

PROBLEM AND PROJECT BASED CURRICULUM VS. CDIO

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ABSTRACT

In engineering education the qualifications and competencies have been determined mainly from the point of view of science and technology. Especially during the 90^{ties} the spectrum of competencies of engineers expanded to concern more social and interpersonal items (teamwork, management), communication (foreign languages, presentation skills), acquisition of knowledge and problem solving: from Theory to Skills. There was a growing gap between the competencies required by the industry and produced by the education system. Traditional engineering curriculum cannot properly face this challenge: there was a need for a fundamental update of the curriculums of engineering programs.

To change the strategy of curriculum totally will start a massive change process, which will cover the whole organisation. All changes create instability to the organisation: the sense of insecurity, incompetence and lack of professionalism. Therefore change management is essential to ensure the continuation of the process. In every change process you need a proper strategy as a backbone of your development process. As a CDIO Collaborator we changed our pedagogical strategy from Problem and Project Learning to CDIO. This means that Problem and Project Learning now has a "tool" status: they are tools for the implementing process.

The Curriculum should be seen as a complete plan, how the learning and teaching are implemented and organized in the program, not just a list of contents. Our present curriculum is based on a hybrid model of Problem Based Learning (PBL) and Project Learning. During the 1st and 2nd study year the basic knowledge and skills are studied mainly with PBL and Project Learning. The focus is on the development of study and process skills. The basic technology of Mechatronics is also learned. In the 3rd and 4th study year the students will work in demanding projects with companies (real life cases). The professional core studies have been integrated in three categories: Automatic Systems, Mechanical Systems and Production Technology. In every study year students will conduct a whole planning and implementation process: from an automatic device (1st year) to whole systems.

In this paper we will discuss how Problem Based and Project Based Learning are related to CDIO and compare PBL and Project Learning to CDIO (key elements, focus, outcomes). We also compare our present curriculum to the 12 CDIO Standards and analyse how they match. How many of the standards are fulfilled from our perspective? As an end result we produce a collection of evidence as a part of that survey and a list of tasks which we have to execute to be considered a CDIO Engineering Program.

KEYWORDS

mechatronics, PBL, Project Learning, curriculum, CDIO Standards

INTRODUCTION

In her article Mélanie L. Sisley refers to many researchers, who state that technological changes have major effects in our minds. High technology is altering our neural pathways faster than ever. Facebook, Youtube, Blogsites and other social medias are forming the personality of our students. This will have significant effects on learning styles and strategies as well. For example young students have learned the way to process data in parallel. They have many parallel mental processes going on simultaneously (“multitasking and partial attention”) [1].

On the other hand, I myself and my colleagues learned to use Internet in the 90^{ties} as clumsy freshmen in the “Electronical World”, which has been changing rapidly ever since. The average age of lecturers in our faculty is nearly fifty years. Our learning styles and strategies were developed during the “Television Era”. We have learned a “one task at a time” strategy: we will be stressed trying to do many tasks simultaneously. Our data processing is “serial”.

In the long run it would be vital for universities and other educational organisations to fill this gap between learning strategies of the teaching staff (professors, lecturers and instructors) and the students. We should also meet the challenges of “new” qualifications for engineers coming from the work life.

With active learning strategies (CDIO, Problem Based Learning, Project Learning) and methods we should update engineering curriculums to face the challenges of the future. Lahti University of Applied Sciences (LUAS) was approved as a CDIO collaborator in November 2010. Just before that we made a faculty level decision to use CDIO as the main pedagogical strategy in the Faculty of Technology. There have been systematic curriculum development projects since the beginning of 90^{ties}. The milestones of that process are listed below.

- Project Learning partially started in 1990 (projects in courses)
- Content update in 1995 (mechanical vs. automation 50/50)
- PBL started partially in 2000
- First Problem and Project Based Curriculum (Engineering) in Finland in 2003
- International PBL Conference in Lahti (with University of Tampere) in 2005 (<http://www.lamk.fi/pblconference>).
- Project Learning as a pedagogical strategy at Faculty of Technology in 2008
- National Project of Engineering Education INSSI in 2008-2011
- First contacts to CDIO (Turku) in 2008
- First faculty level project based curriculums launched in 2009
- Faculty decision to join in CDIO in 2009
- CDIO Fall Meeting in Turku in 2009
- Degree Programmes reduced to four: Environmental, Information, Material and Mechanical in 2010-11
- 6th International CDIO Conference in Montreal in 2010
- PBL triggers will be derived from the projects in 2010-11
- CleanTech-project started in 2010
- CDIO as a pedagogical strategy at Faculty of Technology in 2010
- Project of Engineering Education INSSI II in 2011-2013

PRESENT CURRICULUM IN MECHATRONICS

The first version of our PBL curriculum was completed in February 2003 and it is developing continuously. In September 2003 new students put the curriculum in practice and the results were encouraging. In our curriculum we point out the differences of the planning and implementing processes. This also concerns the developing process of PBL curriculum. On paper everything looks great, but in the implementation process the Quality and Change Management will produce a massive number of problems to solve.

The knowledge is contextualized: we should emphasize the knowledge, that is relevant to the engineer's every-day life. The learning is based on the experimental learning (system) and constructivistic approach (students). At the curriculum level the experimental learning model can be argued by pointing out the Praxis: skills should have the same weight as theoretical studies. The constructivistic learning strategy leads us to build up a genuine student-centred learning environment [2].

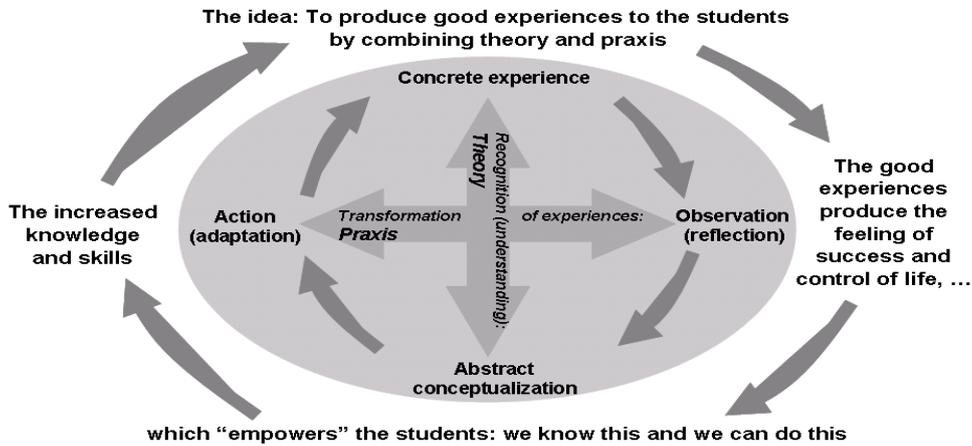


Figure 1: The Experiential Learning (Kolb) and Mechatronics

The starting point to our curriculum development work is Kolb's Cycle: the model of the Experiential Learning by David Kolb (fig. 1). The experiential learning model by Kolb has four phases: a) experience, b) observation (reflection), c) conceptualization and d) action. This is described in the inner circle of Figure 1. The action-observation pair forms the transformation of the experiences axis, which is very strongly related to the Praxis. On the other hand the experiences-conceptualization pair states for the recognition (or understanding) axis, which is based on the Theory [3].

The outer circle of Figure 1 shows how we have adapted this model. By combining Theory and Praxis in every case or problem the students can apply learned theory immediately (not after two years of studies). The structure of the curriculum is presented in Figure 2.

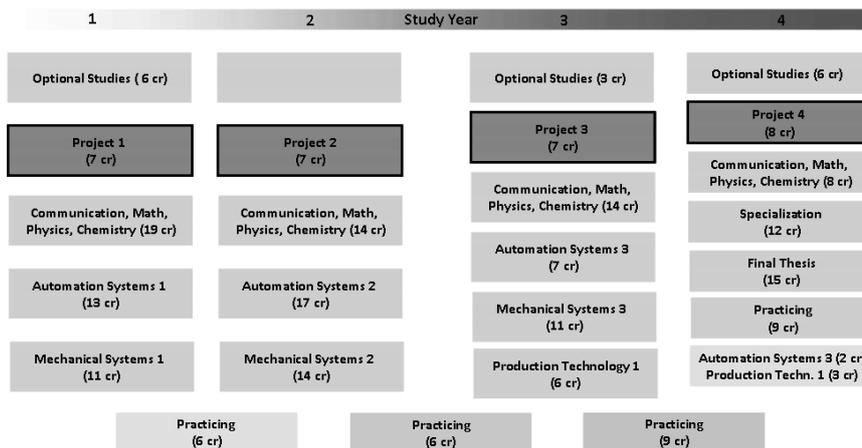


Figure 2: The structure of the curriculum

Mechanics can be described as "the decathlon of Engineering". System thinking is one core concept in our curriculum: the students should learn that the systems in mechatronics form an integrated whole rather than a massive body of components.

Most of the engineers in mechatronics in Finland plan and implement projects. In the Lahti region many companies export over 80% of their production. That is why the engineers should learn how to run international projects. This planning and implementation process of “real projects” was a model for us: every study year we complete one. This project model adopted from the companies was modified in pedagogical form: “Pedagogical Engineering”.

The title for the first year project is “an Automatic Device”: the students should be able to plan and construct such a device as a team. During the second year they are expected to finish a project, which generates accurate movements (positioning, CNC). During later phases of studies the students will make “real” company projects. This preconceives that students are capable to accumulate knowledge in layers.

The assessment and evaluation guides the students` work more than we think: what you order, is what you get. The wider spectrum of qualifications postulates a wider spectrum of means in assessment and evaluation. The assessment system in our curriculum has two major components: a) the process assessment (summative assessment) and b) the result evaluation (formative evaluation), which are equally weighted [4]. The process assessment is based on:

- the students` self-assessment (form) and feedback discussions
- the peer assessment among the study groups and feedback discussions
- the assessment of the tutorial performance by the tutor
- personal and group interviews twice a year.

The components of the result evaluation are tests, skill tests and reports.

The last but not the least feature is the classification of objectives. There are general objectives for the whole education (four years), and process and content objectives for every study year. Every study module has objectives of its own and so does every case or problem.

The documents of the curriculum are a) curriculum description in the student’s guide book (general description of the studies and study modules), b) study module manuals (tutor and student versions) and c) cases (case description, implementation plan and the guide for reporting, assessment and evaluation).

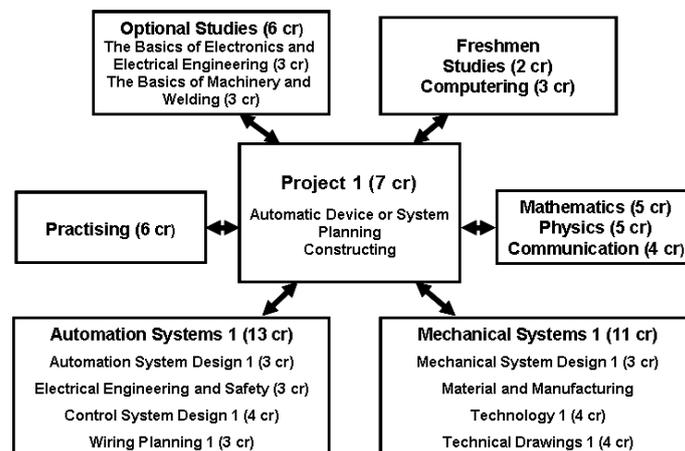


Figure 3: Projects in Focus

Figure 3 shows how the first year studies are implemented. Almost all courses are linked to the project. Courses of Automation and Mechanical Systems are studied with PBL cases, which are derived from the project. For example the case in Control System Design is to produce a PLC program to a system which is very similar to the system in the project. The contents of courses are driven directly from the project. Items which are not relevant to the project have been dropped out. The qualifications of a mechatronics engineer have also been reflected: the contents of the courses must have a direct connection to an engineer’s daily work. In this way we have managed

to provide “on demand” course contents, which focus only on the items necessary to run the project.

COMPARISON OF LEARNING STRATEGIES: PBL, PROJECT LEARNING AND CDIO

The World is full of acronyms, which stand for a large variety of pedagogical strategies and methods: PBL, PPBL, IL, RBL, TPL. The hybrid model of Problem and Project Based Learning is perhaps the most suitable model for engineering education [5]. How are these learning tools connected with CDIO? Which are the key elements, focus and outcome of these methods? Table 1 shows the characteristics of CDIO related to PBL and Project Learning.

The key elements of CDIO are the 12 Standards and the CDIO Syllabus. They form an international framework and overall development strategy. From our perspective the advantages of joining CDIO are international context, benchmarking and continuous program development. In CDIO we can learn from other universities and exchange experiences. CDIO is also a part of our Quality Assurance.

Table 1

Comparison of Problem Based Learning, Project Based Learning and CDIO

	Key Element	Focus	Outcome
CDIO	Standards Syllabus	Overall Development Strategy	International Context Benchmarking Continuous Program Development
Problem Based Learning	Tutorials Cases/Triggers	Learning Process Assessment	Learning Skills Teamwork Self and Peer Assessment Skills
Project Based Learning	Real Life Projects	End Results Evaluation	Planning Skills Construction Skills Product Development Teamwork Project Management Motivation

Problem Based Learning is used as a study model in the courses of Automation and Mechanical Systems. The courses are wrapped around PBL cases and triggers. The students work in small groups (6-9 students) following the study cycle shown in Figure 4. Every student group has been appointed a tutor from the teaching staff, who will guide the group in weekly tutorials and during the study process. The tutor and student group form a team, where both PBL cases and projects are performed. This cycle study model was originally developed in the University of Linköping Sweden and completed by Esa and Sari Poikela with the aspects of assessment [6].

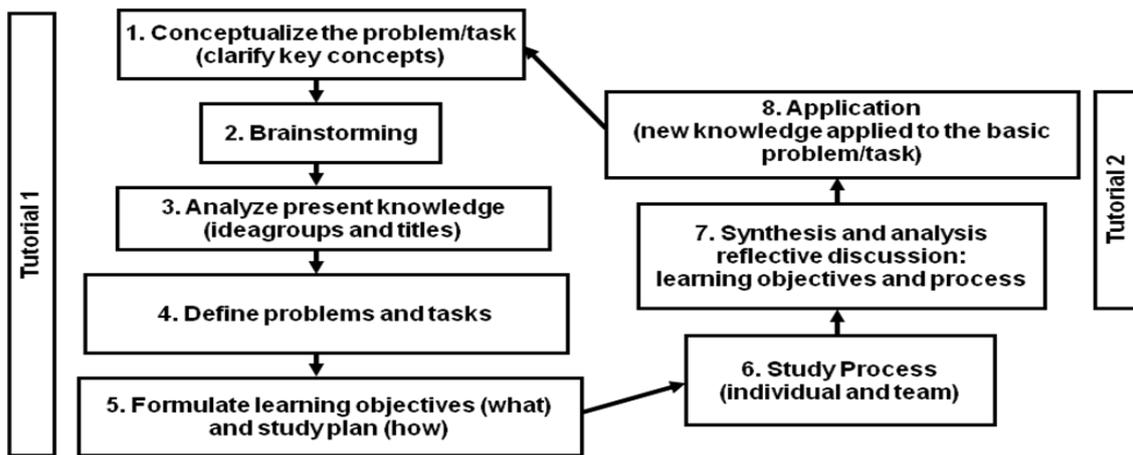


Figure 4: PBL Study Cycle

The cases and triggers are presented in the opening tutorial. The outcome the tutorial is learning objectives for the student group. The idea is that when producing the learning objectives of their own, the students will be better motivated. The ownership of learning is transferred from the tutors to the students. They also learn problem solving methods like Brainstorming. After tutorial follows Study Process. It contains individual and team learning, lectures, exercises and skill training. The final phase is the closing tutorial. There the case or trigger will be closed with reflective discussion. The newly formed knowledge is applied to the original case or trigger: have the learning objectives been met, problem solved and study plan followed? In every phase evaluation and assessment are included. This cycle takes at minimum four weeks and maximum four months.

Henk Schmidt and Jos Moust have analyzed PBL from following aspects:

1. Cognitive processes in tutorial discussions and their impacts on learning results
2. Impacts on motivation
3. Tutor's impact on learning

In this study the researchers suggest that cases or triggers (learning tasks) have a more significant impact on learning than expected. The quality of learning tasks is even more important than the competence of the tutor [7]. Henk Schmidt and Wim Gijsselaers developed the theoretical model of PBL. The model has three groups of factors: input, process and output factors as seen in Figure 5 [8].

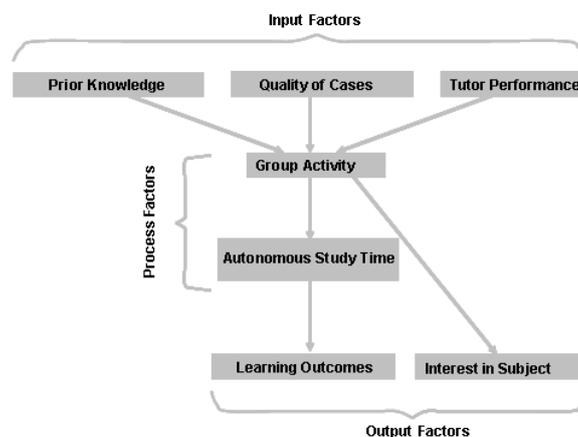


Figure 5: PBL model by Schmidt and Gijsselaers

Input factors refer to the character of students, tutor behaviour and the quality of study materials. Process factors contain the study skills of students (especially during the autonomous study time), study hours and the guiding process. In output factors you can find learning outcomes and the

interest in the subject, which has an outstanding impact on motivation. The researches completed their model by calculating the correlation between the factors (fig. 6). Correlation varies between -100...+100. The larger number means stronger correlation.

The strongest correlation is between the group activity and the interest in the subject (57). The quality of triggers activates prior knowledge and has a major impact on group activity. Tutor competence has lower correlation than the quality of triggers. As a conclusion, in the PBL study process tutor does not have to be a “Superman or –woman” but the triggers have to be carefully planned. The main factors in tutor competence are social and cognitive congruence and use of professionalism.

With the Problem Based Learning study process it is difficult to solve complicated real-life engineering problems. Project Learning model would do better. In Project Learning the end results are emphasized and the study process is more straightforward than in the Problem Based Learning. With projects you learn practical planning and construction skills. Every project is also a product development process. If students run the project in the same small group as PBL cases, they can utilize PBL study skills to recognize problems and solve them in their projects as well.

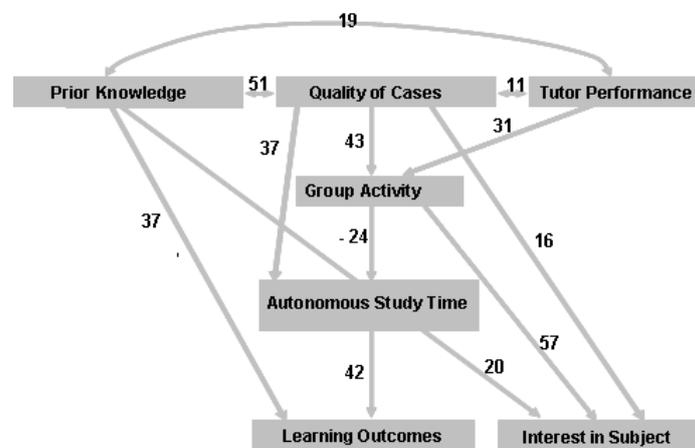


Figure 6: PBL Model with correlations

The results of the PBL Model can be generalized to concern also the projects: especially the first two projects must be carefully planned. They should be complicated enough to provide intellectual challenges for the students. On the other hand the knowledge and skills learned during the first study year should be adequate to finish the project. They should also have a strong connection to work life (realistic projects). From the project management point of view these projects are demanding for the tutors. When the students are using machines and making electrical installations, safety must be secured and they should be supervised and instructed. This requires planning and designing skills from the tutors.

Here are some examples of the projects implemented in 2009-2010:

- Project 1: "Poor Man`s Segway"
- Project 2: Automatic cable measuring and cutting device
- Projects 3 and 4 are company projects: Testing device for surface switches, RFID (Radio Frequency Identification) system in production, Machine vision system for food industry

THE 12 CDIO STANDARDS VS. PRESENT CURRICULUM

The 12 CDIO Standards were updated in December 2010. In this revised edition each standard is disassembled in three sections: description, rationale and evidence. The description explains the meaning of the standard, the rationale highlights reasons for setting the standard, and evidence gives examples of documentation and events that demonstrate compliance with the standard [9]. We have reflected the standards through our program development in mechatronics. The results are shown in Table 2.

Table 2
The 12 CDIO Standards and Program Evaluation

CDIO Standard	Condition	Evidence
1. CDIO as Context	Mission statement done Deployment: conversion PBL to CDIO under construction	Faculty Decision OK Approval as CDIO Collaborator 11/2010
2. CDIO Syllabus Outcomes	Done	Learning outcomes in curriculum validated by stakeholders
3. Integrated Curriculum	Mainly done Mapping under construction	Curriculum
4. Introduction to Engineering	Done	Project 1, Freshmen Studies, Curriculum, choices of elective courses
5. Design-build Experiences	Done	Projects
6. CDIO Workspaces	Mainly done Workshops should be modernized	Laptops, workshops, labs, Moodle, teamwork rooms
7. Integrated Learning Experiences	Done	PBL, Projects, Company projects and seminars, final thesis
8. Active Learning	Mainly done High level of achievement of all CDIO learning outcomes?	PBL, Projects, Student feedback
9. Enhancement of Faculty CDIO Skills	Mainly done Hiring policies should be improved	CDIO as Pedagogical Strategy, Pedagogical Training Program
10. Enhancement Faculty Teaching Skills	Done	Pedagogical Training Program, National Evaluation Meters, Follow-up of study progress and backup, guidance
11. CDIO Skills Assessment	Done	Evaluation and Assessment System, Projects, PBL
12. CDIO Program Evaluation	Mainly done Documentation should be improved	Student Feedback System, Company Projects

Since we have used active learning methods in the degree program of mechatronics for over 20 years, it is obvious that our learning objectives and outcomes match the CDIO Standards. Our main pedagogical strategy has been PBL and Project Learning. Therefore our students and staff are familiar with the PBL, but not yet so much with CDIO. That will be changed in the near future. Mapping of learning objectives and outcomes has to be done during the next academic year (major update in curriculums). We have satisfactory CDIO Workplaces, but they should be modernized. How to measure high level of achievement of all CDIO learning standards? In the future we will also pay more attention to the recruiting process and use CDIO skills as one qualification. In internal program evaluation we should improve the documentation. A more detailed external evaluation takes place every 2-3 years.

CONCLUSION

The hybrid model combining Problem and Project Based Learning provide a firm basis for the curriculum development of a CDIO Engineering Program. The learning outcomes in Problem and Project Based Learning will match those of the CDIO Syllabus. Problem Based Learning is effective in "learning to learn": reflective attitude, assessment and teamwork skills. Project Based Learning could be adopted when the raw end results should be produced: when evaluation, problem solving, scheduling, project management and performance of work are required.

From our perspective, the curriculum of Mechatronics will meet six of the 12 CDIO Standards. The rest of them will be passed in two years (2013). A detailed mapping of learning outcomes between the CDIO Syllabus and the present curriculum is the main task to do.

The key elements of CDIO are the 12 standards and the CDIO Syllabus. These documents will answer the question “what” you should do to develop a CDIO Program Curriculum. To get the answer to “how” to do it, the tools have to be chosen for curriculum reform. With these tools the “educational system” can be planned and implemented. The Learning takes place, when the “system” makes the persons (students, staff and stakeholders) work as a team together to create new knowledge and skills.

Biographical Information

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