

PBL CURRICULUM STRATEGIES

From Course Based PBL to a Systemic PBL Approach

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PBL in Engineering Education

International Perspectives on Curriculum Change

Aida Guerra, Ronald Ulseth and
Anette Kolmos (Eds.)



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PBL in Engineering Education

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International Perspectives on Curriculum Change

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RON ULSETH AND AIDA GUERRA

INTRODUCTION

During 2014–2015, a series of webinars entitled PBL History and Diversity was broadcast from the UNESCO Centre for PBL in engineering science and sustainability at Aalborg University. Following is the description of the series: “In the 1960s and 1970s, a handful of higher education institutions implemented a new and innovate learning approach – Problem Based Learning (PBL). PBL aims to develop a more student centred, close to practice and meaningful learning. For 40 years, PBL did not only survive but it has also grown and evolved due to research, development and implementation in several higher education institutions across the world, resulting in different models and practices. Nevertheless, the different PBL models relate with each other through basic principles around which the learning process is organised. Problem based, team based, self-directed and contextual learning are examples of these principles. This first series of webinars starts with PBL history by presenting its origins and philosophy, followed by seven examples of models PBL developed and practiced around the world” (taken from www.ucpbl.net).

The goals of the webinars were to understand PBL philosophies, models, and practices and further, to relate the models through learning principles and dimensions. This book arises from the webinar series. All of the PBL programs described in the chapters of this book were highlighted in the webinar series.

The intended audience for the book includes higher education institutions as well as researchers and practitioners who aim to implement, or change, their teaching and learning practices to PBL (i.e. problem based, project organized learning). All of the programs highlighted represent engineering education, however the case examples are described taking PBL principles as the point of departure which can make this book an inspiration for other disciplines and areas of educational research.

CONTENT

The book is composed of eight chapters. The first chapter by Anette Kolmos, Chair of the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO, addresses three main strategies of curriculum changes allowing the identification of three types of institutions depending on the type of strategy used. Furthermore, the different strategies underlie different types of drivers/triggers and problems addressed by the change process.

The following chapters present six PBL models from Singapore, Malaysia, Tunisia, Portugal, Spain and the U.S.A.

These models exemplify curriculum change in engineering education and are described based on: (i) objectives and knowledge; (ii) types of problems, projects and lectures; (iii) progression, size and duration; (iv) students' learning; (v) academic staff and facilitation; (vi) space and organization; (vii) assessment and evaluation (Kolmos, de Graaff, & Du, 2009). There is also a focus on a perspective of the time of the change process. Therefore, additional aspects such as drivers, implementation, challenges and perspectives, to the above guidelines are included, providing a holistic understanding of change process. These cases not only exemplify some aspects of the type of change addressed in the first chapter, they are also stories of thriving success which can be an inspiration for those who aim to implement PBL and change their engineering education practices.

The motivation for the book is to bring new theoretical insights to PBL theory and principles, and descriptions of PBL curriculum that thrived through time and from different contexts.

DISCUSSION

Leading off the book, Anette Kolmos defines PBL and provides a historic perspective. She invokes Barnett's (Barnett, 2009; Barnett & Coate, 2004) categorization of knowing, acting, and being to highlight three modes of universities, which are academic, market-driven and community based. Then, further discusses the placement of PBL within the 3 modes. Kolmos and her colleagues (Jamison et al., 2014; Kolmos, Hadgraft, & Holgaard, 2016) created a characterization of curriculum change strategies as being add-on, integration, or rebuilding. She describes the three in detail. As a result of these discussions, Kolmos provides the reader multiple perspectives through which to view the PBL programs that are described in the following chapters, really setting the stage for the characterization of learning and PBL within learning.

Mohd-Yusof describes independent courses that utilize PBL at the Universiti Teknologi Malaysia (UTM), in "Sustaining Change for PBL at the Course Level" (Chapter 2). The UTM approach is characterized as course-based, cooperative PBL that is instituted using a scholarly approach and highly influenced by the principles from cooperative learning and the medical school PBL cycle.

Lima, Dinis-Carvalho, Sousa, Alves, Moreira, Fernandes, and Mesquita, in "Ten Years of Project Based Learning in Industrial Engineering and Management" (Chapter 3) at the University of Minho (Portugal) describe how PBL is implemented in semesters 1 and 7 in a 10-semester Master's degree program. Characteristics of the Minho program include interdisciplinary project with a dual focus on the development of both technical and transversal competences in the engineering graduates.

In the "Iron Range Engineering (IRE) Model" (Chapter 4), Johnson and Ulseth describe a PBL model in the USA that is in the market-driven mode that was created using a rebuild change process. Vertically integrated project teams, oral exams,

and deep development of reflective practices uniquely characterize the IRE model. The semester-length projects sit at the heart of the curriculum. The IRE model is delivered in semesters 5–8 of an 8-semester Bachelor's degree.

“PBL in Engineering Education: Republic Polytechnic's (Singapore) Experience” (Chapter 5) is presented by Wang, Yap, and Goh. In place since 2002, the Republic Polytechnic (RP) program, consisting of 6 semesters and leading to a diploma degree, is characterized by a series of short, “bite-sized” problems lasting from one to several weeks each. Students in their teams start a typical day at RP with a problem-statement, and then proceed to collaborative research and end with the delivery of a solution and reflection of the day's learning. Through this mode of learning, students develop confidence, teamwork skills, and self-directed learning abilities.

At Mondragon University in Spain, Project Based Learning is delivered in every semester in all Bachelor's and Master's programs. Arana-Arexolaleiba and Zubizarreta describe the model in “PBL Experience in Engineering School of Mondragon University” (Chapter 6). The goal of the PBL implementation is to develop graduates with technical and transversal skill capabilities ready for industry. An initial goal of the implementation was to result in the increase in student motivation to learn.

Finally, Bettaieb, in the “Esprit (Tunisia) PBL Case Study” (Chapter 7), describes how the change to PBL was motivated by the disconnect between the capabilities expected of engineering graduates and the capabilities that were demonstrated by graduates of the traditional model. In the PBL model, students complete projects in 7 out of the 10 semester Master's program. Students on teams of 5–6, complete full semester, complex, ill-defined projects. Students are motivated to deeper learning through the application of real scenarios and the opportunities for control over their own learning.

The book, taken as a whole, shows much diversity in the application of PBL as the social construct that it is. From one-day problems to projects which are a part of the curriculum to programs that are defined by full-semester projects in all semesters. The programs have starting dates that range from 2002 to 2012, with most programs already beyond 10 years of implementation.

Common themes emerge from the narratives. Each program is characterized by continuous improvement. Indeed, change appears to be the only constant for most programs through their developments. The development of employability skills was central to the motivations for change and the results of each program. The language varied from professional skills, to transversal skills, to soft skills, but the sharp focus remained the same for each program. In the programs that reported on research done on their graduates, they showed substantial growth in professional skill development and metacognitive/self-directed learning abilities. Further, most programs showed a proclivity towards developing engineers for industry employment often describing strong partnerships during the education phase.

Upon conclusion of the cases, we have included a closing chapter that compares and contrasts the models using the structures from Kolmos' chapter and the structures

the authors used to construct their cases, “Perspectives on Engineering Curriculum Change – Final Remarks” (Chapter 8).

In closing this introduction, we hope that the reader is inspired to dig into the PBL stories from the diverse (both globally and through implementation) engineering programs. Our intent is to provide you inspiration as you contemplate implementation of PBL or changes to your own PBL models.

REFERENCES

- Barnett, R. (2009). Knowing and becoming in the higher education curriculum. *Studies in Higher Education*, 34(4), 429–440. doi:10.1080/03075070902771978
- Barnett, R., & Coate, K. (2004). *Engaging the curriculum in higher education* (1st ed.). Maidenhead & New York, NY: Open University Press.
- Du, X., de Graaff, E., & Kolmos, A. (2009). *Research on PBL practice in engineering education*. Rotterdam: Sense Publishers
- Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education*, 103(2), 253–273. doi:10.1002/jee.20041
- Kolmos, A., Hadgraft, R. G., & Holgaard, J. E. (2016). Response strategies for curriculum change in engineering. *International Journal of Technology and Design Education*, 26(3), 391–411.

ANETTE KOLMOS

1. PBL CURRICULUM STRATEGIES

From Course Based PBL to a Systemic PBL Approach

While all transition involves change, not all change results in transition. Changes can occur within a single historical epoch that do not profoundly affect it in any way.

(Freire, 1973)

INTRODUCTION

These words are formulated by Freire in *Education for critical consciousness*. We could formulate similar hypotheses: while all problem and project based learning (PBL) transitions involve change, not all PBL changes result in more comprehensive transition. If academic staff and students are not critically aware of the transition from a lecture-based curriculum to a problem and project based curriculum, contradictions increase between ways of knowing, acting and being in the traditional curriculum and an emerging curriculum. The transition might be experienced as a tidal wave with glance moments of understanding the new practice but with emotional drawbacks to a safer position in the known curriculum and a stepping back to known practices.

Freire highlights a very important aspect as the conceptual understanding of what changes that are made and under which transition processes will be very different depending on the context of the critical reflection and the creation of new meaning. There might be a change in the curriculum, but the effect of the change will depend on the degree of implementation at course or institutional level, and on the critical reflection on the learning of knowing, acting and being as objectives for the curriculum. Freire refers to the concepts of transition and change – transition in terms of the process of changing fundamental values, change in terms of single actions. In the literature, the concept of transformation also occurs in combination with change. Transformation is often used in studies on higher education to indicate a complete change from macro- to micro level. All the concepts of transition, change and transformation are often used synonymously without defining the concepts theoretically but much more by examples or by overall change strategies (Kotter, 1995; Reidsema, Hadgraft, Cameron, & King, 2013) or how involvement and engagement can be created in a transformation process (Eckel & Kezar, 2003; Kezar, 2013).

An important part of a transition process is to have a conceptual understanding of the university roles and the overall aim of the curricula. Recent research on types of

university changes has identified three very different university types, see Figure 1 (Jamison, Kolmos, & Holgaard, 2014):

1. A mode 1 academic university with emphasis on theoretical learning and the process of knowing. This is the “traditional” university with a range of parallel courses in a modular system of which some are mandatory and others elective. Basically, the curriculum is aimed at the learning of theory.
2. A mode 2 market driven university focusing much more on relevant knowledge for employers and therefore on action: skills and competencies. How can the knowledge be used? These are typically new process competencies like project management, communication and collaboration. The curriculum expands to integrate projects especially from enterprises.
3. A mode 3 community oriented and hybrid university which focuses on societal needs in general and especially on sustainability, social progress and global awareness. The mode 3 university is driven by a vision for a better and more equal society and it is not a contradiction to either mode 1 or 2, but it is an integration and development of these two modes combined with social progress and sustainability values emerging as a dominant trend. The UN 17 Sustainable Development Goals will definitely saturate and dominate the mode 3 university and therefore the goals will go far beyond both the traditional academic mode 1, as the problems will drive the learning, and it will be much broader in the scope of its application than the mode 2 market driven university which is basically driven by market concerns – both internally at the university in terms of new management control and externally in a more collaboration with private companies.

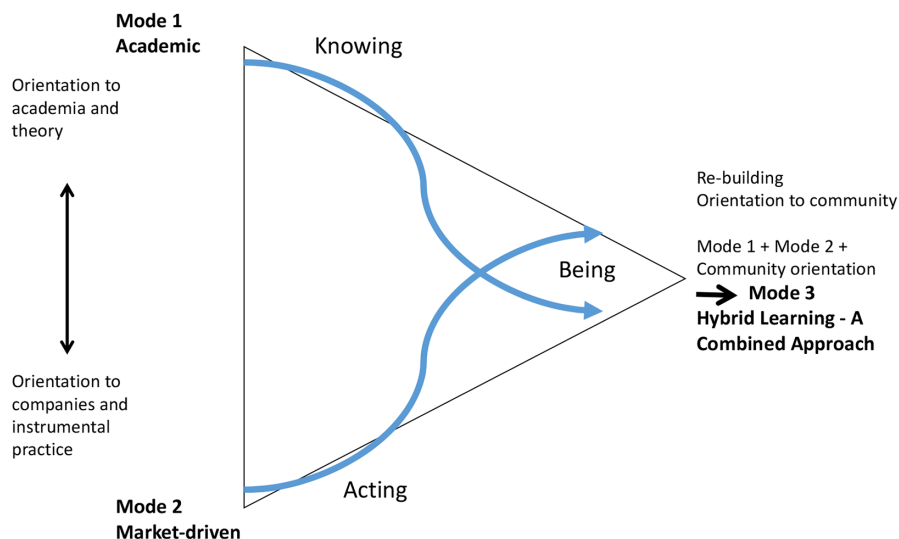


Figure 1. Three university modes (Jamison et al., 2014)

Two Danish universities, Roskilde and Aalborg, originated in the light of a mode 3 vision, with problem oriented project work models. The establishment of Roskilde University in 1972 and Aalborg University in 1974 was part of a critical political discourse. At that time, it was a period with a very strong student movement connected to the left-wing parties and where the values represented in the new pedagogic models reflected these values with strong community orientation and critical thinking. The Danish problem oriented project work models were part of a change in society. In, particular, the universities strove to have a closer relationship with the surrounding society by including societal problems in the students' curriculum and by a critical review of the curriculum especially in the humanities and social sciences. The establishment of the reform universities in Denmark was therefore part of a bigger societal transformation, but it has been embedded and transformed into a much more market oriented agenda in a new technological age.

During the 80s, there was a need for a closer relationship between university research and innovation in companies. New pedagogies like outcome based education started out in the 80s with the emphasis on competencies and skills, and politically this trend was turned into educational policy during the 90s by new accreditation criteria and in Europe by the Bologna process (ABET, 1995; Commision, 2009; EU Commision, 2008; Spady, 1994). Problem and project based learning has been seen as an outcome-based pedagogy as it embraces learning of both knowledge and skills/competencies. Especially within engineering education, the reform pedagogy was applied with the purpose of developing relevant skills and competencies for companies and students started to work on company projects as well as projects with a broader societal aim.

Each of these ideal university modes emphasises different types of curricula. Barnett and Coates (2004) present a new understanding of the curriculum as knowing, acting and being. This approach emphasizes the curriculum as a space for learning processes and that the curriculum should not only address the knowing and acting outcomes, but also the being as a process of identity growth. This approach includes transformative elements where the learner is in the center. The uncertainties and complexities that the graduates will have to deal with the future, will need a much more complex, integrated and deep competence and knowledge understanding which will go beyond the knowledge and skills outcomes which are formulated in today's curricula. Applying Barnett's conceptualisation of curriculum as knowing, acting and being, the mode 1 university will primarily be focused on the learning of knowledge and knowing together with being (Barnett, 2009; Barnett & Coate, 2004). Whereas the mode 2 university will be focused on the learning of action and acting based on knowledge and knowing and, to a lesser degree, be oriented to being and community orientation. However, the mode 2 university will address the relation between academic knowing and context, whereas being will imply a community and value orientation beyond the mode 2 university as being is a much more critical academic approach and it includes citizenship (Christensen, Henriksen, Kolmos et al., 2006).

Problem and project based learning are applied in all three different university types but with very different aims both concerning the type of problems students are working with and in relation to the organisation of the curriculum.

Scope of Problems in the Three Modes

A variety of components defines the PBL philosophy such as: the problem as a starting point, a case or a project organisation, a team aspect, directed participants, contextual and interdisciplinary learning (De Graaff & Kolmos, 2007). The PBL philosophy can be applied in all three ideal university modes and the project organisation, the project management and the team aspect might be similar in the three very different modes. However, the learning of the academic disciplines is approached in very different ways and implicitly the formulation of the problem as the motivational entrance to the discipline will be very different. Therefore, the problem is one of the important components in designing a PBL curriculum.

In the mode 1 university with the emphasis on theoretical and disciplinary learning, the problem will normally be designed by academic staff to suit the disciplinary learning objectives. These will typically be more narrow discipline problems and normally these will be projects only running for shorter periods. In earlier writings, I have called this type of problem the task-problem or the discipline problem. But, I have regretted ever defining a task-problem (Kolmos, 1996). A task-problem means that academic staff have formulated a narrow task for the students to work on. Later writings indicate that this is hardly PBL, but it might be an active learning methodology using teams to solve narrow discipline problems.

In the mode 1 university, there is not so much focus on skills and competencies, whereas there is much more on the learning of general education. Ethics will normally be a discipline which students can choose, although it is not integrated into the other technical disciplines. In the same way, the students might be able to choose service-learning projects, but most often as co-curricular activities, which basically means outside of the formal curriculum.

The mode 2 and 3 universities are characterised by interaction between academic theory and context – although in different variations. The mode 2 university emphasises the collaboration with companies and the learning of skills and competencies. The problems often originate in real companies. However, even if company problems might be much more ill-structured, this mode keeps its focus on the discipline, and in earlier writings this has been called the discipline problem (Kolmos, 1996).

Dealing with authentic problems creates issues in connecting context and academic disciplines. Academic disciplines are developed according to an academic history and not according to real life problems. Introducing real life problems from companies will require more interdisciplinary approaches to the analyses and solving of the problems as well as having a requirement for deeper analysis of the real scope of the problem. e.g. might a problem in the logistics system in a production be

seen, on the surface, as a technical problem, whereas an analysis of the problem might point at miscommunication among employees? Thus, the analysis phase of the problem is a necessary step in any PBL project. Unfortunately, this analysis is often carried out superficially and not with the depth it needs. Engineering students are especially keen to jump directly to solution phases and to try out solutions. This might be a very efficient way of testing out solutions, but, if all the solutions address the wrong authentic problem, then the students are not solving the real problem. In a PBL curriculum, it might sometimes be the case that the students will solve “false or fabricated” problems, when the students go out to companies where the problem has to meet the learning outcomes in the curriculum, e.g. in the case of technical logistics versus human interaction and they solve the technical logistics and not the human interaction. But, in this case, it is even more important that the students know that this is not the most important problem in the particular context. It is a minor problem in the context of the logistics as a whole.

In the emerging mode 3 university, there is an emphasis on the societal context whether it is society in broad terms or specific companies. Skills and competencies are also at the core. However, in comparison with the mode 2 university, the skills and competencies are combined with a more general education – or, in the German language, *Bildung* (Christensen, Henriksen, & Kolmos, 2006). In the *Bildung* tradition, education is regarded as education to become a citizen with a strong ethical approach – and in the mode 3 university, these ethical dimensions are combined with a competence approach integrated into the disciplines. In the earlier literature, the problems in this mode have been called open problems (Kolmos, 1996). This approach involves deep analysis of what kind of problems are going to be solved as well as a much more flexible interaction among the disciplines and, at the end of the day, in the curriculum. e.g. To analyse and solve sustainability issues – first by analysing the issues, formulating the problems and then pointing out the learning outcomes and disciplines involved – will require a flexible curriculum where the learning of methodologies and application of learned methodologies to new problems should be part of the core curriculum. An example of a mode 3 PBL project could be asking students to make an innovation for homeless people so that the homeless can make a living. The students have to understand the situation of the homeless people – and maybe even live together with them to identify potential innovations which would help the individuals. This is a very open-ended project which will involve various disciplines.

There are no fixed boundaries among these three ideal modes of universities and problem approaches, on the contrary there is overlap. Even the mode 1 university dominated by theory will have elements of the other two and vice versa. But, it is necessary to create ideal types as much of PBL implementation only takes place within a single course. This is a short-sighted strategy for education as a whole, although it is probably a great experience for the students and staff involved. However, to increase student centred and active learning, it is important to keep in main ideal modes of alternative universities and curricula.

Curriculum Strategies

Recent research has identified three strategies for the integration of sustainability at the institutional level and the three strategies can also be used to characterise the integration of PBL into the curriculum (Jamison et al., 2014; Kolmos, Hadgraft, & Holgaard, 2016):

1. an add-on and course strategy change to more active learning within the existing courses,
2. an integration strategy consisting of a merger of existing courses and integration of skills and competencies like project management and collaboration,
3. a re-building strategy which involves re-thinking of the role of the university in society and re-thinking the curriculum towards much more flexibility.

These three strategies can easily be applied in characterising the implementation of PBL in the curriculum.

Course strategy in an add-on curriculum. The add-on and course strategy is the most widespread strategy for PBL. In the literature, there is extensive reporting on PBL applied at a course level all over the world and most of the research reviews on PBL reports actually comes from a single course strategy (Shinde, 2014; Shinde & Kolmos, 2011). As mentioned earlier, the problems that the students are most often working on will be academic problems within the disciplines – and, if there are authentic problems, it will be pre-designed problems representing real world problems.

For the single staff member, this is an easy strategy to use, as it only concerns a course that one might control. From a system point of view, it can be a stepping stone to a bigger change as the individual staff members gain experience from a different teaching and learning practices.

However, there are also a number of disadvantages. The first one is that sometimes the time frame for the PBL activities is so short, that one begins to question if this is PBL or if it is a variation of active learning, which in itself is not necessarily a bad thing. Examples from reported PBL practices count e.g. four hours per week over a period of e.g. six weeks. Of course, with such a timeframe, it is not possible to learn the added value of PBL such as the PBL skills. Most often, formulated PBL skills are not included in the formal curriculum.

The second disadvantage is that an overview of the entire curriculum is often lacking. When students are doing a comprehensive PBL course for the first time, it is important to give the students tools for project management and collaboration and to orchestrate the development of the students' learning of PBL skills by reflection. What further complicates the learning of PBL skills is the fact that, in a modular curriculum system, students can select a set of courses. It might not be possible to create a proper progression in the learning of PBL skills, unless there are PBL components in all the mandatory courses. Therefore, the scaffolding of PBL skills is often lacking at the curriculum level.

The third constraint is that students might encounter PBL in two, or even three, parallel courses at the same time. The issue with this is that students experience an extra workload as they get much more involved and engaged in the learning.

The fourth complication concerns the stability of the academic staff, as the single teacher decides on his or her own course and course pedagogy. There might be a lack of communication among academic staff members and a lack of coordination in the educational program. If the single staff member leaves, there is no continuity to keep a PBL approach in the system.

However, having pointed out some of the disadvantages, the advantage of the course strategy is that academic staff gain experience and trust in doing something new. They experiment with small-scale PBL – or maybe in more correct terms – active learning methodologies. It can be a very important starting point in an institutional transition that academic staff are positive and have some experience.

Integration strategy. Whereas the course strategy can be an individual strategy for the single academic staff member, the two other strategies will require a system approach with a high level of coordination at system level. The integration strategy is very much oriented towards integration of competencies and projects into the curriculum across existing courses, especially company projects which will most often require a cross disciplinary approach.

The integration strategy can be exemplified and found in the Concieve-Design-Implement-Operate (CDIO) community. CDIO contains a long list of standards covering the system level with quality assurance and academic staff development, the integration of skills and competencies into the curriculum and, at a minimum, the integration of real-life projects, mostly company projects, where the students learn to conceive, design, implement and operate (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014; Edström & Kolmos, 2014). Furthermore, there is a set of criteria oriented more to the engineering profession.

Analysing the criteria at the curriculum level, there are many similarities to PBL and many of the standards can be applied directly to a change process to PBL (Edström & Kolmos, 2014). Researchers have formulated roadmaps for how to change the curriculum at the system level encompassing all elements, e.g. mapping the learning outcomes in all the courses and identifying which courses would benefit from combining discipline knowledge with relevant competencies and adequate learning methods.

Figure 2 illustrates such a mapping framework, where specific competencies are integrated into single courses and some of the courses are merged into one course.

There are many ways of re-organising the entire curriculum. Another way is to have a project applying to most of the course disciplines. Figure 3 represents such an approach where existing courses feed knowledge into one common project in a semester.

This structure resembles the capstone project in US engineering education, where the students use the various disciplines in one final project (Dutson, Todd, Magleby,

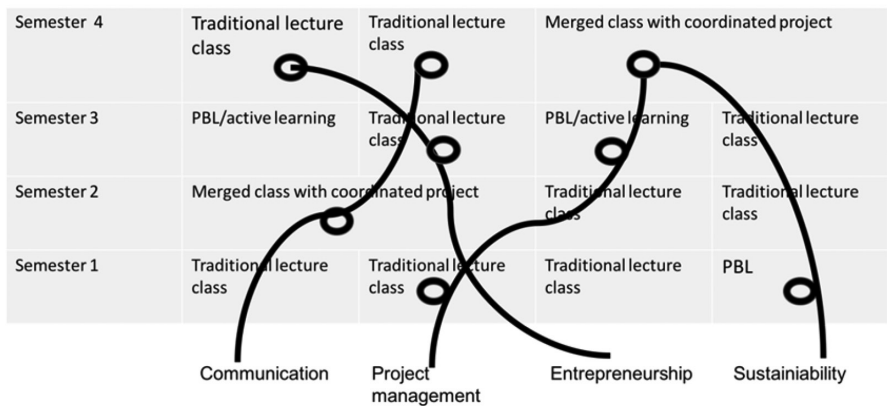


Figure 2. Integration of competencies into the curriculum (Edström & Kolmos, 2014)

& Sorensen, 1997; Todd, Magleby, Sorensen, Swan, & Anthony, 1995). However, there is a huge difference as the capstone project comes at the end of the curriculum, whereas the integration strategy is conceived as a curriculum model which can be used throughout the entire curriculum from the first semester to the final year. Furthermore, it is important that the students try out project several times to learn the PBL skills.

Re-building strategy. Re-building of curricula happens when the entire curriculum is re-structured and/or by building up a new institution or a new program. The re-building strategy emphasises the societal context as the starting point for learning. Students learn to analyse the contextual problems in a critical interdisciplinary academic perspective – and with no given answers, not even from the academic

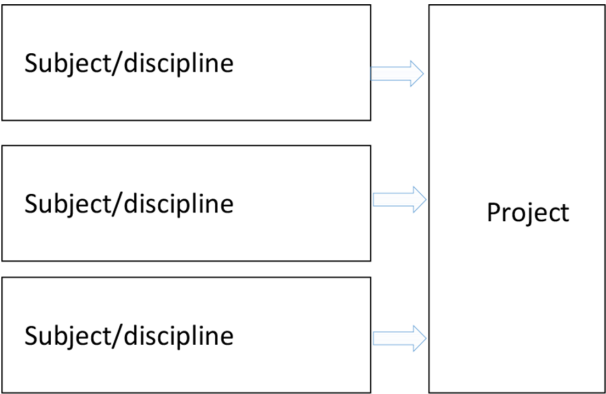


Figure 3. Integration strategy

research societies. The philosophy is to let the students think outside the box to create new ideas for societal development and green innovation. Disciplines do exist; however, these are shaped as a reflection of contemporary issues in society and are presented as societal themes to the students.

An example could be to let the students work on smart technologies in huge cities – e.g. Rio in Brazil where the favelas are intertwined with the rich areas. How can Rio increase sustainability and become a green smart city? This could be the theme – and actually cover most of the programs across all faculties. Then the students should identify problems and issues they would like to work on – and let the taught courses be selected according to the problem and project that the students are working on.

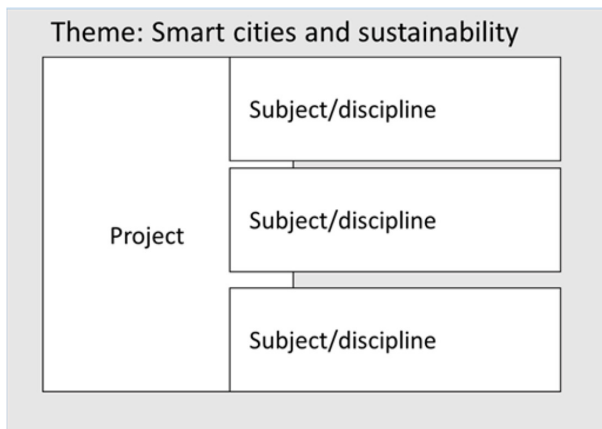


Figure 4. Re-building strategy

In this way, the project will determine the choice of disciplines. Maybe that kind of curriculum is around the corner as the integration of open learning platforms and online courses like MOOCS will allow for a much more flexible blended curriculum, where the just-in-time principles for learning the academic disciplines can be more flexible. Maybe a much more blended and flexible curriculum can also solve the schedule issues, which occur in most PBL implementation as it will be an advantage for students to have coherent time to work on the projects.

Does PBL Make a Transition or a Change?

At a first glance, the three strategies could match the three ideal university modes. Although it might be the most dominant curriculum change strategy, the different university modes will also apply other strategies. However, the mode 1 university will very rarely apply a rebuilding strategy as this will involve a more comprehensive

change in merging disciplines and theory and practice. The same counts for the mode 3 university where the add-on strategy can be difficult to apply.

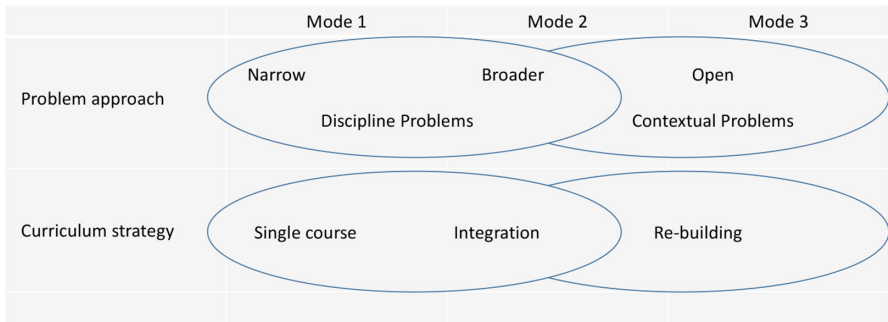


Figure 5. Combining modes, problems and curriculum strategies

In Figure 5, these overlaps are illustrated. What is missing here is that there will also be an overlap between the mode 3 and mode 1 university in the critical academic thinking. Going back to Paolo Freire, his statement on democratic education is important:

Democracy and democratic education are founded on faith in men, on the belief that they not only can but should discuss the problems of their country, of their continent, their world, their work, the problems of democracy itself. Education is an act of love, and thus an act of courage. It cannot fear the analysis of reality or, under pain of revealing itself as a farce, avoid creative discussion. (Freire, 1973)

Freire emphasise here my point that any implementation of problem- and project based learning might not necessarily be a sign of change or transition. It all depends on the intention of the change process, the extent of the change and the actual practice. But, education should contain a democratic element and, according to Freire, be a place of reflection on society and reflection with society. PBL and democracy are interrelated by the team and contextual aspects when students learn to analyse context from a critical analytical perspective and learn democratic values in teams by academic discussion, negotiation, collaboration, argumentation, disagreement, and agreement. Education is an act of love, engagement and commitment – involving societal values and personal identity in an integrated and hybrid learning process. In Paolo Freire’s context, his writing about education was as a space of freedom in relationship to the dictatorship in Brazil at that time, but his thinking reminds all of us that, in general, education should be the space of freedom and critical reflection on society. It is only by allowing freedom and trust in the learners’ capability for critical academic thinking and development of competencies for the good of society in general, that education will

fulfil the role of being an actor for the future. This is true in terms of critical analysis of the present and the creation of a vision for a more equal and balanced future.

Therefore, the three university modes and the possibilities for practicing student centred curricula are very important. At each institution, there will be elements of modes 1, 2 and 3, however the mode 3 will normally be underrepresented in terms of the integration of contextual issues, the open-ended problem approach and, not least, the interdisciplinary curriculum. Sustainability and community orientation are important in education to prepare students for solving the problems of today and tomorrow.

REFERENCES

- ABET. (1995). *A vision for change: A summary of the ABET/NSF industry workshops*. Baltimore, MD: ABET, Inc. Retrieved from http://bioinfo.uib.es/~joe/sem doc/PlansEstudis/ABET_Criteria_PTE/Vision.pdf
- Barnett, R. (2009). Knowing and becoming in the higher education curriculum. *Studies in Higher Education*, 34(4), 429–440. doi:10.1080/03075070902771978
- Barnett, R., & Coate, K. (2004). *Engaging the curriculum in higher education* (1st ed.). Maidenhead & New York, NY: Open University Press.
- Christensen, J., Henriksen, L. B., & Kolmos, A. (2006). *Engineering science, skills and bildung*. Aalborg: Aalborg Universitetsforlag.
- Christensen, J., Henriksen, L. B., Kolmos, A., & Christensen, J. (2006). Engineering science, skills, and bildung. In A. Kolmos & A. Kolmos (Eds.), *Engineering science, skills, and bildung* (pp. 7–19). Aalborg: Aalborg Universitetsforlag.
- EURASHE. (2009). *The Bologna process 2020 the European higher education area in the new decade*. Brussels: European Association of Institutions in Higher Education (EURASHE). Retrieved from https://www.eurashe.eu/library/bologna_2009_leuven-communique-pdf/
- Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *The CDIO approach: Rethinking engineering education* (pp. 11–45). New York, NY: Springer.
- De Graaf, E., & Kolmos, A. (2007). *Management of change: Implementation of problem-based and project-based learning in engineering* (1st ed.). Rotterdam, The Netherlands: Sense Publishers.
- Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A review of literature on teaching engineering design through project-oriented capstone courses. *Journal of Engineering Education*, 86(1), 17–28.
- Eckel, P. D., & Kezar, A. (2003). Key strategies for making new institutional sense: Ingredients to higher education transformation. *Higher Education Policy*, 16(1), 39–53.
- Edström, K., & Kolmos, A. (2014). PBL and CDIO: Complementary models for engineering education development. *European Journal of Engineering Education*, 39(5), 539–555. doi:10.1080/03043797.2014.895703
- EU Commission. (2008). *Improving competences for the 21st century: An agenda for European cooperation on schools*. Brussels: Commission of the European Communities. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52008DC0425>
- Freire, P. (1973). *Education for critical consciousness* (Vol. 1). New York, NY: Bloomsbury Publishing.
- Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education*, 103(2), 253–273. doi:10.1002/jee.20041
- Kezar, A. (2013). Understanding sensemaking/sensegiving in transformational change processes from the bottom up. *Higher Education*, 65, 761–780. doi:10.1007/s10734-012-9575-7
- Kolmos, A. (1996). Reflections on project work and problem-based learning. *European Journal of Engineering Education*, 21(2), 141–148. Retrieved from <http://www.tandfonline.com/doi/pdf/10.1080/03043799608923397>

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- Kolmos, A., Hadgraft, R. G., & Holgaard, J. E. (2016). Response strategies for curriculum change in engineering. *International Journal of Technology and Design Education*, 26(3), 391–411.
- Kotter, J. P. (1995). Leading change: Why transformation efforts fail. *Harvard Business Review*, 73, 59–67.
- Moesby, E. (2008). *What is an effective approach to introducing PBL/POPBL in an institution*. Aalborg: Institut for Samfundsudvikling og Planlægning, Aalborg Universitet.
- Reidsema, C., Hadgraft, R., Cameron, I., & King, R. (2013). Change strategies for educational transformation. *Australasian Journal of Engineering Education*, 19(2), 101–108. Retrieved from <http://search.informit.com.au/documentSummary;dn=810983996591111;res=IELENG>
- Shinde, V. (2014). *Design of course level project based learning models for an Indian engineering institute: An assessment of students' learning experiences and learning outcomes*. Aalborg: Aalborg University. Retrieved from: [http://vbn.aau.dk/en/publications/design-of-course-level-project-based-learning-models-for-an-indian-engineering-institute\(e3d036d7-0fed-4460-867d-a6785c27285d\).html](http://vbn.aau.dk/en/publications/design-of-course-level-project-based-learning-models-for-an-indian-engineering-institute(e3d036d7-0fed-4460-867d-a6785c27285d).html)
- Shinde, V., & Kolmos, A. (2011). Problem based learning in Indian engineering education: Drivers and challenges. In *Proceedings of Wireless VITAE 2011* (pp. 179–184). Bangalore: IEEE Press.
- Spady, W. G. (1994). *Outcome-based education: Critical issues and answers*. Arlington, VA: American Association of School Administrators.
- Todd, R. H., Magleby, S. P., Sorensen, C. D., Swan, B. R., & Anthony, D. K. (1995). A survey of capstone engineering courses in North America. *Journal of Engineering Education-Washington*, 84, 165–174.

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