ON THE CONNECTIONS BETWEEN THE CDIO FRAMEWORK AND CHALLENGE-BASED LEARNING

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ABSTRACT

Challenge-based learning (CBL) is a learning approach that has received increased attention during the last years. In some of the publications about CBL the connections to the CDIO (conceive-design-implement-operate) framework is discussed, and the purpose of this paper is to discuss these connections further. CBL has connections to both Problem-based learning (PBL) and Project-based learning (PjBL), but while these are learning approaches, the CDIO framework has a program perspective, including aspects of learning approaches, and hence a wider scope. The connections and differences between CBL and CDIO are discussed based on the components of the CDIO Standards.

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1 INTRODUCTION

Challenge-based learning (CBL) has received increased attention during the last years, and numerous papers have been published. In some of the papers there are references to the CDIO framework, and connections between CBL and the CDIO framework are discussed. The purpose of this paper is to study these connections and discuss the similarities and differences in some more detail. The paper starts with brief overviews over the CDIO framework and CBL in general, and this is followed by some comments about the use of CBL within the ECIU University initiative.

The CDIO framework has existed for more than two decades, and it has been developed within the CDIO Initiative. The CDIO Initiative started as a project involving the three Swedish universities Chalmers University of Technology, Royal Institute of Technology (KTH), and Linköping University, and MIT (Massachusetts Institute of Technology) in the USA. After some years the project evolved and grew into a network of universities all over the world, with an annual conference and several other activities. The key references presenting the CDIO Initiative and the framework are [1] and [2]. For example, via the web site [2] it is possible to reache the Knowledge library, which contains a large collection of papers from previous CDIO conferences.

The framework consists of four key components:

- A characterization of the role of an engineer.
- Goals for the desired knowledge and skills of an engineer formulated using the document CDIO Syllabus.
- Goals for the properties of an engineering education program collected in the document CDIO Standards.
- Methods and tools for systematic development and management of education programs.

It should be stressed that most of the components that form the framework existed and have been known before the CDIO Initiative was formed, and that the key point of the CDIO framework is that the components have been put together in a systematic way. Therefore the CDIO framework can be described as *structured common sense*. Originally the framework was developed for engineering education, but over the years it has been generalized, adapted, and applied in other disciplines outside the engineering field, and examples of this can be found via the Knowledge library [2].

Two of the earlier references discussing the connections between CBL and the CDIO framework are [3] and [4]. The paper [3] presents interesting experiences from Master's theses carried out using CBL in a multidisciplinary setting and with sustainability focus. An important component in [3] is a also the use of the Chalmers Challenge Lab, which is a learning space specially designed for CBL activities. In [3], CBL is presented as an evolution of CDIO, but to a large extent this is based on the view that CDIO is equivalent to project-based learning. In [4] the authors discuss challenge-driven education (CDE) in an international context, and CDE is seen as more or less equivalent to CBL. Also, in [4] CDE is described as an evolution of PBL,

where the acronym stands for both project-based and problem-based learning, which means that they are considered to be quivalent. Even though the paper is about CDE the authors use the word project repeatedly when talking about the actual work of the students. However, these comments are not meant to criticize the authors of these paper, but more to illustrate that clear definitions of the different learning approaches are missing.

As mentioned, numerous papers dealing with various aspects of CBL have been published during the last years, and the paper [5] presents an excellent literature overview based on almost one hundred papers. One of the main conclusions of the paper is that the interpretations and applications of CBL vary a lot, and that there is a need for a more unified view of CBL. Some of the common features of the approach include open ended tasks, multidisciplinary and team-based learning activities, interaction with external stakeholders, and often emphasis on challenges related to sustainablitiy. CBL is also seen as a suitable approach to enable for the students to develop various skills. Several of these aspects are discussed in the comparison with CDIO in the sections below.

One context where CBL is an important component is the ECIU University, which is one of the pilot projects within the European Universities initiative from EU. ECIU (European Consortium of European Universities) is a network of thirteen European universities and is running this pilot project together. More information about the ECIU University and the use of CBL within this context can be found via [6]. In [7] the authors discuss the connections between the CDIO framework and the development of the ECIU University in general, which also includes brief discussions about the connections to CBL.

The connections between CBL and the CDIO framework are maybe known to many members of the engineering education community, but since aspects and concepts, despite this, sometimes are mixed up, it is motivated to make an attempt to clarify similarities and differences further.

2 METHODOLOGY

The results and observatons presented below are based on literature studies, various presentations, and participation in both the CDIO Initiative and the ECIU University project. To enable a systematic treatment, the connections between CBL and the CDIO framework are discussed using the CDIO Standards as reference. Thorough descriptions of the CDIO Standards can be found via [1] and [2]. The main purpose of the CDIO Standards is to define twelwe important components for the design, management and execution of an education program. The twelwe items of the CDIO Standards can be split in the following main parts:

- The context, the role of the graduate, and learning outcomes. 1 - 2
- Intregrated curriculum, including an introduction to the intended role. 3 - 4
- Design-implement experiences and related workspaces. 5 - 6
- Integrated learning and active learning approaches. 7 - 8

- Faculty development and student learning assessment. 9 – 11
- Program evaluation. 12

The subsections below are based on most of the elements of the CDIO Standards.

3 RESULTS

3.1 Program perspective – The context

The starting point of the CDIO framework is a characterization of the role of the graduate, connected to Standard 1. Also, the framework has been adapted to other disciplines with corresponding characterizations of the role of the graduate. This relies on a program perspective, where the education program is aiming for a professional role. In the literature CBL is sometimes discussed in a program perspective, but more often as a learning approach as such. The overview in [5] gives that the main part of the applications of CBL can be found within engineering and computer science, but the learning approach itself should be suitable for most types of education contexts. Also, Standard 12 is about Program evaluation, which is a very important aspect of any type of education program. The question if the design and execution of the education program enable for the students to reach the intended program goals is fundamental, but it is based on the program perspective. Hence, Standards 1 and 12 show that the CDIO framework has a wider perspective than CBL.

3.2 Integrated learning experiences and active learning

Standard 7 is about integrated learning experiences, which according to [2] should lead to *acquisition of disciplinary knowledge, as well as personal and interpersonal skills,* which implies that CBL is very much in line with this standard. Here interpersonal skills refer to Section 3 of the CDIO Syllabus, which includes Subsections 3.1 about *Teamwork* and 3.2 about *Communication*. Development of these skills are often referred to as motivating factors for the use of CBL, and in terms of intended learning outcomes the four C:s from the 21st Century skills are often used as reference, where *Communication* and *Collaboration* are tightly connected to 3.1 and 3.2. Standard 8 talks about *active and experiental learning methods*, and since CBL is a highly student centered and active learning approach, it aligns very well with also this standard. The conclusion is hence that CBL is an excellent alternative, among other learning approaches, in line with Standards 7 and 8.

3.3 Design-Implement Experiences

Design-implement experiences, i.e. Standard 5, are key components in engineering education programs. The purpose is to include learning activities that mimic the intended profession, and enable for the students to develop various skills related to this profession. Since more complex design-implement experiences require contributions from several participants, this type of activity is often carried out as team-based activity. The results of such team-based activities are often the most visual and spectactular outomes from a CDIO-based education, ans this has led to that the CDIO framework sometimes is seen as equivalent with PjBL, which is a somewhat limited view. It can be noted that neither the Description nor the Rationale of Standard 5

mention the word project, and that PjBL existed long before the CDIO Initiative was established. The purpose of the design-implement experience is to mimic the real profession, and for that purpose PjBL is a useful learning approach in engineering education. It is natural that PBL or CBL can have similar purposes in education programs aiming for other professions.

A key observation in [5] is that CBL has many different meanings, and similar observations have been reported for PBL and PjBL. For example, there are different version of how PjBL is carried out, depending on the discipline, how the work process is organized, the expected outcome of the project, assessment methods used, composition of the team, etc. Wikipedia's definition of a project reads: *A project consists of a concrete and organized effort motivated by a perceived opportunity when facing a problem, a need, a desire or a source of discomfort. It seeks the realization of a unique and innovative deliverable, such as a product, a service, a process, or in some cases, a scientific research.* In some interpreatations of CBL the process should start even earlier with a very open *Big Idea,* and from that define a challenge that is possible to treat given the available time and other resources. It gradually becomes a question about semantics, but starting from words *need*, *desire*, or *source of discomfort* in the definition of a project it is relatively straightforward to formulate a Big Idea.

Since there are many common aspects between CBL, PjBL and PBL it is desirable to focus on those and make use of the experiences that have been collected. These aspects include:

- Formulation of intended learning outcomes
- Characterization and choice of the Big Idea/challenge/project task/…
- Team formation, roles in the team, and team operation and development
- Structure and methods for the work process
- Methods and tools for continuous feedback and assessment
- The role of the teacher/coach/facilitator/mentor/…
- Interaction with externa stakeholders/challenge providers/…

The importance of these aspects can vary between the different learning approaches and different implementations of them, but it should be possible to extract common factors and enable transfer of experiences. See the illustration in Figure 1.

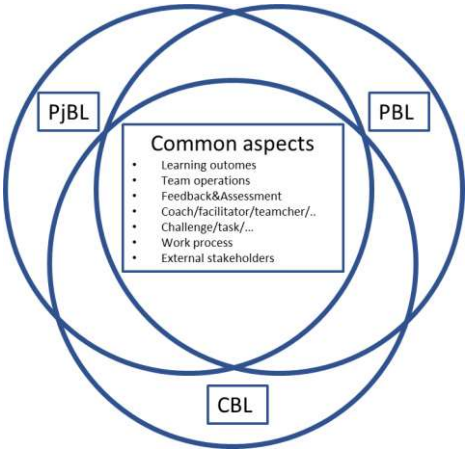

Fig. 1. Common aspects of PjBL, PBL, and CBL.

3.4 Learning outcomes

One of the main arguments behind both the CDIO framework and CBL is the necessity to develop the skills of the students, in addition to the subject knowledge. Within the CDIO framework, Standard 2 is focusing on this question. There are many important aspects of this that need to be discussed, and first it should be noted that there is a big variety concerning the vocabulary which is used when discussing skills. The words and expressions that are used in the literature include, for example, transversal skills, soft skills, transferable skills, generic attributes, and generic competencies. In addition, since there are no strict definitions of what is included in each of these expressions the discussion becomes somewhat vague. The CDIO Syllabus talks about *Personal and professional skills* in Section 2, and *Interpersonal skills* in Section 3, while it is more diversified in the literature about CBL. Second, and partly related to the question about the use of vocabulary, is the reference frame that is used when discussing and formulating learning outcomes. Within CDIO the Syllabus is the natural reference, but also here it is more diversified when it comes to CBL. As mentioned before, the 21st Century skills is one alternative, but there are several possible alternatives.

Via the principle of *constructive alignment* there is a direct link from learning outcomes, via the learning activities to the assessment. Assessment is even more challenging when it comes to assessment of skills. Since CBL, PjBL, and PBL often have related types of learning outcomes concerning skills, the question of assessment of this type of learning outcomes are of common interest. Some papers spend considerable effort on stressing the differences between these learning approaches, but it would be more fruitful to focus on the common aspects, where formulation of learning goals and related assessment for various skills is the most vital component.

3.5 Faculty development

Related to assessment but also teaching and learning in general is the need for faculty development. The literature about CBL stress the somewhat different role of the teacher in CBL, and there often is a need for faculty deveplopment. In the CDIO framework Standards 9 and 10 address the need for faculty development explicitly.

4 SUMMARY

The connections between the CBL and the CDIO framework have been studied, and the main messages of the paper are the following:

- The CDIO framework has a program perspective and hence a wider scope than CBL. The framework includes e.g. curriculum design, learning workspaces, faculty development, and program evaluation, and CDIO is not limited to one specific learning approach.
- CBL is a very good example of an active and integrated learning approach, and hence it fits very well as a compontent in the CDIO framework, where active and integrated learning are key components, as indicated by Standards 7 and 8.

As illustrated in Fig 1, there are many common aspects of CBL, PjBL, and PBL, and the potential for fruitful knowledge exchange concerning these aspects is very good. However, before considering which learning method to use, it is important to first reflect upon the learning goals, in terms of the knowledge and skills that are expected for the intended role of the graduate. Then, in a second step, one can choose a learning approach, including assessment methods, that is suitable in order to enable for the students to reaach the learning goals.

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