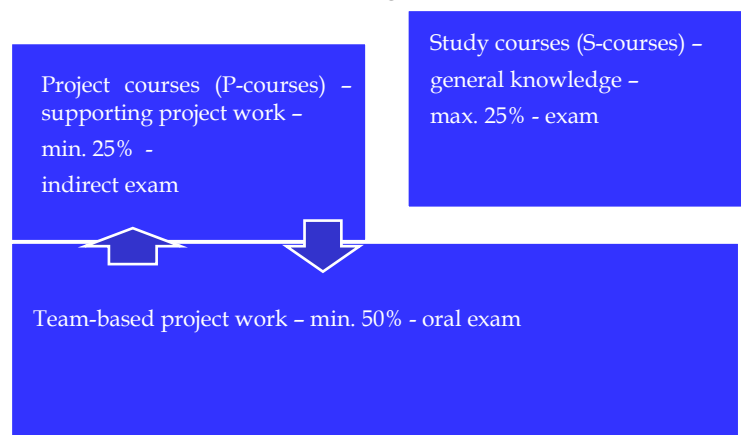
By *problem orientation* is meant that the starting point for the learning process is a real-life problem which the students choose themselves, thus ensuring *participant control*. Real-life problems are located in a certain social, economic, political and cultural context, thus both problem analysis and problem solution will necessarily be *interdisciplinary*, i.e. knowledge from social and humanistic disciplines has to be combined with knowledge from different technical disciplines in order to analyse the problem and propose an optimal solution.

The students' work with the problem is organised as a *project*, consisting of a number of complex subtasks which have to be carried out to reach the goal; therefore the project cannot be carried out by one person alone; instead, the students work in *teams* of 4 – 7 students, formed by the students themselves at the beginning of every term.

### The Study Structure

The academic year in Denmark consists of two semesters, each 20 weeks long. The engineering faculty at Aalborg University has Masters and Bachelors programmes but all students start their studies in the so-called Basic Year, i.e. a year of study which mainly serves the purpose of transforming high school pupils into independent university students. Part of the teaching and learning activities in the Basic Year is an introduction to the PBL learning approach applied within the university.

A student has to participate in at least three different types of study activities: The project work; P-courses; S-courses. A fourth type of study activities are optional, so-called Free Study activities. The typical overall distribution of time tabled study time between these main types of study activities in a normal semester can be seen from figure 3.



**Figure 3:** Overall semester timing in a normal semester at the Faculties of Engineering, Science and Medicine, Aalborg University.

By far the most important study activity is the problem oriented and interdisciplinary *project work*, which constitutes a minimum of 50% of the study time in a normal semester. Closely related to the project work are the so-called *project courses*<sup>1</sup> (P-courses) which constitute at least 25% of the study time. The project work and the P-courses together constitute what is called the *project unit* which is examined via an oral examination. This means that the P-courses do not have an own exam; assessment of the students' knowledge within these courses is carried out indirectly via the project unit examination. The last proportion of the study time in a semester is taken up by so-called *study courses* (S-courses), taught like P-courses but examined directly with an examination mark given for each S-course. S-courses cannot take up more than a maximum of 25% of the study time.

In figure 4 is shown a typical semester time table. The smallest unit in the time table is one mini module (mm), equivalent to 4 hours or ½ day, i.e. the semester time table contains 15 weeks and 10 mm per week. The semester time table is centrally prepared and thus common for all students

<sup>1</sup> By the word 'course' is meant a series of 5 - 15 lectures within a given subject, accompanied by assignments closely related to the lectures, with a lecture and related assignment lasting a total of 4 hours = ½ day = one 'mini module' (1 mm).

within a certain semester and field of engineering. The time set aside for project work has to be further scheduled and planned for by the students' teams.

Mm. 1	S-course 1	S-course 2	
Mm. 2	S-course 1	S-course 2	
Mm. 3	P-course 1	S-course 2	
Mm. 4	P-course 1	P-course 4	
Mm. 5	P-course 2		Project work
Mm. 6	P-course 2		
Mm. 7	P-course 3	Project work	
Mm. 8	Project work		
Mm. 9	Project work		
Mm. 10	Free study activity	Free study activity	Free study activity
	5 weeks	5 weeks	5 weeks

**Figure 4:** A typical semester time table for a standard semester at the Faculties of Engineering, Science and Medicine, Aalborg University.

The most characteristic feature of the time table is the dominance of courses during the beginning of the semester and the overwhelming dominance of project work during the last part of the semester. P-courses which feed into the project work (indicated by the arrows) are mainly taught in the beginning of the semester while S-courses may be taught at the beginning or in the middle of the semester.

### A Project Example

A project example from Electronics Engineering, 2. semester, 2007, may serve to illustrate the generalised information given above. In this case<sup>2</sup> the project was chosen from a catalogue of proposals prepared by the group of lecturers. The project title was: *An intelligent thermometer* and the following description was the problem trigger:

"Pasteurisation is a heating process whereby water may be cleaned of bacteria etc. to become suitable as drinking water. In Tanzania this heating is most often done using firewood which is in short supply. Using solar energy of which there is plenty it is possible to reach temperatures high enough for pasteurisation of a given fluid, depending upon how the fluid is kept. But a problem with solar energy is that it cannot be controlled.

Thus, there is a need for a simple and cheap device which can monitor temperature and time and in a simple way inform the Tanzanian user (who may be illiterate) when the pasteurisation is successfully completed." (EE 2007)

In analysing and solving this problem the group of 6 male students had to study and learn matters from the following technical disciplines: Temperature transducers; circuit theory; electronics; microprocessors; programming; display techniques. They also had to study and learn a number of

<sup>2</sup> Problems and projects may be proposed by students, by teachers, by companies and by other groups in society.

social science disciplines to some extent, such as: Facts about Tanzania; development theories; waterborne diseases; pasteurisation methods; stakeholder analysis. The P-courses provided to support the students' learning efforts were in the areas of Circuit theory; Electronics; Stakeholder Analysis. As for the rest of the knowledge needed the students had to acquire that by themselves. Two supervisors were assigned to assist the group with the project work as well as with the group dynamics within the group, i.e. the role of supervisors was to facilitate students' learning processes. By the end of the project period the team had written a 100 page project report, describing the project work and a 15 page reflective process analysis with a self-evaluation of the working processes of the group. Furthermore, they had constructed a digitalised thermometer, using a microprocessor as the 'intelligent' unit. In an oral exam the students presented and defended their project. More information about the engineering study at Aalborg University can be found in Dahms and Spliid (2008).

Having described the Aalborg PBL model in some detail, in the next subsection we will describe a very different model of implementation of PBL, the 'one day - one problem' model of the Republic Polytechnic in Singapore.

## **4.2 Republic Polytechnic, Singapore**

The following information about the study programme at Republic Polytechnic is mainly solicited from conference presentations (O'Grady and Alwis 2002) and from the web site ([www.rp.sg](http://www.rp.sg)). The study programme at Republic Polytechnic (RP) is a Diploma programme of 3 years duration, with 16 weeks per semester.

A class of 25 students is divided into 5 groups of 5 students and all groups within a class are given the same problem trigger in the morning, including a scaffolding worksheet with a number of questions at different levels of difficulty, to guide the students through the process of solving the problem. Together with the facilitator assigned to the class the students identify what they already know about the problem, what they do not know and what they need to learn, and they assign learning tasks to each individual student. After this first meeting (1 hour) they split up and go searching for information at sources of information available to them.

After a period of information collection (1 hour) they come back and together with the facilitator they discuss progress and still outstanding issues (1 hour), after which they again split up to solicit the remaining information. They meet again to teach each other and to prepare a presentation of the problem solution (2 hours), which is presented to the other groups and the facilitator by the end of the day (1 hour). A short assessment in the form of self-assessment and notes in a reflective learning journal is carried out as the last activity of the day (½ hour).

An example of a problem 'trigger' with the title: *Overbooking* in the module 'Statistical Methods for Engineers', including scaffolding work sheet follows.

"Budget Hotel Singapore is a newly established 200 room hotel. Last minute cancellations result in many rooms being left empty for the night. Therefore management has decided to allow overbooking. Target is at least 90% occupancy and the risk of more guests than rooms as low as possible.

As part of the quality assurance team of the hotel you are tasked to perform a statistical analysis and present recommendations to hotel management, highlighting any risks to be considered."

The scaffolding consists of a worksheet with a total of 12 questions conc. statistics, some of which are shown in the following:

- 1) A coin is biased so that the probability of head is  $\frac{2}{3}$ . What is the probability that a tail will happen in the next toss of the coin?
- 4) What is the probability that exactly four heads will come up when the coin is tossed 7 times?
- 8) For Budget Hotel Singapore, is the random variable of overbooking of hotel rooms binomially distributed?
- 11) What is the meaning of allowing the guests to overbook? What problems or risks do you think may happen when you overbook?

Obviously, this 'one day - one problem' model is different in a number of aspects from the 'one semester - one problem' model applied at Aalborg University but the competences acquired by the students are remarkably similar, such as: Ability to understand, share and apply knowledge; ability to inquire and think independently; communication and negotiation skills; team working skills; learning-enabled.

#### 4.3 Summing up on PBL Implementation

The two PBL models described above have been compared on different aspects in figure 5 below. This comparison is made for reasons of overview of differences, not for evaluating the two models, since there is no 'right' or 'best' PBL model.

	RP	AAU
No. of stud.	5	4 – 7
Lectures - problem work	No lectures	$\frac{1}{2}$ lectures $\frac{1}{2}$ project
Length of problem work	One day	One semester
Pre-structure of problem	High	Low
'Teacher' direction	High	Low to medium
Outcome	Presentation + learning	Report, product, presentation + learning
Assessment	Individual Daily+'understand'	Individual S-course+project

Figure 5: Comparison of the AAU and the RP PBL models.

The above two cases of PBL implementation have illustrated the diversity of PBL models. Interestingly, however, is the observation that the competences developed in students of PBL show great similarities, independent upon the practical implementation, i.e. what matters in the development of competences are the PBL principles rather than the specific way of implementation. To conclude, each educational institution wishing to implement a PBL approach to teaching and learning should develop its own particular model of PBL, based on the PBL principles but adapted to the institution's own specific conditions and to the local context, be it social, political, economical or cultural.

In the next section we will turn to the discussion of problem based learning for development, drawing upon the information provided in the previous sections.

## **5 PROBLEM BASED LEARNING FOR DEVELOPMENT**

As knowledge becomes a key factor in 'development', whether human, social or economic, the importance of higher education as a generator of knowledge is increasing throughout the world. This new and increasing importance of higher education poses challenges to universities everywhere but in 'developing' countries in general and in the African countries specifically it adds to a number of long-standing challenges to higher education due to social and economic problems specific to the continent (World Bank 2000; World Bank 2002; Bloom et. al. 2006). In this last section we will describe the challenges facing universities in 'developing' countries in general and more specifically in Sub-Saharan Africa. Based on this description we will discuss how the introduction of a problem based learning approach to teaching and learning in engineering education might present a viable solution to a number of the challenges. Before we elaborate on challenges and propose solution we will first take a short historical detour to Brazil.

### **5.1 The First 'Developmental' University**

Probably the first university ever to implement an institution-wide problem based learning approach was University of Brasilia (UnB), located in a so-called 'developing' country, Brazil. UnB was founded in 1960 under a progressive socialist regime aiming at development, modernisation and democratisation of Brazilian society. The two main aims of UnB were to counteract the scientific dependency on the West and to help solve development problems within the society. Key principles of UnB were, for example: problem solving; interdisciplinarity; experimentation; collaboration with society; (self-)critical approach to teaching and research. Both teaching and research activities had to be closely related to Brazilian society, because science was supposed to benefit society.

Unfortunately, the university was a short-lived initiative: After the military coup in 1964 UnB was considered a subversive activity, teachers and students were killed, jailed or exiled and the university was exposed to very strict military control and underwent major transformations (Beck and Müller 1992). Today, the PBL approach is applied at some schools in UnB. Also the close collaboration between university and society is secured via a range of community-outreach projects that involve participation of more than 200 professors, more than 13.000 students and nearly 185.000 people in the surrounding society (UnB 2008).

Although a short-lived initiative the UnB experience nevertheless demonstrates the relevance of the PBL approach to development and to 'developing' countries and in the last sub-section this relationship between PBL and 'development' will be further elaborated; but a quick look at the history of African universities may be useful as a primer to understand present challenges and even to point to possible solutions.

## **5.2 The History of African Universities**

At independence most African countries were characterised by an extremely low level of higher education, both in terms of the number of universities and in terms of enrolment into existing universities. Thus, before 1960 only 18 out of 48 Sub-Saharan African countries, excluding South Africa, had universities (Sawyerr 2004). With political independence the establishment of universities was seen as a national strategy in post-colonial development efforts, and universities were to help the new nations build up the human resources needed to take over from colonial administration and to partake in development efforts, i.e. universities were to be 'developmental' universities (Sawyerr 2004).

Public expectations to the performance of universities were high and public funding was equally high, both in terms of funding for infrastructure and staff and in terms of funding of students. Also high in many universities was governmental interference in university affairs. The high expectations were fulfilled, at least as far as the production of highly educated persons was concerned. Also in terms of research production the African university during this first period from 1960 to 1975 did quite well (Sawyerr 2004); for example, University of Dar es Salaam (UDSM) was during this period known to be one of the best universities in Africa, if not in the world, and was seen as the prototype of a 'developmental' university responsive to the society (Mkude et. al. 2003).

From the late 1970s this state of optimism and enthusiasm began to decline due to several factors: Global terms of trade worsened to the detriment of the African producers of primary commodities. Due to worsening trade conditions many African countries became dependent upon international aid and thus acquired enormous debts which needed to be serviced, thus further reducing funding for public spending, such as universities. Dictatorial or one-party rule in many countries led to corruption and mismanagement of funds and often also to alienation between government and universities, which have often been seen as sources of political opposition and social critique (Sawyerr 2004; Bollag 2004).

This weak economic situation was further compounded by a number of other factors. The rise of neo-liberalism in the late 1980s eroded the capacity of already weak African states to generate funding through production and at the same time limited the available policy instruments of these weak states to control market forces and ensure provision of basic needs for its people (Sawyerr 2004). Structural Adjustment Programmes (SAPs) during the 1980s and 1990s directed international donor funding away from higher education towards primary education, a trend which was mirrored in African governments' relative neglect of the sector as well (Bollag 2004; Sawyerr 2004). The collapse of the USSR saw the end of generous scholarships for African students in the former communist countries in Eastern Europe, the USSR and Cuba (Bollag 2004).

Concurrent with the reduction of financial resources from government and international donors, universities had to shoulder huge increases in enrolment of students. The total enrolment in African universities went from 181.000 in 1975 to 660.000 in 1985 to 1.975.000 in 1995 and the gross tertiary enrolment ratio, that is, the percentage of young people aged 19-24 who are in university, increased from 1.6% in 1980 to 3.6% in 1996, considerably lower than for any other part of the world (World Bank 2000; Sawyerr 2004). An interesting observation about enrolment is made by Sawyerr:

"It is noteworthy that these enrolment increases continued not only against the background of economic and political crises, but more specifically, despite serious reductions in employment avenues for university graduates." (Sawyerr 2004, p. 8)

Thus, the increase in university enrolment is not likely to stop within the near future. An example illustrating the impact of reduced funding is UDSM: The operating budget in UDSM fell from US\$ 22.8 mill. in 1984/85 to US\$ 6.6 mill. in 1993/94, while student costs per head fell from US\$ 7.824 to US\$ 2.752, in spite of the fact that student enrolment remained almost constant during the decade, as opposed to the situation in most other African countries. During the same decade the value of staff salaries were lowered by 47 % due to inflation (Mkude et. al. 2003). During the 1980s and the first half of the 1990s African universities have thus been faced with the double challenge of decreasing funds and increasing enrolment, a combination which has led to a prolonged crisis from which many of the universities have only partly recovered (Sawyerr 2004).

During the last decade, after hitting the bottom in the mid 1990s, most universities have started to look for solutions in the form of university reforms (Bollag 2004) and some, such as UDSM (Mkude et. al. 2003) and Makerere University (Sawyerr 2004), have undertaken successful institutional reforms, mainly aimed at improving the financial situation. What still remains to be carried out, however, are major reforms aimed at improving the teaching and learning processes as well as the curriculum in many study programmes (Mkude et. al. 2003). We will take up this issue in the last sub-section, after having shortly discussed the major challenges facing African universities today.

### 5.3 Challenges facing African Universities

From the above history of African universities from independence up to now it appears that a consistent neglect of higher education and thus a longstanding lack of sufficient funds is one of the root causes of many of the challenges facing African universities up to this day. As was also pointed out, however, many universities have started addressing this challenge through institutional reform programmes focusing upon financial sustainability and self-sufficiency. Therefore, in this sub-section we will not discuss this main challenge, but rather focus upon those challenges which may be addressed by the introduction of a problem based learning approach.

One major challenge which African universities did indeed address, albeit with limited success during the first years of independence, is the *de-colonisation* of higher education, re-defining and re-adjusting the curricula to be(come) relevant in an African context. The curricula need to be responsive to problems in African society and to deliver solutions useful in the African context. Thus, there is a need to move from Eurocentric and US-centric perceptions of education and knowledge to specific African perceptions of these concepts and to specific African curricula, developed by and for Africans in Africa.



A challenge stemming from the above mentioned increasing importance of higher education in the global knowledge economy is the *changed mode of knowledge production*:

"The new patterns of knowledge creation imply not only a reconfiguration of departments into a different institutional map but more importantly the reorganization of research and training around **the search for solutions to complex problems**, rather than the analytical practices of traditional academic disciplines." (World Bank 2002, p. 37; emphasis added)

Closely linked to changes in knowledge production are of course *changes in learning and teaching*. The challenge is to improve the learning and teaching processes to cater for an increasing demand for graduates who are able to process and apply knowledge:

"The learning process now needs to be increasingly based on **the capacity to find and access knowledge and to apply it in problem solving**. Learning to learn, learning to transform information into new knowledge, and learning to translate new knowledge into applications become more important than memorizing specific information." (World Bank 2002, p. 29; emphasis added)

As was mentioned above high and increasing enrolment is likely to continue for some time to come. A challenge for universities is to cope with *mass education*, i.e. high numbers of students, some of whom have poor entry qualifications and most of whom are male students from well-to-do families from certain regions of the countries (Mkude et. al. 2003). Thus, issues of *poor entry qualifications* and of increasing *inequities* concerning both ethnic and socio-economic background and gender feature high on the list of challenges to be addresses by African universities (Sawyer 2004).

A challenge which is linked to the incomplete de-colonisation process and thus the lack of relevance of curricula is the unresponsiveness of higher education to the needs of enterprises, communities and society in general. The lack of close links between the institutions of knowledge creation and the beneficiaries of this knowledge leads to *weak innovative capacity*. A part of this challenge has to do with the dominant paradigm of neo-liberalism: The downsizing of employment opportunities which has taken place in most Sub-Saharan African countries due to dismantling or privatisation of governmental and parastatal corporations and companies means that, where graduates earlier were guaranteed a job after graduation, they now have to look for jobs themselves in a small formal private sector which is often not satisfied with the competences of the graduates or else create their own jobs. This has led to fairly high *unemployment* rates among university graduates (Mkude et. al. 2003).

The last but not the least challenge to be discussed is the 'brain drain' from Africa to the US and Europe. This is certainly not a new challenge - the exodus of highly qualified Africans, educated in their home countries and emigrating to the West, started already during the first decade after independence but increased dramatically during the late 1970s and the 1980s. Thus, an estimated average per year of 1.800 highly skilled migrants left Africa during 1960-75, a figure that rose to 23.000 from 1984-87 (Ndulu 2004). To give an indication of the extent of the problem Ndulu writes:

"More African scientists and engineers are working in the United States than there are in Africa. The emigration of technically skilled people has left only 20,000 scientists and engineers in Africa to provide services to 600 million people." (IOM 2000; here quoted from Ndulu 2004, p. 60)

This brain drain is connected to the above mentioned unemployment rates as well as to the generally poor prospects of finding jobs providing satisfactory living conditions in poor African countries as compared to the rich Western countries. It is, however, also connected to a discourse of not regarding knowledge "constructed" in an African institution as valid – one must go to the West to obtain "real" knowledge. Students going abroad for further studies contribute to the brain drain; thus, estimates indicate that approximately one-third of foreign students studying in the US never return to their home countries (World Bank 2000). The brain drain costs Africa large sums of money in terms of educational investment. In 1990 alone it is estimated that educational investment in highly skilled emigrants to the US was US\$ 640 mill. (Ndulu 2004).

Another aspect of this problem which could be labelled 'virtual brain drain' is the fact that African researchers often choose research topics and methods that mimic Western research, rather than working with local problems, in order to be(come) part of mainstream research (World Bank 2000).

The challenges discussed above are but a part of the challenges facing African universities. They are, however, challenges which we postulate could be addressed by introducing a problem based approach to learning and teaching. In the last sub-section we will turn to the discussion of the possible impact of problem based learning on the above challenges and end the paper with a discussion of PBL and 'development'.

#### **5.4 Overcoming the Challenges through PBL?**

In this final sub-section of the paper we will draw the links between the advantages of introducing problem based learning as described and documented in sections 2 and 3 and the above described challenges facing African universities, in an attempt to point to possible solutions to some of the challenges. The following discussion is structured according to the five main challenges discussed above, with the very last paragraph discussing the relation between PBL and 'development'.

*De-colonisation:* Introducing a PBL approach may to a great extent assist in the move from Westernised to Africanised knowledge, due to the emphasis on identifying and applying local, formal and informal knowledge in the analysis and solution of a local real-life problem, rooted in a social context rather than within a textbook. The project example in sub-section 4.1 was obviously not drawn from a local Danish context; however, it was a contextualised and not a textbook problem. Students in a PBL curriculum draw upon local contextualised indigenous knowledge as a source of input to their learning processes, thereby enhancing the status of this knowledge, while at the same time integrating it with the de-contextualised knowledge created in the West which they have to adapt to the local context and to the local needs.

Moving away from the traditional Eurocentric modes of education will also mean moving away from a constant measuring of self and of society against the un-attainable standards of the West.

Instead, the quality of a project should be measured against its theoretical and practical contributions to the solving of problems rooted in the context of the country and the continent.

*Changing perceptions of knowledge, learning and teaching:* The creation of knowledge for complex problem solving is one of the hall marks of problem based learning, as are the characteristics of learning called for in the above quote from the World Bank report (2002, p. 29), namely: 'learning to learn, learning to transform information into new knowledge, and learning to translate new knowledge into applications' dealing with problem solving.

Furthermore, because PBL integrates formal and informal learning from a diversity of different sources of information and learning, introducing PBL in African universities may assist in emphasising and promoting the specific and valuable African “niche” of knowledge in the global knowledge economy where knowledge more and more is becoming a commodity.

Introducing PBL in the first years of university education will boost the research capacity of students from an early stage onwards and not only during their final thesis work, as the situation is at present. This might turn out good researchers who in turn may become new staff in the universities (Arthur 2008).

A last advantage to be mentioned here is that PBL emphasises a democratic approach to teaching and learning. This is particularly evident in the student-teacher relationship where critical thinking is encouraged and students are expected to raise questions rather than to answer questions in order to be able to solve their problem. Knowledge is not something to be handed from teacher to student without any questions, but rather something to be negotiated in class, with teachers and not least within student teams when addressing their project work. Thus, a PBL approach enhances democratic ways of negotiating and interacting within students' teams and within society (Du et. al. 2007; Qvist 2008).

*Mass education, poor entry qualifications and inequities:* One important aspect of the team work is that students will teach each other, so-called peer teaching accompanied by peer learning, which according to research on learning is one of the most effective ways of learning. Peer teaching can reduce work load for staff dealing with large numbers of students, while at the same time developing in the students a sense of responsibility for his/her own learning. Introducing PBL may also reduce the amount of time spend by staff on lecturing and marking individual exam papers (Arthur 2008). As was documented in sub-section 3.3, PBL can considerably improve the performance of so-called ‘poor’ students, even more so than of so-called ‘good’ students, partly because other competences than the traditional 'academic' ones are needed to achieve success in a PBL environment.

On the issue of ethnic and socio-economic inequities in recruitment and access to higher education: A PBL curriculum may not be able to make much of an impact here, other than in terms of the improved performance of 'poor' students, as mentioned above. Concerning gender, however, the fact that in PBL students deal with real-life problems may attract more women to especially engineering studies, since research documents clearly that for women to be attracted to these hard-core technical studies they need to be able to visualise the application of technical systems and devices to solve real-life problems for real-life people (Du 2006).

*Weak innovative capacity and unemployment:* A 'national system of innovation' is strongly dependent upon good institutions of higher education and research, especially in science and engineering (Masinda 1998). Therefore it is crucial that the knowledge generated in universities also reaches out and is applied in enterprises and companies, both in the formal and in the informal sector. One way of securing this knowledge transfer from universities to industry and society is by securing that the graduates can indeed find a job after graduation. From a Danish context it was documented in sub-section 3.4 that engineering graduates have the competences required by industry, i.e. a PBL approach to higher education responds more appropriately to the needs of the labour market. Whether this would also be the case in an African country remains to be seen but already there are a number of universities which have introduced PBL to address the issues of relevance of the curriculum and to "contribute to tearing down the wall between the university and its surroundings" (Ng'ethe 2003, p. 10). Furthermore, as was also documented in 3.4 the PBL graduates have innovative competences to a higher degree than graduates from traditional curricula. Finally, PBL enhances the entrepreneurial skills of students by allowing them to have experiences of success, being able to solve real-life problems which matters to real-life people.

*Brain drain:* The introduction of PBL in teaching and learning as well as in research would provide both students and staff with an intellectually challenging, relevant and motivating learning and research environment; thus, it might help stem the 'brain drain' from Africa. Furthermore, a PBL approach may contribute to the students' sense of ownership; not just of their own education and projects but also of their societies and the country and thus may inculcate in the students a sense of responsibility for the development of these societies as well. This sense of responsibility might in turn reduce the brain drain.

Another aspect is that in a PBL environment it would be considerably easier to make good use of the intellectual capacity of the African Diaspora in the pursuit of higher education than would be the case in a traditional lecture based setting. In PBL African academics living and working abroad could act as assistant supervisor, providing easy access to sources of information which might otherwise be more difficult to access for African students.

*PBL and 'development':* The need for changes in pedagogical approaches to teaching and learning in higher education in Africa has been voiced by several authors, among them one of the 'fathers' of the concept of 'national systems of innovation, Bengt-Åke Lundvall who writes:

"We recommend less developed countries to build universities more strongly rooted in the regional context.....We also recommend deep reform of teaching methods establishing stronger emphasis on problem-based learning, where problems are taken from the domestic reality, as well as integration of local practical experience in study programs." (Lundvall 2007; p. 2)

Through PBL approaches students and researchers are encouraged to work with the imminent issues of 'development' present in the local and regional society rather than focusing on abstract theoretical aspects often far removed from everyday realities. In this aspiration to solve local real-life problems PBL almost 'automatically' generates a focus on development. Through PBL students will gain a clear focus on social, economic and technical problems facing society and will be trained to address such problems in a structured and solution-oriented manner, while generating,

acquiring, adapting and applying knowledge to the solution of the problems. Consequently, rather than being taught that they live in an 'underdeveloped' and problem-ridden country, students will be taught to find solutions to the problems they encounter. Thus, by identifying, analysing and solving local real-life problems the students contribute to local development, while at the same time learning the important skills needed for problem solving.

The link between innovation and 'development' has been mentioned before, as has the fact that innovation is furthered by diversity. Thus, increasing diversity by overcoming the challenge of ethnic, socio-economic and gender inequities in access to higher education would be likely to increase the innovativeness of universities and thereby enhance their contribution to national 'development' through national systems of innovation. Furthermore, as was documented in sub-section 3.4, PBL enhances innovative skills, partly because students are allowed to think and research for themselves, partly because PBL enhances diversity in knowledge generation through interdisciplinarity and thus releases the innovative potential of a diverse student body.

A thoughtful final comment on the way forward for African universities from Bollag:

"...traditional university policies and practices are losing their relevance in the context of rapid social and economic changes in the 21st century and .... tertiary institutions in Africa, much like their counterparts around the world, are actively in pursuit of the innovation and modernization necessary for them to meet the evolving expectations of their societies and their governments. To this end, African universities are challenging long-established procedures and successfully devising "things that work" as they find new ways to meet their historic mission of teaching, research and community service." (Bollag 2004, p. 26)

We would like to add that it is high time that the de-colonisation project be completed and that African universities become the 'developmental' universities they were meant to be and need to become to fulfil their historic mission of national 'development'. African universities need to be in a position to create, acquire, adapt and apply knowledge, African and Western knowledge alike, not only to develop their own genuine solutions to the problems facing the countries and the continent but also to help place Africa in its rightful place in the global knowledge economy. The introduction of problem based learning might well be part of such a de-colonisation process!

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