DESIGN AND OUTCOME OF A CDIO SYLLABUS SURVEY FOR A BIOMEDICINE PROGRAM

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ABSTRACT

The CDIO Syllabus survey has successfully been applied to the Bachelor's and Master's programs in Experimental and Medical Biosciences, within the Faculty of Medicine and Health Sciences at Linköping University, Sweden. The programs are and have been, subject to considerable redesign with strong influence from the CDIO framework. One of the main drivers for the redesign is a shift concerning the main job market after graduation, from an academic career to industry and healthcare. One of the steps in the development process has been to carry out a Syllabus survey based on an adapted version of the CDIO Syllabus. The survey was sent out to students and to various categories of professionals, and in total 87 responses were received. The adapted version of the Syllabus and the design, execution, and outcome of the survey is presented.

KEYWORDS

CDIO Syllabus, curriculum design, stakeholders, Standards: 1, 2, 3,12.

INTRODUCTION

The biomedicine program at Linköping University was initiated around 20 years ago by pure academic needs. The program had a high number of applicants, and it was rewarded with a good success rate with regards to students completing the program as well as the graduating students' employment situation following completed studies. However, there have been drastic changes in the need from the life science sector as well as the health care system during the last years, and therefore the program is in the process of a thorough redesign. The first group of students, following the redesigned program, began their studies in fall 2018. It is the first international Bachelor's program, i.e. taught entirely in English, at Linköping University. The redesigned program has been named "Bachelor's program in Experimental and Industrial Biomedicine". As previously stated, the primary goal is to prepare students for employment outside academia as well as continued studies at advanced and research level. This includes motivation of students for active learning by a strong professional identity. Through project-driven courses based on typical situations/problems from academia, healthcare and industry, students will be provided with a multidisciplinary base, the latest approaches in project management, and an understanding of bio-entrepreneurship. The intention is that the program will train the students to be able to identify, assess and implement biomedical ideas, and to understand how these concepts can be developed into products in the wider biomedical field. The program aims to integrate in-depth knowledge of medical biology with the latest experimental methods in biomedical research. Throughout the program, the students will receive practical experience in project management, laboratory techniques, as well as in data analysis, report writing and presentation techniques. Students will also meet industrial collaborators where they will be trained to translate biomedical knowledge into biomedical applications, to prepare for further work in academia, healthcare or business. Students will have the opportunity to spend a semester at an academic or industrial actor in Sweden or abroad.

An important step in the redesign is to ensure that the new program meets the needs, in terms of knowledge and skills, of the future profession. In that process, it is important to give the stakeholders the opportunity to take part in the development process. This has been accomplished by several means, such as conferences and meetings of different types. Another valuable tool is the CDIO Syllabus survey, which has been applied to a set of stakeholders consisting of both students and professionals, and this is the topic of this paper. The outcome of the survey can be used to confirm the steps already taken in the redesign and to guide the revision of the later parts of the program.

The CDIO framework was designed for engineering education, but there are a few examples of extensions and applications of the framework to disciplines outside engineering. Fahlgren et al. (2018) was probably the first example of application within the biomedicine field. Another interesting publication is Malmqvist et al. (2016), where various examples, from different disciplines and countries, of applications of CDIO outside engineering are presented. An additional example is given in Martins et al. (2017).

The paper is organized as follows. It will start by a brief introduction to the CDIO framework in general and the key components of the framework followed by a short description of how the Syllabus survey has been used within the engineering field. The next section describes how the CDIO Syllabus has been adapted to suit education programs within the biomedicine field, and this is followed by a section where the design and execution of the survey are described. The next section contains a summary and analysis of the results, and this is followed by the conclusions.

THE CDIO FRAMEWORK

The CDIO framework is a powerful and widespread tool for design and management of engineering education. A thorough introduction to the framework is given in Crawley et al. (2014) and the web site: The CDIO Initiative (2019). In the engineering context, the framework consists of four key components:

- A definition of the role of an engineer.
- Clearly defined and documented goals for the desired knowledge and skills of an engineer (The CDIO Syllabus).
- Clearly defined and documented goals for the properties of the engineering education program (The CDIO Standards).
- An engineering approach to the development and management of education programs.

However, provided it is possible to describe the intended role of the graduates from an education program in some other field it should be possible to apply the CDIO framework also there. According to the CDIO framework, see Crawley et al (2014), page 50, the goal of engineering education is that every graduating engineer should be able to:

Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.

An initial challenge in the work is hence to formulate a corresponding statement for graduates from the biomedicine program, and this work is carried out in collaboration with various stakeholders of the education program. Provided a formulation of the role of the graduates has been stated the next steps will be to investigate to what extent the fundamental documents the CDIO Syllabus and the CDIO Standards need to be adapted to the new context.

The CDIO Syllabus was first presented in Crawley (2001), and it is one of the two fundamental documents of the CDIO framework. The document, together with revised and translated versions of it, can be found via the CDIO web site: CDIO Initiative (2019). The document is the basis for formulation of the learning outcomes of both individual courses and the entire program. The CDIO Syllabus consists of four main sections with corresponding sub-sections and sub-sub-sections.

I - Disciplinary knowledge and reasoning.
II - Personal and professional skills and attributes
III - Interpersonal skills: Teamwork and communication.
IV - Conceiving, designing, implementing and operating systems in the enterprise, societal, and environmental context – The innovation process.

When applying the CDIO framework to the new field the main efforts will be on adapting the document to the new type of education and intended profession. In addition to introducing the CDIO Syllabus, Crawley (2001) presents the first examples of the application of the Syllabus survey. This was later followed by, e.g. Bankel et el (2003), and that publication presents the outcome of the Syllabus survey from the four original collaborating universities in the CDIO Initiative. A thorough description of how the survey is designed is given in Crawley et al. (2014). In the survey, a selected set of stakeholders are asked to, from their perspective, rate the expected levels of proficiency of the graduates in the CDIO Syllabus knowledge and skills, according to a proposed scale. As in, e.g. Crawley (2001) and Bankel et al. (2003), the focus has been on Sections 2, 3, and 4 of the CDIO Syllabus. It should be stressed that there are numerous other examples of applications of the survey, and it is not the intention to give a complete overview here. Further examples can be found via the link Knowledge library of the CDIO web site.

ADAPTATION OF THE CDIO SYLLABUS

Since the CDIO Syllabus was designed for engineering education a first step in the process was to split Section 4 into two slightly different versions reflecting the two main career paths of the graduates, i.e. academia or industry. Section 4 is hence more directed to a career in industry, while Section 5 is focused on an academic career, Sections 2 and 3 are almost identical with the corresponding sections on the CDIO web site, but in order to help the reader to interpret the data below also Sections 2 and 3 are given below. Hence, the four sections, subsections, and sub-subsections are:

Section 2 – Personal and professional skills and attributes

2.1. Analytical thinking, reasoning and problem solving: Problem identification and formulation. Modelling. Estimation and qualitative analysis. Analysis with uncertainty
2.2. Experimentation, investigation and knowledge discovery: Hypothesis formulation. Survey of print and electronic literature. Experimental Inquiry. Hypothesis test and defense

2.3. System thinking: Thinking holistically. Emergence and interactions in systems. Prioritization and focus. Balance in resolution
2.4. Initiative and willingness to make Decisions in the face of uncertainty. Urgency and will to deliver. Creative thinking. Critical thinking. Self-awareness and knowledge integration. Curiosity and lifelong learning. Time and resource management
2.5. Ethics, integrity and social responsibility: Professional behavior, Responsibility and accountability. Professional behavior. Proactively planning for one's career. Staying current on the world of biomedicine

Section 3 – Communication and teamwork

3.1. Teamwork: Forming effective teams. Team operation. Team growth and evolution. Team leadership

3.2. Communications: Communications strategy. Communications structure. Written communication. Electronic/multimedia communication. Graphical communication. Oral presentation and interpersonal communications

Section 4 – To conceive, design, implement and operate systems in the enterprise and societal context

4.1. External and societal context: Roles and responsibility of a biomedical professional. The impact of biomedicine in society. Society's regulations of biomedicine. The historical and cultural context. Contemporary issues and values
4.2. Enterprise and business context: Appreciating different enterprise cultures. Enterprise strategy, goals, and planning. Bio-entrepreneurship
4.3. Understand and identify the need for biomedical products and systems: Setting system goals and requirements. Defining function, concept and architecture. Modelling of the system and ensuring goals can be met. Development. Project management.
4.4. Designing new biomedical products and systems: The design process. The design process phasing and approaches. Utilization of knowledge in design. Disciplinary design.
4.5. Implementing new biomedical products and systems: Designing the implementation. Process hardware manufacturing process. Software implementation. Process hardware software Integration. Test, verification, validation, and certification. Implementation management.
4.6. Operating new biomedical products and systems: Designing and optimizing operations. Training and operations. Supporting the system. Lifecycle system improvement and evolution. Disposal and life-end issues. Operations management.

Section 5 – Research and development projects in a scientific and societal context

5.1. Societal terms and conditions: Individual responsibility. Knowledge of societal and environmental effects. Rules and regulations. Global development. Sustainability and the need for sustainable development.
5.2. Financial terms and conditions: Understanding financial and economical tools for control. Planning, strategies, and goals for knowledge development. Knowledge-based entrepreneurship. Working in an organization. Working in an international organization. Development and evaluation of acquired knowledge.

5.3. Identification of research need: Specify project aim(s). Define project function, components and delimiters. Organize project components according to project aim(s). Lead the project during the planning phase.
5.4. Implementation of the research project: Knowledge of the project´s phases and methods. Knowledge of projects within one´s field and of translational projects. Knowledge of a sustainable work process. Experimental design and research planning. Interaction between theoretical and experimental knowledge. Testing and verification of results. Leadership and follow-up during implementation.
5.5. Presentation and evaluation: Present knowledge in a scientific manner. Present knowledge using layman-terms. Implementation of acquired knowledge. Evaluation of the work process.

DESIGN AND EXECUTION OF THE SURVEY

To a large extent, the design of the syllabus survey follows the description in Crawley et al. (2014). The first step is to identify relevant stakeholder groups for the program. In this case, the stakeholder groups included students and professionals (both alumni and non-alumni), and the professionals were from academia, health care or industry. In some of the previous uses of the syllabus survey also a group of faculty members was included, but this was not the case here. The survey was done using a web interface, and the participants were contacted via e-mail, or through social media by the Facebook alumni group, in which the background and the purpose of the survey were described.

The survey used the grading scale that is proposed in Crawley et al. (2014) i.e.
1. To have experience or been exposed to.
2. To be able to participate and contribute to.
3. To be able to understand and explain.
4. To be skilled in practice or implementation.
5. To be able to lead or innovate in.

The participants were informed that they will perform the survey regularly during the education program. They were also asked to be aware of the limited time for an education program and hence avoid putting the highest score on all items in order to leave access to progression. (A possibility would be to maximize the total sum of the grades given. This possibility was discussed, but the limited time did not allow the implementation.) In total 87 answers were obtained, and the distribution over the different stakeholder categories is shown in Table 1. Comparing with the results in Bankel et al. (2003), the total number of responses is of the same order of magnitude. Also, the number of responses from professionals, i.e. 58, is even higher than the corresponding categories for several of the participating universities in Bankel et al. (2003). Notably, faculty was included in Bankel et al. (2003) but, as mentioned above, not in the study presented here.

Table 1. The number of responses in the different stakeholder groups.

Participants		Response (n)
Students (n=29)		
	BSc old	6
	BAc new	7
	MSc	16
Alumni (n=41)		

	Academia	16
	Healthcare	8
	Industry	17
Non-alumni (n=17)		
	Academia	13
	Healthcare	2
	Industry	2

SURVEY RESULTS AND ANALYSIS

The mean value for each item averaged over all answers is given in the diagram in Figure 1.

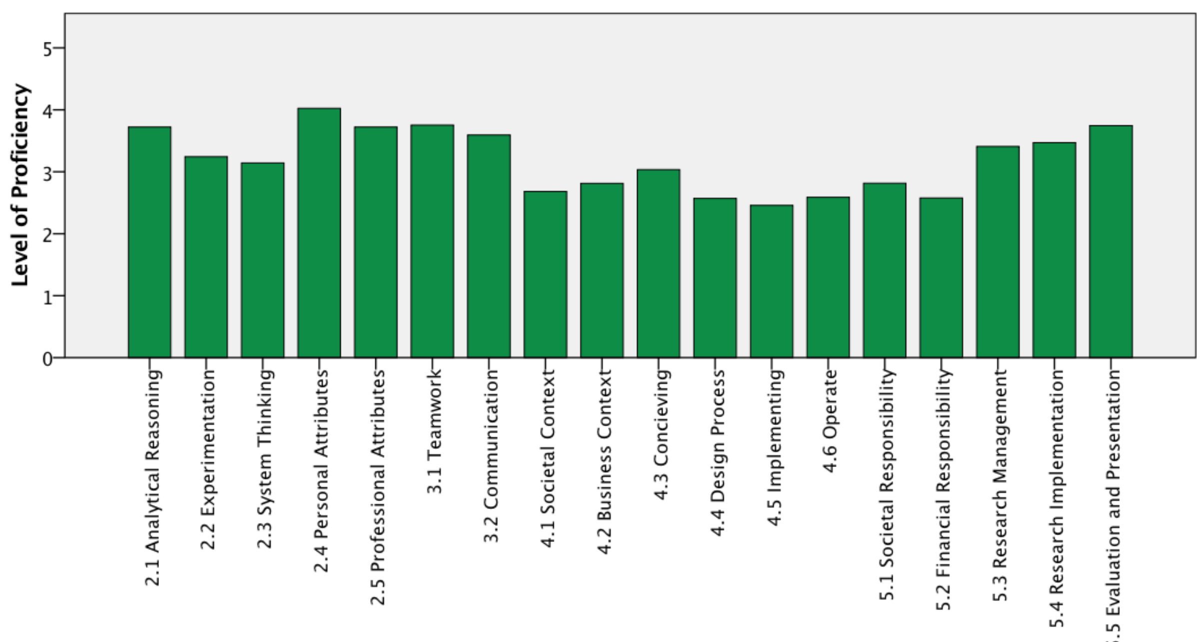

Figure 1. Mean values over all 87 responses. For a detailed description of the items in the adapted Syllabus see above.

First, it can be noted that the variation of the mean values is relatively small and that they range between 2.4 and 4.0. Figure 1 shows that the highest scores are given for items 2.1 (average 3.7), 2.4 (average 4.0), and 2.5 (average 3.7) respectively, connected to the personal and professional skills. Furthermore, items 3.1 (average 3.8) and 3.2 (average 3.6) about teamwork and communication get high scores. Also, item 5.5 (average 3.8), presentation and evaluation, is given a high score. It can also be seen that items 5.x, i.e. corresponding to the academic career, in most cases are given higher scores than the corresponding items in section 4.

Comparing with e.g. Figure 3.9 in Crawley et al. (2014), showing the results for MIT professionals (including both faculty and industry), it is found that items 2.1, 2.4, 3.1, and 3.2 are given relatively high scores. One noticeable difference is found for section 4 were the MIT results show a big difference between the different items. Items 4.1 and 4.2 get very low scores, 2.0 or lower, while the other items, particularly 4.3 and 4.4, get larger scores. In Figure 1 the average scores of the different items in section 4 have a flatter distribution.

Figure 3.10 in Crawley et al. (2014) shows a comparison between alumni from MIT and Queens University in Belfast (QUB). The QUB alumni also put comparatively high scores for 2.1, 2.4, 3.1, and 3.2, but the distribution of the items of the section looks more like the one in Figure 1.

Figure 2 shows the mean value for each item when the responses have been split into the two groups of students (29 answers) and professional (57 answers). The student group includes both Bachelor’s and Master’s level students, and the professional's group include both alumni and others.

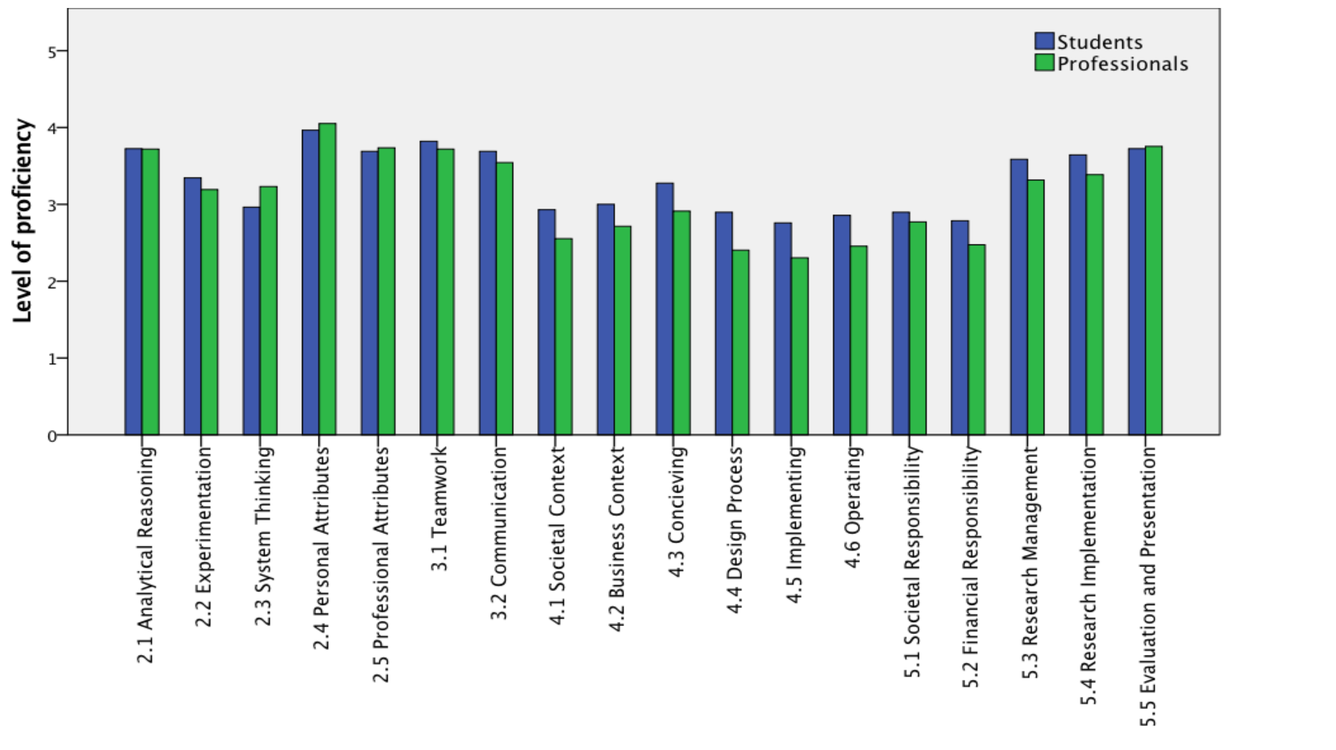

Figure 2. Mean values for the 29 students and the 58 professionals respectively. For a detailed description of the items in the adapted Syllabus see above.

The main observation in Figure 2 is that there is no big difference in the results between the two categories. The students seem to choose somewhat higher scores, but in general, the distribution over the sections and the items are similar.

Figure 3 shows the mean values of the scores for professionals split into the groups; industry (19 responses), healthcare (10 responses), and academia (29 responses) respectively.

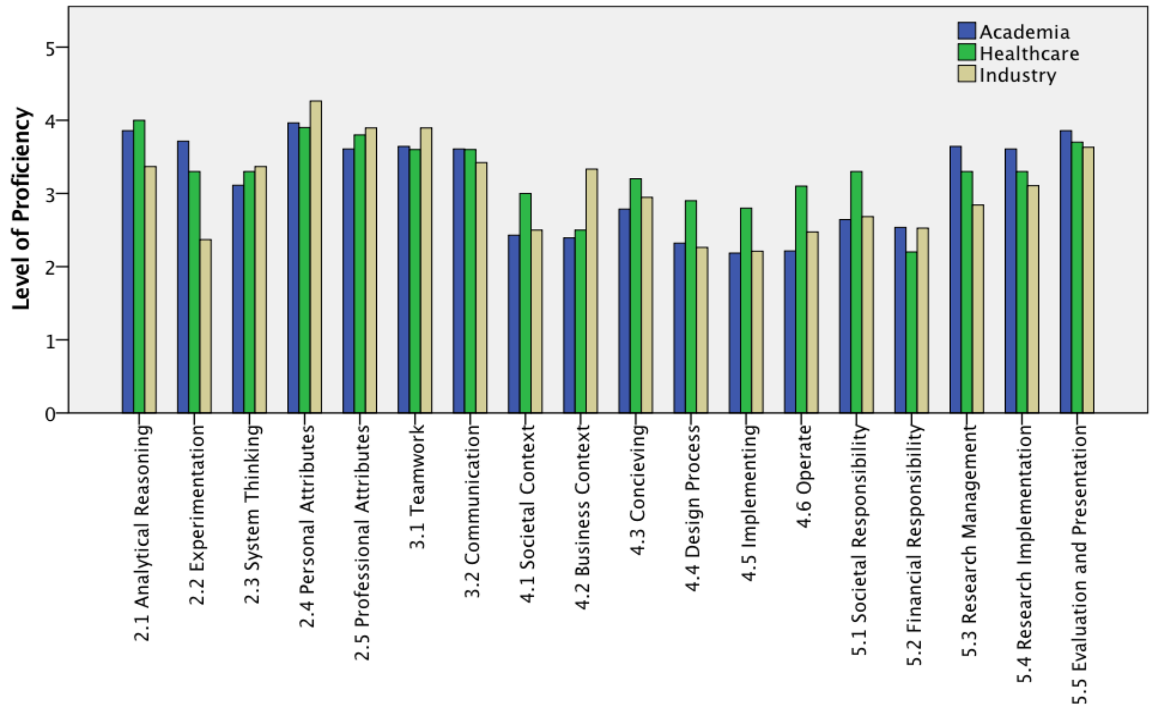

Figure 3. Mean values for the different categories of professionals; industry, healthcare and academia. For a detailed description of the items in the adapted Syllabus see above.

Keeping in mind that there are relatively few responses in some of the groups some interesting observations can be made using Figure 3. For section 4, which is more focused on an industrial career, the healthcare group gives the highest scores. The exception is 4.2, i.e. Business context, for which the group industry has put the highest score. Item 4.2 includes keywords such as bio-entrepreneurship and enterprise strategy, and it is hence reasonable that this is rated high by the group industry. The high scores from the healthcare group for items 4.2 – 4.6 can be understood by considering the typical role for a biomedicine graduate in the healthcare sector. For section 5, which has a research focus, the acedemia group has the highest average score, which also is reasonable. It is notable that the highest score of all is the given by the group industry for item 2.4, i.e. personal attributes.

CONCLUSIONS

The paper has presented an application of the CDIO Syllabus survey to the Bachelor's and Master's programs in Experimental and Medical Biosciences, within the Faculty of Medicine and Health Sciences at Linköping University, Sweden. The programs have been, and are, subject to considerable redesign with strong influence from the CDIO framework. One of the steps in the development process has been to carry out a Syllabus survey based on an adapted version of the CDIO Syllabus. The survey was sent out to students and various categories of professionals, and in total, 87 answers were given. The main conclusions of the results are:

- Like engineering education, see, e.g. Bankel et al. (2003), the items Analytical Reasoning (2.1), Personal Attributes (2.4), Teamwork (3.1), and Communication (3.2) are given the highest scores.
- There is no dramatic difference in the answers between students and professionals.
- For the three groups of professionals there are similarities but also differences in the responses, e.g. Experimentation (2.2) - less needed in industry, and this will be the topic for further investigations.

The outcome of the survey supports the steps already taken in the redesign of the program and provides very useful guidance for the ongoing work dealing with redesign of the later parts of the program. In addition, the results in the paper show that the CDIO framework is applicable and very useful also for a program within the biomedicine field and that the Syllabus survey is a convenient and systematic tool for getting stakeholder input in the processes for program management and development.

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