APPROACHING WORK INTEGRATED LEARNING THROUGH LEARNING OUTCOMES AND EVALUATIONS

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ABSTRACT

The core of CDIO addresses criticism from engineering industry according engineering education having too much focus on theoretical training. Here, practice, and especially integrating theory and practice, has had a peripheral role implying students not being well enough prepared for the complexity of industry's real world problems and solutions. CDIO aims to meet that criticism through especially illuminating on project based educational forms, where sections of the, so called, CDIO Syllabus point out desired knowledge and skills that are needed to fulfil complex enough projects in engineering education. That approach not only prepares students in appropriate ways for the benefits of industry, but also increases their value of being employable. CDIO does not explicitly point out industry close work placement in education, neither in the CDIO syllabus, nor in the CDIO Standards. Still, many universities strive after work integrated learning, in purposes of, e.g., employability, and real world preparation. Experiences show problems in work integrated learning due to several reasons, such as, establishing sustainable academy–industry contacts, strategies for project ownership and IPR (Intellectual Property Rights), and guarantees according fulfillment of academic requirements on learning outcomes.

The concept of Demola relates to a platform for collaborations between academy and industry with focus on multi-disciplinary student projects. Especially, focus is on innovation, where industry may experiment with new ideas at low cost. Demola has proved itself to be a successful approach, with developed templates for student-industry contracts, and process models. Still, to be an attractive choice for work integrated learning, the Demola approach also has to be clear with respect to academic contexts of courses' learning outcomes, and course evaluations.

The aim of this contribution is to point out a set of learning outcomes in a purpose of clarifying on such set being an inherent part of Demola. That set, which is based on CDIO Syllabus, shall map towards a tool for evaluations, where the two-dimensional multi-valued tool ZEFsurvey, is chosen. Overviews, case studies, and discussions will be provided, where one purpose is to point out the adaptability of Demola in an international context.

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KEYWORDS

University-Industry cooperation, project based work, work integrated learning, CDIO learning outcomes, course evaluation, Standards: 1, 2, 7, 8.

INTRODUCTION

By work integrated learning (WIL) we often mean educational forms, especially projects, where industrial participants are more or less involved in the students' work. Typically, the industrial participants stand for problem statements, guidance and feedback, and being receivers of project results. WIL relates well to Integrated Learning Experiences (CDIO Standard 7), and Active Learning (Standard 8), to students' employability, and to the core of CDIO concerning industry-oriented training. Obviously, academia is gained by including WIL in educational programs. Still, experiences show resistance towards that, probably due to several reasons, including difficulties in establishing sustainable structures for industry contacts, uncertainties according ownership of project work, and lack of academic control of required learning outcomes (LO) and course evaluations.

Demola is a collaborative open innovation platform for students, universities and companies, and has been elected the best cross-border and cross-sector innovator in the Baltic Sea Region (Vinnova, 2012). Here, agreements between universities, students, and companies are based on well-established contracts where aspects, such as project ownership, are handled. Concepts of Demola include structures for process models, and interactions between students and companies. Amongst the responsibilities of the local Demola organization lies establishing sustainable structures for regional companies and universities to cooperate, where multi-disciplinary student teams develop innovative industry-oriented prototypes.

It seems that Demola clarifies several points of uncertainties related to WIL, and thus may work well as a platform for this. Further unclear aspects relate to universities' demands on obligations concerning LO and course evaluations. Therefore, the Demola concept needs to be extended in appropriate ways to live up to such demands. In order to be flexible, and work well in different national contexts, Demola should be gained by being correlated to a worldwide meta-level educational framework, rather than more restricted national frameworks. Here, CDIO, with its Syllabus, may serve as a fundament for that meta-level framework. Still, while being independent of national obligations, CDIO has been proven to correspond well to several national frameworks (Crawley et. al., 2013), that strengthens the choice of CDIO as a supportive model to Demola even more. Moreover, ZEFsurvey (ZEF, 2016) is an advanced tool for making two dimensional, multi-valued surveys, where activities are ongoing in order to use ZEFsurvey as an inherent part of Demola course evaluations. To further serve as a valuable foundation for WIL, a well-defined set of the CDIO Syllabus LO should be chosen, where those should be appropriately matched by the ZEFsurvey. 2D multi-valued surveys implies that the survey answers shall be reflected and given in a matrix where the x- and y-axes correspond to two different scales, i.e.: importance (from less important to more important) and acknowledgement (from disagree to agree) etc. As opposed to 1D surveys, where the participants shall answer by choosing one value on a scale, i.e. between 0 and 10, or 1 and 7 etc., the answers in 2D surveys focuses on the relation between the two scales when placing an answer on the matrix. Moreover, as the 2D ZEFsurveys focus on the relation between two scales, the absolute values of the survey are normalized using z-scoring (briefly described later) algorithm (Selkälä, et al., 2011). Figure 1 below shows an example of a ZEFsurvey result on 2D multi-valued matrix.

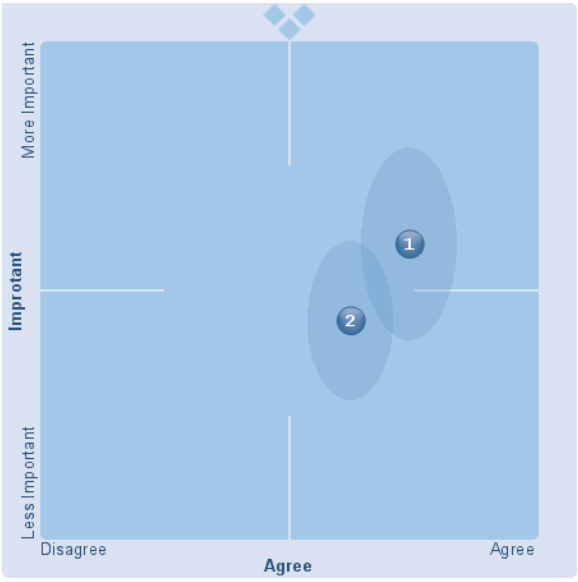


Figure 1. Example of ZEFsurvey result on 2D multi-valued matrix with two statements

Currently, activities are ongoing to integrate ZEFsurvey as an inherent part of Demola. So far the use of ZEFsurvey in contexts of Demola has shown promising results.

We have earlier experienced Demola projects and their reflected LO (Einarson, Wendin, & Saplacan, 2015). The aim of this contribution is to propose a set of LO from CDIO Syllabus to be integrated as an inherent part of Demola, and map that set to the ZEFsurvey-tool. Discussions will furthermore be provided to show that the choice of CDIO Syllabus as a reference framework, will increase the adaptability of Demola in national, as well as, international contexts.

APPROACH

In this paper, two main parameters that stand at the basis of our suggested LO for Demola projects have been chosen: CDIO Syllabus, and LO reflected by Demola. Each of those are briefly described below. The reflected LO are later considered as a result of a case study. The motivation of this contribution lies in the fact that university educational programs are dependent on national regulation systems, here exemplified through the Swedish Higher Education Ordinance, where LO, as well as course evaluations should be considered.

On Swedish Higher Education Ordinance

The Swedish educational system is regulated by law through the Swedish Higher Education Ordinance, where the Swedish Higher Education Authority has the main responsibility of supervising the Swedish higher education institutions (UKÄ). Among other things the Ordinance regulates the intended learning outcomes for a certain educational program, as shown in (UHR, Annex 2) and enforces requirements on course evaluations, as pointed out at (UHR, Annex 2). In contexts of WIL, experiences show conflicts between industry close practical training and scientific ambitions of academia. Here, Kristianstad University (home university of two of the authors) introduces the concept of *research based work placement* to especially emphasize that practical training should be clearly based on academic principles.

With this in mind, the need for academic influences on LO and evaluations, as well as supervision and examination is obvious.

On CDIO Syllabus

According (UHR, Chapter 1) *Higher education institutions shall enable students who are participating in or have completed a course to express their experiences of and views on the course through a course evaluation to be organised by the higher education institution*. This may typically be implemented through course surveys, where state of course is investigated, as well as how well course LO are met. Hence, WIL projects of Swedish educational programs, e.g., Demola projects, also have those obligations. However, due to the concept of Demola being an international approach, this should be gained by having an international approach to LO. Here CDIO with its developed Syllabus may be an appropriate choice, especially since it has been shown that the CDIO Syllabus corresponds well to several national educational frameworks for LO (Crawley et. al., 2013). From (Crawley et. al., 2013) comparisons between CDIO Syllabus Level 2, and ABET of USA, and CEAB of Canada are made, and corresponding comparison with engineering education of Sweden is outlined. Moreover, (Crawley et. al., 2013) states that version 2.0 of CDIO Syllabus has been modified to meet national accreditation boards. This even more motivates CDIO as a meta-level reference system for educational frameworks at an international level, which in turn points out the potentials in using CDIO as a reference system also in contexts of Demola.

Still, as previously has been stated, earlier attempts to use CDIO Syllabus LO in contexts of Demola projects, have shown the need for a more focused approach on this. First, a clearer LO subset needs to be pointed out. Then, experiences show difficulties in students' understanding of CDIO Syllabus based LO, pointing out the need of challenging the students with a process of developing an awareness of a meaning behind such LO. A conclusion is therefore that the approach should include:

1. A focused subset of CDIO Syllabus-based LO
2. A plan to develop a deeper understanding of that subset for the students
3. Matching that subset against an evaluation tool, in this case the ZEFsurvey

According point 1 and point 2, a subset is first chosen at the CDIO Syllabus Levels 1-2. Rather than performing course surveys at the end of a course, it will be initiated quite early. During the course there will all in all be two course surveys, preferably three. At the second appointment the survey will be based on CDIO Syllabus Levels 3-4.

On reflected LO from previous Demola project

The reflected LO from the previous experiment are listed below according to the observations from (Einarson, Wendin, & Saplacan, 2015):

- CDIO Syllabus Section 2: 2.1.1 Problem Formulation and Identification, 2.1.2 Modelling, 2.3.1 Thinking Holistically, 2.4 Attitudes, Thoughts and Learning
- CDIO Syllabus Section 3: 3.1.1 Forming Effective Teams, 3.1.2 Team Operation, 3.1.3 Team Growth and Evolution, 3.1.5 Technical and Multidisciplinary Teaming
- CDIO Syllabus Section 4: 4.3 Conceiving, 4.3.1 Understanding Needs and Setting Goals, 4.3.2 Defining Function, Concept and Architecture, 4.4 Designing, 4.5 Implementing

Case Study

Presentation of the Context

To isolate the experiment an introductory level non-Demola course has been chosen, still with close enough process and project structures. The project assignment was chosen by the course instructors: to build a small robot and an algorithm that shall make the robot follow a pre-defined path in a minimum amount of time. However, it would not be known in advance in which way the robot shall follow the path: how many times to stop or turn. The students were divided into teams, each of three students. The students were required to form groups by themselves, without the intervention of course instructors.

In the next section we explain how we designed the evaluation of the experiment.

Experiment Design

The students have been given a very brief introduction of what CDIO is during their first lecture of the Introductory Course with Engineering Methodology. The experiment was divided into two parts: a pre-study evaluation and a final evaluation. Each of them are described next.

1. A Pre-Study Evaluation:

The set of questions was divided into three main categories:

- Intro-questions:
  - Have you heard about CDIO? (Yes/No question)
  - What do you know about CDIO? (open question)
  - What does it mean for you Conceive-Design-Implement-Operate (CDIO)? (open question)
- CDIO-related questions: (open questions)
  - Problem solving as such, is a typical core activity of system development. In what ways do you expect the course project to further develop your problem solving skills? **(2.1 Analytic reasoning and problem solving)**
  - Working in projects often mean that you are exposed to situations requiring new knowledge and experiences.
    What are you prepared to do, to meet the required knowledge that you still don't have, to fulfill your part of the project? **(2.2 Experimentation, investigation and knowledge discovery)**
  - Successfully working in software projects do not only require technical skills, but also reasonable ways in how you regard the working process. What are your thoughts according attitudes needed amongst project group members to fulfill a project? **(2.4 Attitudes, thought and learning)**
  - The more complex the project is, the significant is the teamwork. Elaborate on your view on teamwork. What should be especially regarded? **(3.1 Teamwork)**
  - The more complex the project is, the significant is the communication amongst the project group members. What are your thoughts on communicating matters of projects? **(3.2 Communications)**
- Expectations and goals (Mostly positive/Mostly negative scale question)
  - How is your attitude towards the project?
  - How do you feel about working in a team of 3 people?
  - Do you think this course will be relevant for your future courses in your education program?

The table below shows how some of the CDIO syllabus were mapped to the course intended LO.

Table 1. CDIO standard syllabus mapped to course LO

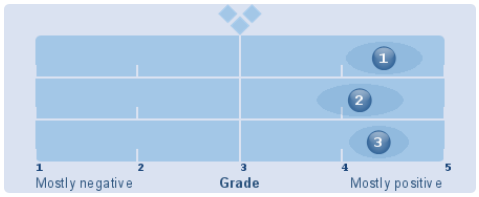
CDIO Syllabus	Course intended LO (CLO)
2.1 Analytic reasoning and problem solving	• be able to search and locate desired information by using computerized and Internet-based search system.
2.2 Experimentation, investigation and knowledge discovery	• be able to search and locate desired information by using computerized and Internet-based search system.
2.4 Attitudes, thought and learning	• be able to make a clear and structured presentation of own work and discuss other students‘ work • be able to write a report that is correct regarding the form and content
3.1 Teamwork	• be able to work in a small development group in a structured manner
3.2 Communications	• be able to make a clear and structured presentation of own work and discuss other students‘ work • be able to write a report that is correct regarding the form and content

2. A Final Evaluation:

As earlier specified, the questions on the pre-study were mainly open-questions. Thereby, the answers on the pre-study were given in the form of plain text, rather than using the built-in matrix with 2D multivalued forms. The reason of designing the questions in this way was to get input on the aspects that were most relevant for students, in order to eventually form a 2D multi-valued final survey.

On one hand, we have looked at the answers given by the participants on the *Intro-questions* and *Expectations and goals* from the pre-study and formulated follow-up questions for the final evaluation. The correspondence between the questions asked in the pre-study and the follow-up questions from the final evaluation is shown in the table 2 below.

Table 2. Intro-questions and Expectations and Goals: Pre-study and Final evaluation

Pre-Study Evaluation	Answers of the Pre-study Evaluation	Final evaluation
Intro-questions		
Have you heard about CDIO?	Majority answered they did not hear about CDIO, although a short introduction was provided during the first lecture.	I feel I understand now more about what a CDIO project implies (scale: important/agree)
What do you know about CDIO?	Many answers included words such as: "nothing", "not much", "almost nothing", "nothing yet" Some answers included a short description showing that they knew that it is an international educational framework, and it is meant to bring industry and academia together	
What does it mean for you Conceive-Design-Implement-Operate	Among the named aspects were: raising quality of education, technical and reasoning ability, carrying out work/project, personal and professional skills, ethics, interpersonal skills, teamwork and communication, business, society, design, implementation, operation, from idea to "product", group work, cross-disciplinary project-based work, and algorithm. Also some acknowledged that they do not know what it means	What does CDIO mean to you? (choose 3 options): framework raising quality of education; technical skills; critical thinking; carrying out project work; personal and professional skills; ethical aspects; interpersonal skills; business; society; prototype or product; group work; cross-disciplinary project based work; algorithm
Expectations and goals		
How is your attitude towards the project How do you feel about working in a team of 3 people? Do you think this course will be relevant for your future courses in your education programme?		I feel I have learned a lot during this project. (scale: important/agree) Did the project meet your expectations and goals? (scale: important/agree) If you would like something to add:

On the other hand, we have formulated follow-up questions regarding the CDIO-syllabus set of questions.

The process of formulating questions for the final evaluation was the following:

1) **Compression**: compressing the answers from the pre-study for each question, either by synthesizing the general idea illustrated in the answers, the ideas that were in contrast to each other, or by citing the students' answers as originary stated.
2) **Matching**: in the next stage we have matched the compressed answers with the CDIO syllabus. However, here we chose to match the answers to the questions to CDIO syllabus levels 3 and 4, in contrast to levels 1 and 2 that were used to formulate the pre-study evaluation questions.
3) **Designing** the questions and/or statements: finally, after stage 2), it could be noticed that among participants' answers, some of the answers matched to level 3 and 4 were repeated. Based on the repeated pattern, we have made a selection of 7 questions. The selection implied the following exclusion criteria, such as: if many of the answers covered some specific parts of the syllabus on level 2, then we chose to specifically exclude questions in the final evaluation on that topic, and rather to select parts of syllabus that had the least amount of mentions. Examples on such exclusions are: CDIO syllabus 2.2, 3.3, 4.2, 4.8.

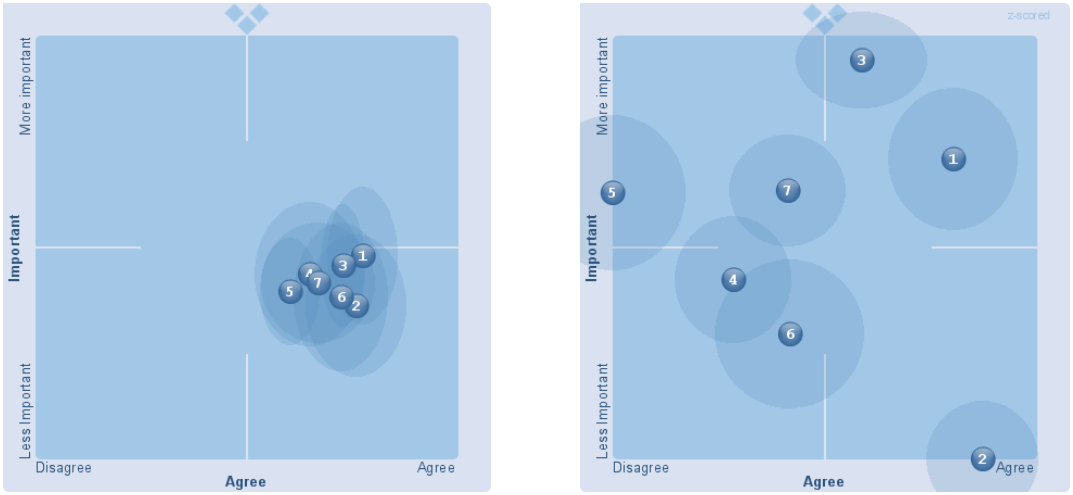
The reason of excluding those was to address also other aspects that were not mentioned by students, but also to increase their awareness concerning those.

Finally, we designed the following set of the CDIO based statements, as a part of the final evaluation:

1. I feel that I have practiced initiative and willingness, to make decisions in face of uncertainty. **(2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty)**
2. I feel that the matter of forming effective teams has been regarded during the project. **(3.1.1 Forming Effective Teams)**
3. I feel that the project has given us opportunities to aspects of communication, such as, inquiry, listening and dialog. **(3.2.7 Inquiry, Listening, Dialog)**
4. I feel that the project has opened up views for me on the impact of engineers on society and the environment. **(4.1.3 Society's Regulation of Engineering)**
5. I feel that I took the group leader role and tried to make use of each of the members' skills and competences in order to achieve the best possible result. **(4.7.5 Building and Leading an Organization and Extended Organization – see its under-levels)**
6. I feel that I made use of time and resources in an efficient way. **(2.4.7 Time and Resource Management)**
7. I feel I discussed with my group mates ethical aspects, integrity principles, and social responsibility when conflict arose in our group work. **(2.5.1 Ethics, Integrity and Social Responsibility)**

RESULTS

Using ZEFsurvey for the Final Survey of our experiment provided us with the insights on the relation between the questions we have asked. Figure 2, shows the values of the answers to the CDIO set of questions from the Final Survey. We can observe here from Figure 2 a, that the overall project experience could be improved with regard to the importance scale, i.e. the majority of the answers to the 7 CDIO questions tending to be viewed as "less important" (right most bottom square). However, these absolute values, and the average of those, do not say too much about the lacks or drawbacks of the project experience, and does not explicitly indicate what shall firstly be improved. ZEFsurvey applies the z-scoring algorithm, such that the values are normalized and *opinion distortion* is removed (Selkälä, et al., 2011). In this way, we can observe that the aspect that was viewed as *least important* for students was 2 *(I feel that the matter of forming effective teams has been regarded during the project. (3.1.1 Forming Effective Teams))*, whereas the aspect which is seen as most important among all is 3 *(I feel that the project has given us opportunities to aspects of communication, such as, inquiry, listening and dialog. (3.2.7 Inquiry, Listening, Dialog))*. 5 *(I feel that I took the group leader role and tried to make use of each of the members' skills and competences in order to achieve the best possible result. (4.7.5 Building and Leading an Organization and Extended Organization – see its under-levels))* seems to be the least regarded aspect, although it is seen as quite important. 1 (*I feel that I have practiced initiative and willingness, to make decisions in face of uncertainty. (2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty)* is the aspect that the majority succeeded mostly with. 4, 6 and 7 can be regarded in the same way.



a. Absolute values b. Normalized values

Figure 2. Absolute and normalized values of the CDIO set of questions from the Final Survey

The chosen set of LO has been based on finding appropriate matches between the CDIO Syllabus, LO from the Swedish Higher Education Ordinance, the reflected LO of the previous Demola project (Einarson, Wendin, & Saplacan, 2015), and the reflected LO of the current experiment.

Proposed Demola LO or project courses LO based on CDIO

1) demonstrate knowledge and understanding in the main field of study **(based on CDIO 1.1)**
2) understand methodologies applicable in the main field of study and demonstrate insights on current research issues, with regard to relevant disciplinary, social and ethical aspects **(based on CDIO 1.2, CDIO 1.3)**
3) demonstrate analytical skills, critical thinking in problem solving, and the ability to work independent **(based on CDIO 2.1)**
4) demonstrate the ability to critically investigate, identify, and formulate a problem, as well as finding solutions to it after gathering information and evaluating it **(based on CDIO 2.2.)**
5) demonstrate the ability to work autonomously in the main field of study within a given time frame, and considering disciplinary, societal, and ethical aspects **(based on CDIO 2.4, CDIO 2.5)**
6) demonstrate the ability to take responsibility and communicate well within- and outside of a team, as well as contributing to the teamwork **(based on CDIO 3.1, CDIO 3.2)**
7) demonstrate the ability to conceive, design, implement and operate a concept or prototype, considering the external, societal and environmental context and the main field of study **(based on CDIO 4.1)**
8) demonstrate project management skills, knowledge about processes, and the ability to identify needs, to formulate and model concepts, and utilize multi-disciplinary knowledge in design, considering sustainability factors **(based on CDIO 4.3, CDIO 4.4 and CDIO 4.5 and reflected LO from both experiments)**

SUMMARY

The main purpose of this contribution has been to propose a set of learning outcomes for the Demola approach to work integrated learning, and map those towards a course evaluation tool. Here, ZEFsurvey has been chosen as an evaluation tool, based on its potential of performing multi-valued analysis. The CDIO Syllabus has here been chosen as a starting point to the set of learning outcomes because of its worldwide meta-level approach, and thus keeping Demola

independent of national obligations. Still, to be adaptable into national contexts, a correspondence with the Swedish Higher Education Ordinance has been pointed out. Incentives for choices have been provided, as well as case studies, and results from those. Future work will include further studies of the choice of the set of learning outcomes. Moreover, students' attitudes and insights as further results of evaluations will be investigated.

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BIOGRAPHICAL INFORMATION

Daniel Einarson has a PhD in Computer Science and has several years of experience in teaching Computer Science and Software Engineering. Furthermore, he has been experimenting with several different forms for project based learning. Moreover, with inspiration from the CDIO initiative he will strive after developing the educational forms for Software Engineering even further. He has also been a key contact person between Kristianstad University and the Demola South Sweden team.

Diana Saplacan has an MSc in Embedded Systems and a BSc in Computer Software Development. She has also been involved in participatory (action) research, and teaching experience in Software Engineering courses. Finally, working as a facilitator at Demola has

made her gaining experience on innovation processes, project management and student coaching.

Pekka Silven has MSc in Education. He is currently the Head of Demola at Oulu University of Applied Sciences. He has over 15 years of experience in IT-education as a lecturer and international course director. He is a leading Zef expert in evaluation, quality and feedback processes and been an expert member in several international projects and program committees.

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