Integrating innovation pedagogy and CDIO (Conceive – Design — Implement — Operate) approach - towards shared expressions in engineering education

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Abstract

In our earlier research, it has been discussed how the CDIO (Conceive – Design — Implement — Operate) approach is interconnected with innovation pedagogy. We have stated that they both face very similar challenges and share parallel goals and objectives. Our conclusion is that the CDIO approach can be strengthened by innovation pedagogy and its objective to provide the students with innovation competences in order enable them to participate in the innovation processes in their future working places and develop them.

However, the integration has its challenges. The essential element in successful integration is communication; the shared language, concepts and expressions. In general, the world of knowledge is very diverse with contradicting views, terms and ideas, and to understand the language of other disciplines usually takes time. Facilitating conversation from several disciplines is demanding, requiring not only awareness of one's own disciplinary bias but also the ability to manage power dynamics among participants.

One of the key elements in the CDIO initiative is the 12 standards that define a framework for good engineering education. These standards aim to guide the development actions of universities. The aim of this paper is to support the integration of innovation pedagogy and CDIO approach by ensuring better communication and shared understanding of both approaches. Therefore innovation pedagogy is now described through CDIO standards in order to show the numerous similarities in both initiatives. The shared language provides opportunities for deeper integration in educational development. This aims to ensure improved learning outcomes in addition to development actions in engineering education and higher education in general.

Keywords: *Innovation pedagogy, CDIO, standards, engineering education, communication*

1. Background

Clark (1998) writes that enterprising universities are those that actively seek to move away from close governmental regulation and sector standardization [1]. Both CDIO approach and Innovation Pedagogy provide tools and framework to differentiate in the higher education markets. An entrepreneurial university seeks to innovate how it operates and functions in its business [1]. Shattock (2010) agrees on this: successful universities will always seek to improve their performance in teaching and research [2]. One of the key elements is maintaining excitement of intellectual enquiry and the sense of learning partnership between teachers and students [2]. The key point both in CDIO and Innovation Pedagogy is the idea to support continuous improvement.

The report of Confederation of Finnish Industries (2011) emphasizes these characteristics too [3]. The society has been moving towards an information society where the capacity to work for new and improved solutions becomes crucial. Education has to promote creativity and adopt methods from work life: experimenting with others without the fear of making a mistake will be encouraged. The future education has to focus on skills in addition to knowledge and working in groups. Furthermore, versatile learning methods prepare students for changing work life. Again we see that the CDIO approach and the Innovation Pedagogy are both focusing on relevant and important issues in education. Since certain similarities exist it is interesting to study how these approaches or frameworks might integrate.

2. Challenges in the integration of the CDIO approach and innovation pedagogy

Modern engineering education programs seek to provide the students with a broad base of knowledge, skills, and attitudes necessary to become successful young engineers. The CDIO approach is a worldwide collaborative to conceive and develop a new vision of engineering education (www.cdio.org). CDIO is based on a commonly shared premise that engineering graduates should be able to Conceive – Design — Implement — Operate complex value-added engineering systems in a modern team-based engineering environment to create systems and products. [4]

A continuous interaction, in which breaking borders between different fields of knowledge and organizations is encouraged, and which encompasses all the actors involved, is a prerequisite for success. This is the challenge that innovation pedagogy, a learning approach that defines in a new way how knowledge is assimilated, produced in a manner that can create innovations, aims to tackle. The core of innovation pedagogy lies in emphasising interactive dialogue between the educational organization, students, and surrounding working life and society. In accordance to this its conceptual core can be divided, into three different spheres:
•   final learning outcomes, creation of innovations and produced capability to participate in diverse innovation processes
•   learning of innovation competences alongside with study programme specific knowledge, skills and attitudes
•   meta-innovations – referring to the necessary cornerstones needed for learning according to innovation pedagogy; innovative learning and teaching methods, cross-disciplinary learning environment/boundary crossing, integrated and extensive research and development activities, flexible curricula, concentration of acknowledging the importance of entrepreneurship and service production and internationalization in the level of research, development and student engagement.

In our earlier research [5] we have stated that the CDIO approach and Innovation pedagogy share similar goals. Both share the ideology about defining the key competences needed in working life and both intend to activate the student and define the learning goals deriving from the needs of the surrounding environment. The CDIO approach has a clear focus on engineering education whereas innovation pedagogy tries to bear in mind the broader needs of the entire economy and focuses on producing valid competencies for the future society where special emphasis is put on innovation creation. Innovation pedagogy can be applied to all the disciplines and to all education be it in the university at any program but also to other levels of education e.g. to secondary education where the basis for the students' understanding of learning is created.

The CDIO syllabus goes to a deep level of detail while defining the necessary competences, but it is good to remember that CDIO syllabus is also a reference list and all of the features are not meant to be followed in detail. Innovation pedagogy focuses on providing the methods and tools to provide the three categories of innovation competencies: individual, interpersonal and networking innovation competences. Innovation pedagogy states that certain cornerstones or "meta-innovations" are needed to succeed in this task. In all, innovation pedagogy can form an extensive pedagogical strategy for any educational institution providing both objectives and methods and tools in order to reach the desired learning outcomes leading to innovation creation.

The integration has its challenges. The essential element in successful integration is communication; the shared language, concepts and expressions. In general, the world of knowledge is very diverse with contradicting views, terms and ideas, and to understand the language of other disciplines usually takes time. Facilitating conversation from several disciplines is demanding, requiring not only awareness of one's own disciplinary bias but also the ability to manage power dynamics among participants. Communication is maybe the most important factor, as beneficial communication also helps to avoid the accumulation of new social problems and brings collaboration closer to its goals at the same time. "New way of working cannot simply be imported to the team but it can only emerge and develop through intense interactions" [6]. "Facilitating conversation from multiple disciplines is a tough job, requiring not only awareness of one's own disciplinary bias but also the ability to manage power dynamics among highly successful and often egoistic participants" [7].

3. Method and approach

One of the key elements in the CDIO initiative is the 12 standards (Figure 1) that define a framework for good engineering education. These standards aim to guide the development actions of universities. The aim of this paper is to support the integration of innovation pedagogy and CDIO approach by ensuring better communication and shared understanding of both approaches. Therefore innovation pedagogy is now described through CDIO standards in order to show the numerous similarities in both initiatives. The shared language provides opportunities for deeper integration in educational development. This aims to ensure improved learning outcomes in addition to development actions in engineering education and higher education in general. Using Tight's (2012) categories of higher education research we can categorize this study to Teaching and learning category [8].

CDIO Standards – Best practices

1. CDIO as Context
Adoption of the principle that product and system lifecycle development and deployment are the context for engineering education
2. CDIO Syllabus Outcomes*
Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by program stakeholders
3. Integrated Curriculum
A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills
4. Introduction to Engineering
An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills
5. Design-Build Experiences
A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level
6. CDIO Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge, and social learning

7. Integrated Learning Experiences
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills
8. Active Learning
Teaching and learning based on active experiential learning methods
9. Enhancement of Faculty CDIO Skills
Actions that enhance faculty competence in personal, interpersonal, and product and system building skills
10. Enhancement of Faculty Teaching Skills
Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning
11. CDIO Skills Assessment
Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge
12. CDIO Program Evaluation
A system that evaluates programs against these 12 standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

Figure 1. CDIO Standards (www.cdio.org) [4]

4. Description of innovation pedagogy with the approach of CDIO standards

Standard 1. Innovation pedagogy as context
Innovation pedagogy is considered the context for all education in that it is the cultural framework, or environment, in which knowledge, skills and attitudes are taught, practiced and learned. The principle is adopted by the education when there is explicit agreement of the university or the faculty to initiate innovation pedagogy, a plan to transition to it, and support from the management to sustain reform initiatives.

Standard 2. Innovation pedagogy syllabus outcomes
The knowledge, skills, and attitudes intended as a result of education, i.e., the learning outcomes, also called learning objectives, detail what students should know and be able to do at the conclusion of their studies. In addition to learning outcomes for study field specific (e.g. technical disciplinary in engineering studies) competences, innovation pedagogy specifies learning outcomes as innovation competences, divided in individual,

interpersonal, and networking competences. The individual level includes independent thinking and decision-making, target-oriented and tenacious actions, creative problem-solving and development of working methods as well as self-assessment and development of one's own skills and learning methods. The interpersonal level focuses on the abilities to co-operate in a diversified team or working community, to take the initiative and to work responsibly according to the targets of the community, to work in research and development projects by applying and combining knowledge and methods of different fields, to work along the principles of ethics and social responsibility as well as to work in interactive communication situations. Finally, the networking level covers the abilities to create and maintain working connections, to work in networks, to co-operate in a multidisciplinary and multicultural environment as well as to communicate and interact in an international environment. They are consistent with educational objectives goals and validated by stakeholders, i.e. primarily the working life.

Standard 3. Integrated and flexible curriculum
A curriculum according to innovation pedagogy is integrated and flexible. An integrated curriculum includes learning experiences that lead to the acquisition of in individual, interpersonal, and networking competences (Standard 2), integrated with the learning of study-field specific competences. An explicit plan identifies in CDIO the ways in which the integration of CDIO skills and multidisciplinary connections are to be made; in innovation pedagogy the competences are also integrated, i.e. innovation competences are mapped to study field competences and co-curricular activities that make up the curriculum. However, a very explicit and detailed plan is not an objective, because the curriculum has to flexible, providing the students with more opportunities to tailor their own professional paths, and answering better to the needs of the constantly changing working life.

Standard 4. Introduction to innovation pedagogy
The 4th CDIO standard emphasizes need for an introduction to engineering course providing a framework for the practice of engineering. The course includes personal and interpersonal knowledge, skills, and attitudes and prepares students for more advanced product and system building experiences. In innovation pedagogy a specific introductory course is not typical, but all studies, from the first beginning, aim to provide the students with broad understanding of needs and expectations of the current and future working life, emphasizing the development of innovation competences in the context of all studies. Therefore the first study units often aim to enhance e.g. team-working in multidisciplinary teams, entrepreneurial attitude and project working skills, interconnected also with study field specific competences.

Standard 5. Constructivist approach to studies
The 5th CDIO standard denotes a range of central engineering activities considered basic or advanced in terms of their scope, complexity, and sequence. Innovation pedagogy, being targeted for all educational areas and aiming to develop students' generic innovation competences in every study field, diverges from CDIO approach here, not focusing on one study field such as engineering, business or design. However, learning experiences are also considered as basic or advanced in innovation pedagogy in terms of their scope, complexity, and sequence in the studies. For example, simpler tasks and learning experiences are included earlier in the studies, while more complex applications appear in later studies designed to help students integrate knowledge and skills acquired in preceding study units and learning activities.

Standard 6. Innovative learning environments
The CDIO standards highlight the physical learning environment in order to support the learning of disciplinary knowledge, and in addition practical hands-on learning is emphasized in physical workspaces. The physical learning environment is crucial in innovation pedagogy as well, making active learning methods possible providing opportunities for practical applications and real problem-solving in authentic environments. The CDIO approach mentions also social learning, that is, settings where students can learn from each other and interact with several groups. This is emphasized in innovation pedagogy much even further; the social learning environment forming the essential element for all learning.

In businesses and organizations, the way of working includes that problems are solved and innovations are created in groups and networks, and there usually are people from many different fields and disciplines who are expected to work effectively together. Equally also the tasks at work many time require knowledge and skills which do not belong to the scope of one and only discipline. Innovative solutions are created through social learning in diverse surroundings and therefore the social learning environment and boundary crossing/ multidisciplinarity play a key role in workspace solutions according to innovation pedagogy [9].

Standard 7. Integrated learning experiences
Learning experiences in innovation pedagogy are equally integrated. The curriculum and learning outcomes can be realized only if there are corresponding pedagogical approaches that make dual use of student learning time. With integrated learning experiences, the students are better prepared to meet the demands of their future profession.

Standard 8. Active learning
Both innovation pedagogy and CDIO approach emphasize active learning methods, which engage students directly in thinking and problem solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analysing, and evaluating ideas. Active learning is considered experiential when students take on roles that simulate professional practice, for example, projects, simulations, and case studies. Innovation pedagogy goes some steps further, including also tacit knowledge and intuition as important in contexts relating to a concrete innovation process [10]. In addition, active learning according to innovation pedagogy includes also earlier mentioned collaborative learning, where different actors are able to work together in dialogue, in such a manner that their own expertise can be efficiently shared and combined in novel ways, resulting in something more than the sum of its parts.

Standard 9 and 10. Enhancement of faculty competence
CDIO approach supports the faculty members to improve their own competence in the personal, interpersonal, and product and system building skills, as well as their teaching skills. Innovation pedagogy was originally developed for universities of applied sciences, where it is a prerequisite that the teaching staff has, in addition to the university degree on the teaching field, also the university degree from educational field (= teacher's education), and third, at least three years' work experience from the teaching field. Thus, deep understanding of teaching and learning has always been the basis for innovation pedagogy. As CDIO, innovation pedagogy encourages the teaching staff for continuous improvement of their own competence. According to innovation pedagogy, learning is a shared process, it's not only the students who learn, but also their teachers and tutors as well as other stakeholders such as businesses and other organizations participating in the learning processes.

Standard 11. Assessment according to innovation pedagogy
CDIO approach and innovation pedagogy share a parallel goal in assessment; effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address not only study field specific competences but innovation competences as well. In innovation pedagogy there are special challenges for the assessment; the assessment of innovation competencies the emphasis is more on performance-oriented competences and lie on interpersonal and networking innovation competencies. This sets special demands especially on the number and timing of assessment, assessment criteria and assessment methods. For this purpose, the INCODE barometer, which can be used in self, peer and tutor assessment of behaviour and its development, has been developed in the co-operation between European partner universities.

Standard 12. Evaluation of innovation pedagogy
Both in CDIO and innovation pedagogy, the feedback forms the basis of decisions about the program and its plans for continuous improvement. A key function of evaluation is to determine the effectiveness and efficiency in reaching the intended goals. Evidence collected during the evaluation process also serves as the basis of continuous program improvement. Moreover, many external evaluators and accreditation bodies require regular and consistent evaluation.

5. Conclusions

Above, we have described innovation pedagogy through CDIO standards in order to show the numerous similarities in both initiatives. Our conclusion is that innovation pedagogy can be easily be described using the 'same language' by using the CDIO standards. The findings can be summed up and presented in a similar format as CDIO standards (Figure 2).

Innovation Pedagogy Standards – Best practices

1. Innovation Pedagogy as Context
Adoption of the principle that Innovation pedagogy is considered the context for all education

2. Innovation Pedagogy Syllabus Outcomes
In addition to learning outcomes for study field specific competences, innovation pedagogy specifies learning outcomes as innovation competences, divided in individual, interpersonal, and networking competences. They are consistent with educational objectives goals and validated by the working life

3. Integrated and Flexible Curriculum
Curriculum that lead to the acquisition of innovation competences integrated with the learning of study-field specific competences, in a flexible way to allow the student to formulate his/her own professional path according to dynamic working life needs.

4. Introduction to Innovation Pedagogy
that provides the students with broad understanding of needs and expectations of the current and future working life

5. Constructivist approach to studies
The learning experiences are considered as basic or advanced in innovation pedagogy in terms of their scope, complexity, and sequence in the studies.; learners are guided to utilise and process their previous experiences while helping them cumulate new ones via diverse learning environments

6. Innovative Learning Environments Innovative solutions are created through social learning in diverse surroundings and therefore the social learning environment and boundary crossing/ multidisciplinarity play a key role in workspace solutions according to innovation pedagogy.

7. Integrated Learning Experiences
The curriculum and learning outcomes can be realized only if there are corresponding pedagogical approaches that make dual use of student learning time.

8. Active Learning
Teaching and learning based on active and often experiential learning methods

9.-10. Enhancement of Faculty Competences
Actions that enhance university staff competences in study field specific competences as well as in teaching and learning competences providing integrated learning experiences

11. Assessment according to Innovation Pedagogy
Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address not only study field specific competences but innovation competences as well.

2. Evaluation of Innovation Pedagogy
The feedback forms the basis of for continuous improvement; a system that provides feedback to students, university, and other stakeholders including the working life, for the purposes of continuous improvement

Figure 2. Innovation Pedagogy Standards

Our aim with this paper is to support the integration of innovation pedagogy and CDIO approach by ensuring communication and shared understanding of both approaches by using a similar expressions and description style, and thus to contribute to the development to engineering education. The shared language provides better opportunities for deeper integration in educational development. This aims to ensure improved learning processes and learning outcomes in addition to development actions in engineering education and higher education in general.

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