DEVELOPING CURRICULA BY BLACK BOX METHOD

Patric Granholm, Kari Haajanen, Mari Ketola, Anne Norström

Turku University of Applied Sciences, Faculty of Technology and Business,
Lemminkäisenkatu 30, FI-20520 Turku, Finland

ABSTRACT

A curriculum can by time develop to a collection of good courses created, executed, and further developed by individual teachers alone. This can lead to curricula where the connection between the courses cannot clearly be seen and the required inputs and outputs between the courses remain unclear. Courses with same content can be arranged twice or lead to a curriculum where crucial content is missing. In this paper we present two cases of curricula development utilizing the black box method. The first case is a curriculum of a recently started education. The curriculum is examined the first time after its creation by the faculty staff. Second case is a curriculum of an education that has been ongoing for several years. In the black box development method, the faculty staff discuss the courses in terms of input and output knowledge and skills only. Every course is considered as a black box. For each course, the faculty members involved in course implementation identify the specific knowledge the students should enter the course with and what knowledge and skills they should bring with them to future courses. The knowledge and skills are expressed as learning outcomes. By collecting this information from all courses in the curriculum, it is possible to identify the connections between different courses and address any inconsistencies such as unnecessary gaps etc. The black box exercise has been performed for two curricula. In the first stage the teachers identified the required input and expected output of the modules. The results from this stage show the need for increased collaboration between teacher teams as well as within the teams. The process has enhanced dialogue and productive discussions among faculty members and increased awareness of the whole curriculum.

KEYWORDS

Black box, curriculum development, higher education, chemical engineering, Standards: 2,11,12

DEVELOPMENT OF CURRICULA AND HOW WE ENDED USING BLACK BOX METHOD

The curriculum of the Degree Program in Chemical Engineering was redesigned in 2015 to comply with the new curriculum requirements and instructions of Turku University of Applied Sciences (Turku UAS). The main requirements at that time were to create a modular curriculum with entities of minimum 5 ETCS and thus avoid highly fragmented curriculum by integrating these entities to larger modules of 15 ECTS. In addition, the strategy of Turku UAS guided the use of innovation pedagogy (Lehto et al and 2013). Since that, the department of Chemical Engineering has expanded and includes today three Degree Programs: Chemical Engineering, Chemical Engineering (multiform) and Energy and Environmental Engineering**.** At the department of Chemical Engineering innovation pedagogy is implemented and applied through the CDIO concept in all curricula for all three Degree Programs.

According to the CDIO framework the curricula are reviewed by the faculty, students, and the advisory board. Department of Chemical Engineering has an advisory board consisting of stakeholders from regional and national companies. A review is made every second year by stakeholders. Their opinion is important, as the content in the curricula gives the elements, and knowledge, that the graduates take with them to their future employers.

In 2020 the Degree Programs were reviewed again, five years after the redesign 2015. It was time to make amendments to the curricula based on both feedback and experience. In general, it was considered that the transition to modular curricula was a success. The goal to create larger entities and to collect subjects connected to a topic to modules was achieved. Though, some problems were noted: Internal planning and discussions within the faculty were lacking and leading to problems. Feedback from student reviews indicated that same of the topics were introduced several times as they were included in multiple courses. It was also noted that the lack of internal planning and discussions led to the fact that some important parts fell entirely out of the curricula. This issue was discussed within the staff and led to the decision to monitor the curricula as whole. As a tool for the monitoring the black box method (Crawley 2007) was used.

THE CURRICULUM AND ITS CONTEXT

The curriculum of the Degree Program in Chemical Engineering is based on the long history of process technology education in Turku University of Applied Sciences (Turku UAS), collaboration and reflection with the local industry and universities, innovation pedagogy “Innopeda®”, CDIO standards, strategy of Turku UAS and feedback from students and advisory board. The basic structure of curriculum in Turku UAS is simple and flexible even for rapid changes. There are only two categories in the curriculum: core competence and complementary competence. The curriculum structure is shown in Figure 1. All courses are in these two categories. The goal is to create flexible curriculum for the faculty and students without tight restrictions.

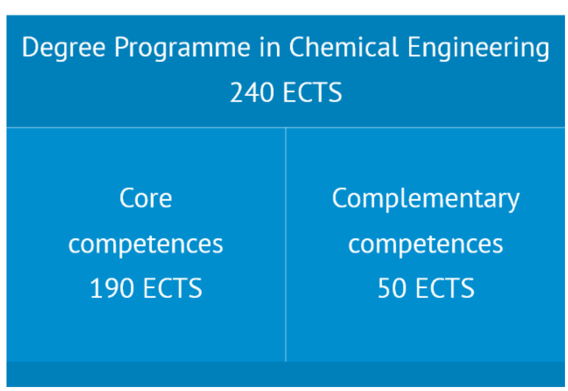

Figure 1. The structure of the curriculum in Chemical Engineering Program.

The goal of innovation pedagogy is to prepare the students to learn new skills needed for future engineering work. The role of teacher in Innopeda® is more like a coach rather than a traditional teacher. There are many similar elements in Innovation Pedagogy and the CDIO concept. The innovation pedagogy structure and competences are presented in Figure 2. Higher education strives to educate students for jobs that do not yet exists, using technologies that have not yet been invented.

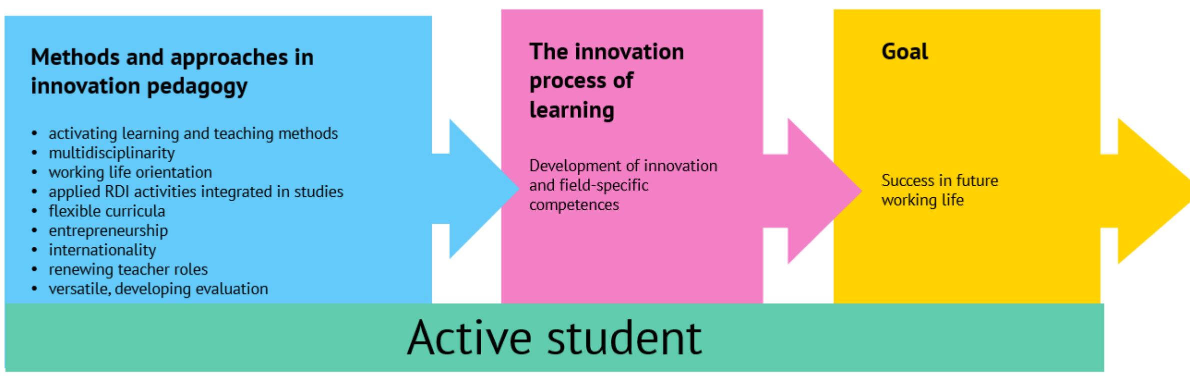

Figure 2. Innovation pedagogy and competences in Turku UAS.

Innovation and project management skills are recognized as one of the most important parts in Turku UAS curricula. Knowledge and skill requirements increase year after year. At the beginning of the studies there are mainly Turku UAS internal projects and the goal is to learn the basics in project management methods and project reporting. Third year Innovation project, Capstone, is often an external project performed in collaboration with the industry partner. These projects are more demanding compared to previous year projects. Innovation competence steps in engineering studies in Turku UAS are presented in Figure 3.

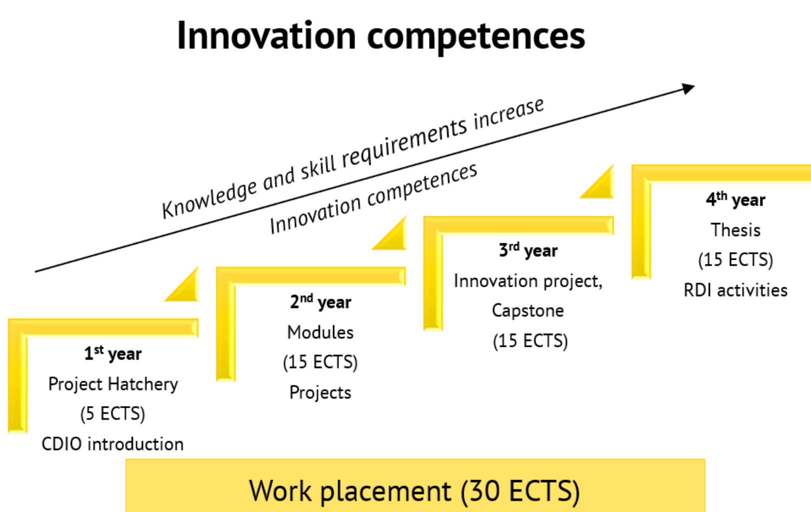

Figure 3. Innovation competences in Turku UAS.

CURRICULUM DEVELOPMENT METHODS

Although a lot is written about curricula it is difficult to find a single definition of what a curriculum is (Grant 2014). IGI Global dictionary lists, on a search “what is curriculum”, 75 sources with definitions from a list of courses to a document that includes content, teaching strategies, assessment methods and learning outcomes (IGI Global). A brief literature review shows that different methods are used for curriculum development depending on the goal of the development work as well as the context.

In cases where the development work is steered by the goal to achieve a formal accreditation the work is usually mission bases, the programme must fulfil strictly defined external requirements. This is typical for healthcare and medical programmes, but formal accreditation can also be made for engineering programmes, see Wellington (2004). In fields, like chemical engineering, where the external steering is on recommendation level, e.g., the Bologna recommendations 2020, given by the European Federation of Chemical Engineering (EFCE 2020), the freedom to design the curriculum is greater. Thus, is also the choice of development method greater. Within the engineering field the methods are often graphical and adapted from different system engineering methods. There are e.g., outcome-oriented methods as the black box method (Crawley 2007), process-oriented methods; Y-charts (Rashid 2014) or user-oriented with basis in object-oriented thinking (Somerville 2006). In all cases there are also an attempt to incorporate methods and values in the curriculum.

The CDIO approach to curriculum development is based on the CDIO standards and the syllabus. The interest for more thorough examination of the curriculum was initiated by the teachers. The teachers were eager to know if the curriculum was a continuous path of courses, where the amount of knowledge is continuously increasing without leaving incoherencies in the learning paths. If incoherencies would be found in this study and the corrections needed would require changes in the whole curriculum, should the issues be addressed to the Dean of the Faculty for acceptance. Minor changes can be approved by the Head of School.

The black box method is used to visualize the links between courses modules in a curriculum. In this method all courses are represented by a black box. Only the input knowledge required for the course, and the output learning outcomes, are made visible. All faculty members are asked to produce a black box element of the course that are responsible for. These elements are then linked together via their input requirements and outcomes. (Crawley 2007). The curricula for the programmes at the Chemical Engineering department could be developed using any of the mentioned methods. However, as Turku UAS has been a member of the CDIO initiative for several years it was most suitable to continue the development work with a CDIO approach using the black box method.

CASE STUDIES

The curriculum of two Chemical Engineering Degree Programmes have been developed by using the black box method. The examples are presented as case 1 and case 2.

Case 1: Recently started education

The teachers are experienced, but the multiform implementation created a need to increase teaching and counseling online. Teacher team consist of teachers working in several educations e.g., chemical engineering and ICT. To provide students with a combination of substance mastery and generic skills co-operation and sharing the practices are needed. The black box method (Crawley 2007) is used as a tool to enhance the co-operation and to understand the big picture. The CDIO Syllabus 2.0 (Crawley 2011) is utilized in identifying the intended learning outcomes.

As the courses are implemented for the first-time teachers formulate the course inputs and outputs while they are planning the implementation. A shared excel-file is used as a planning tool at this stage. The teachers fill in the excel-file independently and the contents are discussed during teacher team meetings. In the next stage a visual description is formed to make the connections between courses visible. In the Figure 4 an example of the visualization is presented. Only few inputs and outputs are selected in this example, there are significantly more inputs and outputs in the actual description. The description is utilized to identify gaps and redundances. It also helps to identify the interfaces and teachers that ensure the connections between the courses.

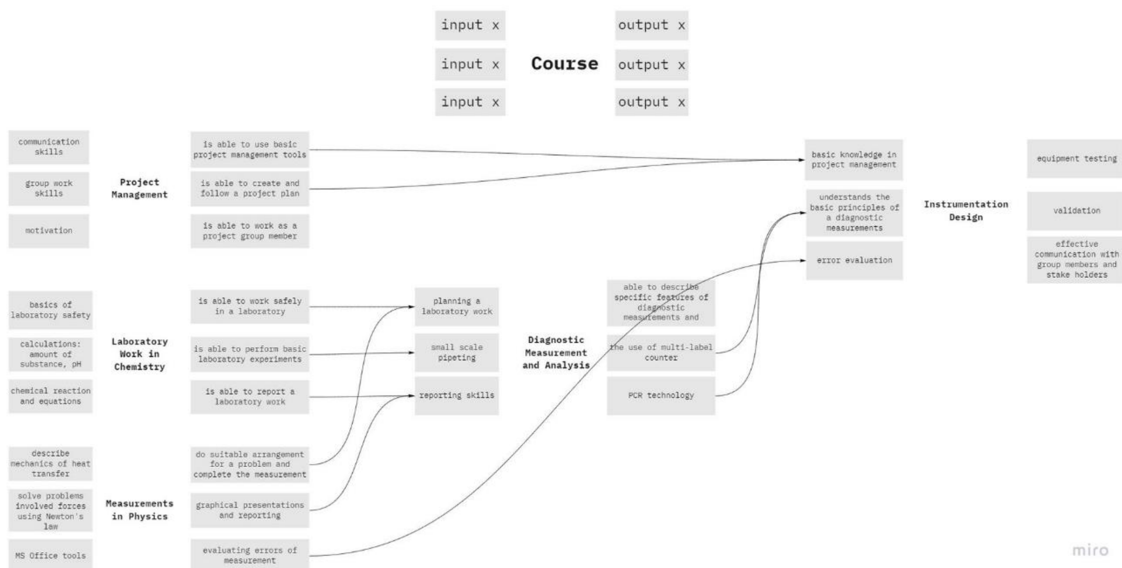

Figure 4. An example of the connections between courses.

Since the black box is used for design of a new degree programme from the very beginning, there is a possibility to react quickly if gaps or redundances are identified. When a teacher is planning the first implementation of the course, the outputs and the student feedback of the prior courses are available. By utilizing this method, it is easy to discuss the next implementation of prior courses if changes are needed.

CDIO Syllabus 2.0 (Crawley 2011) is presented as a table in an excel-file (Figure 5). All courses in the curriculum are presented in rows and the CDIO Syllabus content in columns. At the first stage, teachers mark the skills and attributes covered in their course. The aim is to support the teachers in identifying and enhancing the cross-curricular competencies. A shared file acts as a tool to visualize the entity for the staff involved.

	1 Discliplinary knowledge and reasoning			2 Personal and professional skills and attributes					
	1.1 Knowledge of underlying mathematics and sciences	1.2 Core engineering fundamental knowledge	1.3 Advanced engineering fundamental knowledge, methods and tools	2.1 Analytical reasoning and problem solving	2.1.1 Problem identification and formulation	2.1.2 Modeling	2.1.3 Estimation and qualitative analysis	2.1.4 Analysis with uncertainty	2.1.5 Solution and recommendation
Cource									
Software Tools for Professionals 1		x	x						
Software Tools for Professionals 2	x			x		x	x		x
Project Management					x				x
Mathematics for Engineers	x	x	x	x	x	x	x		x
Differential calculus	x	x	x	x	x	x	x	x	x
Statistical Data Analysis and Experiment Design	x	x	x	x	x	x	x	x	x

Figure 5. An example of the use of CDIO Syllabus 2.0 table.

Now the second academic year is ongoing. All the courses implemented so far are documented in the black box file and in the CDIO Syllabus file. A new group has started their first academic year following the curriculum modified based on black box design. The use of black box methods has so far increased the communication and discussion between teachers even though the visual description of the entity is still lacking.

According to our experience so far, it is very important to document the process, steps, and the actions, while creating the final documentation of the black box exercise. This documentation is then utilized in creating a process flow chart that can be used as a tool in future development work. Formulating the inputs and outputs for a single course is not time-consuming and the work is done parallel by individual teachers and proceeds fluently. Generating the visual description takes more time and has turned out to be challenging. Few software has been tested but we have not yet been able to find a suitable and practical tool.

Case 2: Education that has been ongoing for several years

Bachelor's Degree Programme in process and food industry technologies were founded 1970. Today parts of old curricula can still be found in Chemical Engineering Programme curricula. The program name has been updated to correspond to new trends and the content of the program. But still the roots of basics process industry exist strongly in chemical engineering background in Turku UAS.

It is challenging to update the structures and content of a traditional curriculum. The black box –method offered a new and neutral tool to analyze the situation in a new way. The development work was performed as described in the previous chapter and the entire process is presented in Figure 6.

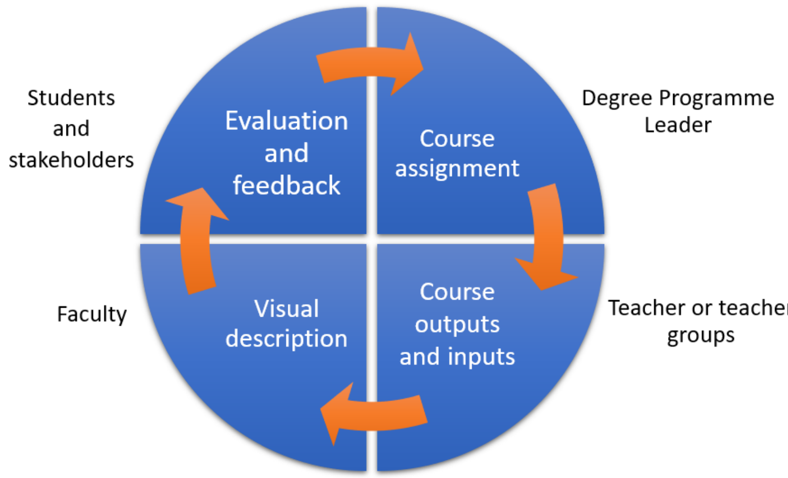

Figure 6. Black box development process.

CONCLUSIONS AND FUTURE DEVELOPMENT WORK

In the case of recently started education inputs and outputs are formulated by a teacher or the teachers that teach the course concerned. Biggers teams, consisting of teachers teaching courses in the same field, have been working with the inputs and outputs from the work described in case 2. The discussion is more profound from the beginning of the process when bigger teams are working together. On the other hand, in the case of the recently started education, it was easy to write the outputs and inputs for black box documentation while planning the implementation of a course. Furthermore, there was no need to arrange separate, time-consuming meetings, as it was in the case of the case example 2.

When the entire curriculum is reviewed as a whole, the big picture becomes visible sooner. Considerable amount of time must be reserved to complete the work. By reviewing the curriculum course by course, is less time required. On the other hand, longer time is needed to visualize the entity.

One of the most important result is that all the faculty members work together in this curricula development work. Active communication between managers, lecturers, researchers, and technical staff increases the general knowhow of courses and the connections between implementations. Changes in the curriculum can now be made rapidly and more efficiently.
As described earlier stake holders review the curricula every second year. In the sector of Chemical Engineering the advisory board is very active, and the co-operation is continuously developed. The black box documentation will be presented to the advisory board for them to give feedback as working life representatives.

Students should be engaged more during the whole development process. Students review the curriculum regularly but the black box and CDIO Syllabus documentation should be reviewed by the students as well.

An interesting continuation of this work could be a comparative study of the impact of the curriculum design method. Would a change of design method from black box to a process- or user-based method, in the same context, result in a different curriculum? A study like this could be an eye-opener for further development work.

The black box method activates staff members first in small groups with specified topics and at the end of the process the entire curriculum will be in focus. Better results will be achieved when the educational development work is done co-operatively. The development work continues in both programmes and will be repeated in two-years cycle.

REFERENCES

Crawley, E. (2011). *The CDIO Syllabus v2.0 An Updated Statement of Goals for Engineering Education*. CDIO Knowledge Library. Cambridge, MA; Worldwide CDIO Initiative. http://www.cdio.org, Dr. Edward F. Crawley, crawley@mit.edu

Crawley, E., Malmqvist, J., Ostlund,S., & Brodeur, D. (2007). *Rethinking Engineering Education: The CDIO Approach.* Springer Science & Business Media

EFCE (2020). *EFCE Bologna Recommendations 2020.* European Federation of Chemical Engineering.

Grant, J,. (2014) *Uderstanding Medical Education: Evidence, Theory and Practice, Second Edition.* Ed. Tim Swanwick. The Association for the Study of Medical Education. Published 2014 by John Wiley & Sons, Ltd.

IGI Global (2021, January 9). *What is curriculum.* https://www.igi-global.com/dictionary/curriculum/6468

Lehto, A. and Penttilä, T (eds), (2013). *Pedagogical Views on Innovation Competences and entrepreneurship*. *Innovation pedagogy and other approaches*, Turku University of Applied Sciences, Reports 171

Rashid, M., & Tasaduk, I. A. (2014) *Holistic Development of Computer Engineering Curricula Using Y-Chart Methodology*. IEEE Transactions on Education, vol. 57, mo. 3.

M. Somerville, J. Geddes, B. Linder, O. Eris, and J. Stolk, "Special Session - Incorporating Values: A User-Oriented Approach to Curriculum Design," Proceedings. Frontiers in Education. 36th Annual Conference, San Diego, CA, 2006, pp. 1-2, doi: 10.1109/FIE.2006.322621.

Wellington, C., (2004) *Designing an ABET accreditable computer science bachelor's program within the constraints of a teaching university*, *34th Annual Frontiers in Education, FIE 2004.* Savannah, GA, pp. T3G/18-T3G/23 Vol. 1, doi: 10.1109/FIE.2004.1408547.

BIOGRAPHICAL INFORMATION

Patric Granholm is a Principal Lecturer at Turku University of Applied Sciences, Faculty of Engineering and Business. He is an experimental physicist with experience in nuclear physics and nuclear safety, solid state physics, electrical conductivity in organic materials, measurement techniques and data analysis. He has a special interest in engineering ethics. His teaching activities has lately been focused on statistical data analysis for quality control, measurement technology and physics. He is an ambassador for the Phyphox app in Finland.

Kari Haajanen is a Degree Programme Leader at the Department of Technology and Business in the Sector of Chemical Industry at Turku University of Applied Sciences. He has experienced project manager with a demonstrated history of working in the higher education industry. He is skilled in research and development (R&D), biotechnology, teamwork, higher education, and project management. He has worked as a Capstone innovation project coordinator for several years.

Mari Ketola is a Senior Lecturer and Degree Programme Leader at Turku University of Applied Sciences, Faculty of Engineering and Business, Chemical Engineering (multiform). She has a special interest in active learning methods and e-learning. Her teaching activities has lately focused on material technology and project-based courses. She is a Project Hatchery coordinator and the leader of the project learning environment of Chemical Engineering.

Anne Norström, is currently the Head of Education and Research at the Department of Technology and Business in the Sector of Chemical Industry at Turku University of Applied Sciences. She is a member of the Swedish Technical Science Academy of Finland. Her research interests are surface and colloid chemistry, circular economy, improvement of student learning and engineering education. The CDIO framework is currently adopted to all engineering education curricula within her Sector.

Corresponding author

Dr (Tech.) Anne Norström
Turku University of Applied Sciences
Faculty of Technology and Business
Lemminkäisenkatu 30
FI-20520 Turku, Finland
Tel. +358-40-355 0365
anne.norstrom@turkuamk.fi