ALIGNING STAKEHOLDER NEEDS WITH PROGRAM REQUIREMENTS USING A MULTI-STAKEHOLDER SURVEY

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ABSTRACT

From the 2020/21, the School of Engineering at the University of Navarra joined the CDIO network. This paper describes the first step of the process of adapting the programs to the CDIO paradigm: the extent of compliance of the implemented programs with the key components of the CDIO syllabus as well as the extent to which these programs provide graduates with skills specified in the CDIO syllabus. Multiple approaches to data collection were used. The skills and competencies of the different engineering programs were mapped against the components of the CDIO syllabus. This was followed by a questionnaire survey for employers of past graduates. The core of this questionnaire consisted of their opinions of the importance of the various components of the CDIO syllabus and an assessment of the level of proficiency of these skills and competencies in our graduates who work in their companies. A second survey, a tracer study of engineering alumni, also consisted of their opinions on the extent to which the engineering programs provided them with the skills and competencies specified in the CDIO syllabus. Finally, a third survey was conducted among the School's teachers on the importance of a subset of these competencies and the possibility of developing them in their courses. The mapping exercise confirmed the presence of the competencies in the syllabuses; however, the employer survey revealed gaps in the required proficiency levels of the most important skills. The results of alumni and teachers also provided information on the quality of the degree programs and are useful in validating employers' opinions. In addition, information was obtained from the teacher's survey in order to draw up the map of competencies for each program.

KEYWORDS

CDIO syllabus, program assessment, stakeholders, employers, alumni, CDIO Standards: 2, 12.

INTRODUCTION

Training an engineer requires multiple competencies that must be used simultaneously. However, a common problem in engineering education has been the lack of alignment between graduate attributes and the skill as well as competency requirements of stakeholders such as employers, professional and other regulatory entities (see, for example Prados, Peterson and Aberle, 2001; Crawley et al, 2007; Lover at al, 2011; Kolmos and Holgaard, 2019). Some primary consequences of this lack of alignment include graduate unemployment, difficulty in attaining professional certification and the necessity of employers to invest in additional training to make their graduate employees able to discharge their functions. Responsive programmes around the world have attempted to remedy this problem by using the results of stakeholder consultation as a way of either validating the programme learning outcomes of engineering degrees (May and Strong, 2006; Khoo, Zegwaard and Adam, 2020).

The CDIO syllabus provides a not only a framework for specifying the skills and competencies required of engineering graduates. Standard 2 of the syllabus requires a CDIO compliant engineering programme to have, as learning outcomes, a detailed specification of the personal, interpersonal, product and system building skills that have been validated through a process of stakeholder consultation (Malmqvist, Edstrom, Gunnarson, Ostlund, 2005).

Edwards, Sanchez-Ruiz and Sanchez-Diaz (2009) observed that Spain lagged other countries in adopting an explicit competence-based approach to curriculum design. Fuentes Del Burgo and Navarro Astor (2016) used a qualitative study of 34 Spanish building engineers to identify gaps between graduate attributes and employer requirements in building engineering. To the best of our knowledge, no study has investigated the views of multiple stakeholders across different engineering disciplines in Spain.

Standard 12 address the need of "a system that evaluates programs against the twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement". The goal of this study was to conduct an initial assessment of the alignment between the learning outcomes of the different engineering programs at the University of Navarra against the CDIO syllabus. The objective of this assessment is to identify competence gaps that can be addressed through programme improvements in order to meet the expectations of not just the employers but also alumni and internal stakeholders such as faculty members. This study is important in providing a cross-disciplinary snapshot of the desired skills by employers and graduates in engineering. It will be the basis for decisions made about the programs and continuous improvement plans. The study also provides evidence on which curriculum adjustments can be made by other engineering education providers in Spain.

The rest of the paper is structured as follows. A brief description of the CDIO syllabus which formed the basis of the competencies that were evaluated are presented. This is followed by a literature review which places this study within the context of other stakeholder studies in engineering education, followed by a description of the methodology employed in this study. In the results section we summarize the main findings obtained from the surveys followed by a brief discussion of the results and conclusions derived from the study.

THE CDIO SYLLABUS

The conceive-design-implement-operate (CDIO) was developed in the late 1990s to address the gap between engineering education and professional practice (Crawley, 2001). It sought to answer the question of what the full set of knowledge, skills, and attitudes of engineering graduates must be (Edstrom and Kolmos, 2014). These answers formed the basis for a curriculum development process that sought to produce graduates proficient in technical knowledge and reasoning, with the personal and professional skills and attributes required of an engineer. This graduate is a team worker with strong communication skills, who is also able to conceive, design, implement, and operate engineering systems (Crawley, 2001; Crawley, Malmqvist, Ostlund, and Brodeur, 2007; Crawley et al., 2014).

The components of the syllabus are the result of a systematic process of soliciting and harmonizing multiple stakeholder inputs of both the educational process and outcomes. The graduate competency descriptions that are created from a synthesis of the stakeholder inputs become the purpose of the degree program, resulting in an education process and outcomes that are responsive to stakeholder needs

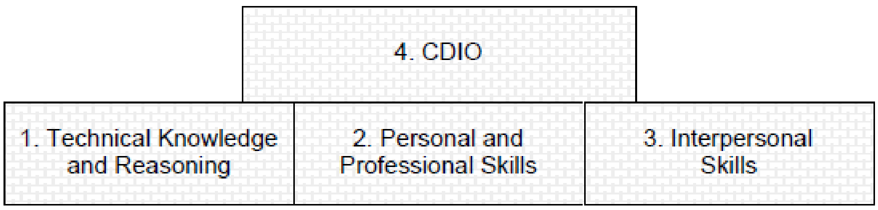

Figure 1. Components of the CDIO syllabus. Source: Crawley, 2001

Figure 1 shows the components of the CDIO syllabus which can be decomposed into different levels of detail.

ENGINEERING STAKEHOLDER STUDIES

The CDIO process was an attempt to address the gap that was identified between engineering curricula structure and the needs of stakeholders such as employers, accreditation agencies, the universities and alumni. The outcomes of the process, the CDIO syllabus described above, was the result of the codification of industry requirements, validated by a multiple stakeholder study (Crawley, 2001). Several other authors have also performed stakeholder studies for engineering education.

Khoo, Zegwaard and Adam (2020) used focus group discussions and surveys to explore employer and academic staff views of engineering graduate competencies in New Zealand at the time of the study and in in ten years. They found teamwork, written communication, problem solving, oral communication, and interpersonal relationships currently important for employers. May and Strong (2006) focused on the gap between employer needs and Canadian graduate attributes in engineering design as the latest contribution to years of similar studies in North America. They compared incoming and exit interviews of engineering students in engineering capstone courses in order to assess if any changes occur in knowledge, skills and attitudes as a result of the final design capstone course. In addition, alumni and industry representatives were surveyed on similar items concerning the engineering design skills of Canadian students of multiple engineering disciplines. Employers complained about the absence of problem solving, communication, business and teamwork skills. Grant and Dickson

(2006) compared recent graduates´ self-assessment of their proficiency in specific personal skills with their ranking of the importance of the same skills at work: teamworking; problem solving; numeracy and IT skills; self-learning. Not surprisingly, skill deficits were identified, necessitating curriculum modification recommendations for the chemical engineering degree in the University of Strathclyde in Scotland.

In Spain, a similar study was undertaken by Fuentes Del Burgo and Navarro Astor (2016). However, it covered only 34 building engineers working as site managers in a particular region of Spain. This study found a gap between a Spanish engineering curriculum dominated by abstract engineering principles with few applications and employer requirements. Prior to that, Edwards, Sanchez Ruiz and Sanchez Diaz (2009) discussed the importance of competence-based education as the basis of engineering education design. Key competencies identified by employers for this purpose include problem solving, decision making, as well as planning, coordination and organizing. However, this study was also restricted to one program – electronic engineering. Nevertheless, the argued for future multi-stakeholder studies involving academics, students, alumni and employers.

The existing Spanish studies either cover a single engineering discipline, or a single set of professionals in a specific activity, i.e., building site management. The rest of engineering practice and the various engineering disciplines have been omitted. It was therefore important to pursue a broader stakeholder study covering a multiplicity of engineering skills contained in the CDIO syllabus to serve as a guide for engineering educators in Spain. The key research question therefore is: what is the relative importance of the core and optional competencies contained in the CDIO syllabus?

METHODOLOGY

To address this question, a multi-stakeholder study was implemented using questionnaires addressed to employers, alumni, and teachers as units of analysis. Pinsonneault and Kraemer (1993) characterised survey research as designed to produce quantitative descriptions/analyses of target populations, through structured questions the answers to which constitute the data to be analysed. As it is usually impractical to collect data about the entire population, surveys are designed to collect information about a subset of the population in a way that allows the analyses to be generalisable. For these reasons, the authors chose to employ a questionnaire survey as the primary means of data collection.

26 competencies were chosen based on a combination of items from the CDIO syllabus and additional skills that were being taught at Tecnun for years through a personal coaching program (Lleo, A. et al., 2018). A brief description of each competence was included in the surveys. Table 1 shows the competencies assessed in the questionnaire, grouped in six categories for employers, alumni and faculty.

Table 1. Skills covered for employers, alumni and faculty

		Employers and alumni	Faculty
1. Technical skills			
1.1	Technical knowledge.	x	
1.2	Problem solving	x	x
1.3	Conducting experiments and research	x	
1.4	Global vision	x	x
2. Personal skills			
2.1	Decision making	x	x
2.2	Emotional balance	x	x
2.3	Self-knowledge	x	x
2.4	Motivation and enthusiasm	x	x
2.5	Effort capacity	x	x
2.6	Time management	x	x
3. Interpersonal skills			
3.1	Social skills	x	x
3.2	Communication	x	x
3.3	Communications in English	x	x
3.4	Conflict management	x	x
3.5	Teamwork	x	x
4. Business vision and entrepreneurial initiative			
4.1	Creativity	x	
4.2	Initiative	x	x
4.3	Opportunities identification	x	
4.4	Business vision	x	x
5. Social responsibility and global perspective			
5.1	Integrity	x	x
5.2	Professional behavior	x	x
5.3	Sustainability	x	
6. Orientation to results			
6.1	Requirements and planning	x	
6.2	Technical design	x	
6.3	Implementation	x	
6.4	Operation	x	

Employers survey

Tecnun has an Advisory Board made up of 32 companies and institutions with which it maintains collaboration agreements to review, in a joint and structured way, the quality of engineering training in order to improve the competency profile of graduates and its adaptation to the labour market. A total of 51 companies were chosen based on several criteria: all those on the Advisory Board had to be included, they had to cover a wide range of sectors, and all of them had to include a representative number of Tecnun graduates. It was also decided to include some consulting firms even though they were not on the Advisory Board because they hire Tecnun students.

The survey had two parts. In the first part the employees were asked to grade with a five-point Likert scale the importance given to these competencies in the profile of an engineer (1 represented "not important" and 5 represented "very important").

In the second part, the respondents had to evaluate Tecnun engineers in these competencies. The NIH Proficiency Scale[1] (National Institutes of Health, 2019) was used, which is an instrument to measure one's ability to demonstrate a competency on the job. The scale ranges from proficiency levels 1-5. Each level in the proficiency scale had a detailed description to help identify the employee's level of proficiency.

1. Fundamental Awareness (basic knowledge - understanding of basic concepts and techniques)
2. Novice (limited experience - level of experience acquired in a classroom and / or experimental settings or as an apprentice on the job)
3. Intermediate (practical application - able to successfully complete the tasks of this competence as requested. Expert help may be required from time to time, but you can usually perform the skill independently)
4. Advanced (can perform the actions associated with this competence without help)
5. Expert (recognized authority - can provide guidance, troubleshoot, and answer questions related to this area of expertise and the field in which the skill is used)

Alumni survey

The questionnaire sent to the alumni dealt with the same competencies as that of the companies. They were asked to rank the level of competence achieved throughout their undergraduate studies. As in the second part of the employer's survey, the NIH Proficiency Scale was used. The questionnaire was sent to 387 alumni that finished his degree between 2016 and 2020.

Faculty survey

Once the evaluation of the employers and alumni were collected, the committee analysed the data in order to specify improvements and define the next steps to be taken. We selected those competencies in which there was a greater gap between the importance given by the companies and how our students were doing in those competencies (either because the companies or the Alumni themselves thought so). Therefore, out of the 26 initial competencies, 17 were selected to continue with the analysis (Table 1).

Since faculty were going to be one of the main agents in achieving the objectives that were set, the committee thought it would be important to listen to their opinion. Moreover, although all members of the School of Engineering were aware of Tecnun's recent incorporation to the CDIO, the professors were not yet familiar with it, so it was a good opportunity to start getting to know this approach.

Teachers conducted a two-part survey. In the first part, as in the case of companies, they were asked to rate with a five-point Likert scale the importance of each competence in the professional life of an engineer. In the second part, they were asked to indicate whether

[1] https://hr.nih.gov/working-nih/competencies/competencies-proficiency-scale

learning outcomes related to these competencies could be included in the subjects they teach. In this way we collected practical information for the establishment of objectives for the improvement of the programmes. In this work, we do not analyse the results of the second part of faculty survey.

RESULTS

The results obtained from the three surveys are summarized in Table 2. It shows the mean value (and standard deviation) for each skill and survey.

Table 2. Responses of Employers, Alumni and Faculty Teachers.

Skill		Importance of skill		Level of proficiency	
		Employer	Faculty	Employer	Alumni
1. Technical skills					
1.1	Technical knowledge.	4,105 (0,658)		4,105 (0,567)	3,800 (0,806)
1.2	Problem solving	4,789 (0,419)	4,838 (0,406)	3,947 (0,524)	4,100 (0,664)
1.3	Conducting experiments and research	3,737 (0,991)		3,421 (0,507)	3,600 (0,907)
1.4	Global vision	4,579 (0,507)	4,426 (0,577)	3,421 (1,071)	3,971 (0,751)
2. Personal skills					
2.1	Decision making	4,632 (0,496)	4,441 (0,627)	3,421 (0,902)	3,929 (0,773)
2.2	Emotional balance	4,211 (0,631)	4,044 (0,848)	3,316 (0,582)	3,943 (0,887)
2.3	Self-knowledge	4,000 (0,745)	4,044 (0,775)	3,105 (0,737)	3,843 (0,844)
2.4	Motivation and enthusiasm	4,368 (0,597)	4,176 (0,640)	3,895 (0,875)	4,114 (0,924)
2.5	Effort capacity	4,526 (0,697)	4,471 (0,581)	4,000 (0,745)	4,443 (0,744)
2.6	Time management	4,421 (0,607)	4,603 (0,572)	3,947 (0,621)	4,029 (0,878)
3. Interpersonal skills					
3.1	Social skills	4,158 (0,602)	3,912 (0,702)	3,368 (0,831)	4,043 (0,853)
3.2	Communication	4,263 (0,872)	4,353 (0,681)	3,368 (0,761)	3,886 (0,878)
3.3	Communications in English	4,579 (0,607)	4,250 (0,672)	3,737 (0,806)	3,843 (1,013)
3.4	Conflict management	4,158 (0,765)	4,162 (0,699)	3,316 (0,885)	3,886 (0,793)
3.5	Teamwork	4,579 (0,507)	4,529 (0,629)	3,842 (0,898)	4,357 (0,663)

4. Business vision and entrepreneurial initiative					
4.1	Creativity	3,895 (0,809)		3,474 (0,697)	3,557 (0,924)
4.2	Initiative	4,158 (0,765)	3,750 (0,930)	3,421 (0,692)	3,757 (0,885)
4.3	Opportunities identification	3,895 (0,809)		3,474 (0,905)	3,729 (0,922)
4.4	Business vision	4,053 (0,970)	3,574 (0,880)	3,211 (0,918)	3,514 (1,067)
5. Social responsibility and global perspective					
5.1	Integrity	4,684 (0,478)	4,735 (0,559)	4,263 (0,562)	4,457 (0,801)
5.2	Professional behavior	4,368 (0,597)	4,412 (0,647)	4,000 (0,745)	4,443 (0,704)
5.3	Sustainability	3,684 (0,820)		3,474 (0,612)	3,971 (0,841)
6. Orientation to results					
6.1	Requirements and planning	4,105 (0,809)		3,737 (0,806)	3,971 (0,874)
6.2	Technical design	3,526 (0,697)		3,842 (0,688)	3,757 (0,901)
6.3	Implementation	3,842 (0,602)		3,632 (0,496)	3,743 (0,838)
6.4	Operation	3,737 (0,733)		3,684 (0,582)	3,771 (0,778)

A total of 20 employers responded to the survey, a response rate of 39 percent. Of the 20 companies, 9 were industrial companies, 6 were consulting firms, 2 were research centres: one technological and the other health, 1 was an engineering company, 1 was a business group and 1 was a foundation. From these survey responses we observe that:

- The respondent companies consider all the competencies included and described in the questionnaires to be important: only seven of them are rated below 4 with the average lowest rating being 3.526.
- Regarding the observed level of proficiency of the skills of our graduates, all of them reach a score bigger than 3.0 meaning employers believe TECNUN graduates to be capable of practical application of not just engineering tools and concepts but also all the other skills.
- The skills that companies consider most important (with a score higher than 4.5) were found to be Problem solving, Integrity, Decision making, Global vision, Communication in English, Teamwork and Effort capacity. In these competencies our graduates are rated above 3.4, although only in Integrity and Effort reach a score greater than or equal to 4.0.
- Our graduates are rated with an average greater than or equal to 4.0 in four competencies: Integrity, Technical knowledge, Effort capacity and Professional behavior. The worst ratings are in Self-knowledge, Business vision, Conflict management, Emotional balance, Social skills and Communication, all with a score between 3.0 and 3.4. There is no overlap between the latter and those considered most important by the companies.

For the survey conducted administered on our graduates, the number of responses was 71, a response rate of 18 percent.

The distribution of respondents' year of completion of studies was as follows: 8 in 2016, 14 in 2017, 21 in 2018, 14 in 2019 and 14 in 2020. Table 3 shows the distribution of the alumni who responded to the survey according to degrees. Respondents were working in the following sectors: Industry (automotive, railway, energy solutions, construction, etc.) (28), Medical or pharmaceutical industry (9), Consultancy (12), Software developers (4), University (9), Research (2), others (7).

Table 3. Degree of Alumni Respondents

Degree	**Number of respondents**
Industrial Technologies Engineering	28
Mechanical Engineering	13
Electrical Engineering	1
Industrial Design Engineering and Product Development	2
Industrial Management Engineering	8
Telecommunication Systems Engineering	6
Biomedical Engineering	13
Total	71

In this case it can be seen that

- The evaluation of the competencies ranges between 3.4 and 4.5 which suggests that in general the alumni value themselves higher than their employers do: while in employers' survey the number of skills with a level of competence with a mean score greater than 4.0 is four, for graduates' survey that number is eight.
- The graduates' self-evaluation matches the companies' evaluation in the areas of Integrity, Capacity for effort and Professional behavior as strengths. However, in the case of Technical knowledge, which the employers value with 4.105, the graduates do not feel so confident and value their level of competence of this skill a bit lower, with an average of 3.8.

Regarding the survey conducted by faculty, a total of 68 teachers responded to the survey, a response rate of 46 percent. Faculty, viewed Problem solving, Integrity, Time management and Teamwork as the most important competencies for engineering graduates (score higher or equal than 4.5). All of them coincide with those most highly rated by companies, except for Time Management, which, although not among them, had a good score (4.421).

In view of the results, four competences were selected which are very important for companies and teachers and yet our students do not reach the desired levels. These competences are Problem solving, Decision making, Global vision and Teamwork.

CONCLUSIONS

In this paper we assessed the alignment between the learning outcomes of the different engineering programs at the Engineering School of the University of Navarra against the CDIO syllabus using a multi-stakeholder survey. Data from different stakeholders were collected to assess the relative importance of competencies outlined in the modified CDIO syllabus, the level of competence our graduates reach upon completing their undergraduate studies, as well as alumni self-evaluation of their own proficiency level with respect to the same skills and competencies.

Even though the employer and alumni surveys confirmed the presence of competencies in the study programs, in general, graduates have not attained the best ratings in terms of the level of proficiency in the skills considered most important by employers. This is consistent with findings by Fuentes Del Burgo and Navarro Astor (2016), May and Strong (2006), Grant and Dickson (2006). This points to the need for changes in the programs, provides guidance on the direction in which further work needs to be done and helps to set concrete targets for improvement in the teaching-learning process of these competencies.

A surprising finding is the relative importance of English language as necessary skill by Spanish employers. A possible explanation could be the international scope of activities by Spanish engineering employers as well as the dominance of the English language in international business.

The fact that companies and teachers agree on the competencies they consider most important is a positive factor. Changes to be made to programs can be proposed by the commission in charge of the CDIO implementation process, but teachers should also be involved to some extent in the process of defining improvements, as they will ultimately be the ones who will have to implement them in the teaching of their subjects.

Our findings provide valuable feedback on the skill requirements of multiple stakeholders across multiple engineering subdisciplines. This should be useful for other universities across Spain. At the same time, the number of respondent companies and alumni may not be representative of the entire engineering sector in Spain. Further studies involving a larger employer and alumni list across different universities could improve the validity of findings from a similar study.

LIMITATIONS

Some of the findings could be complemented with follow-up qualitative studies. Although valuable results were obtained from the alumni survey, the response rate was low (18%). The number of companies interviewed was not high (20 companies). The main reason was that the companies interviewed needed to get to know Tecnun alumni closely enough to be able to assess their proficiency in the specified skills and competences. Future research could separate the two parts of this survey, expanding both the sample of companies in the part corresponding to the assessment of the importance of the competences and engineering alumni from other universities.

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