CDIO & COMPETENCE BASED CURRICULUM DESIGN TECHNIQUES: UNITEC COMPUTER SCIENCE PROGRAM REFORM

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ABSTRACT

Curriculum design is a challenging task, institutions need to close the gap from the demands of industry, the future demands of the global market, the expectations of the students, and the paradigms of the faculty. The final goal should be to secure, as much as it is possible, appropriate jobs for the students at the moment of graduation. To this end this paper presents the experience that the faculty of the Computer Science (CS) Department in the Universidad Tecnologica Centroamericana (UNITEC) had in the latest CS Program reform, where CDIO was incorporated along with a competence based curricula design.

KEYWORDS

CDIO, Competence Based Curriculum, Computer Science, Competence Matrix, Standards 1, 2, 3, 4, 8

INTRODUCTION

UNITEC is a private university in Honduras that currently offers 10 engineering programs (Computer Science, Industrial, Mechatronics, Civil, Biomedical, among others). The university as a whole has a total enrollment of over 26,000 students, from which more than 5,000 are engineering students (Registrar Office, 2017).

Before 2008 UNITEC curricular model was a goal – content based curriculum, in 2008 the University decided that the whole model needed to be updated, and it changed its educational philosophy to a competence based curriculum design. Since that point in time, all programs creation and reforms are built under this paradigm. Around 2009 some faculty in UNITEC (mostly from the Computer Science Department) participated in LASPAU sponsored workshops to improve engineering education that included the CDIO initiative, and at that moment engineering program design and teaching changed. In 2010 three engineering programs received accreditation from ACCAI (ACAAI, 2017), a regional accreditation institution, among these programs was the Computer Science undergraduate program. The original plan was to incorporate the CDIO initiative in the 2011 curricular reform, but accreditation had priority at that moment. After the accreditation process, the Computer Science program started its curricular revision, that was due in 2011, and the plan was to reflect the CDIO initiative there, and afterwards to run for an ABET accreditation. Several events prevented this plan to be fulfilled, and the program revision was done until 2014, at this

time some CDIO standards were included, and the Engineering School has plans to start the self-study for ABET accreditation in 2017.

In Honduras the higher education authority is known as Higher Education Direction (DES abbreviated in Spanish), and it is the office of the government that regulates all higher education institutions (HEI). When a university wants to offer a new degree, there are certain requirements that must be met to be presented and approved by the DES before that program can lawfully operate in the country. Additionally when a program reaches 5 years after its creation or last update/reform, the program can be updated to conform to new market and industry demands. By law, all programs must be reformed before 10 years have passed since their last update or creation.

The previous CS program revision was in 2006, so as stated before the process was resumed in 2014, to be able to comply with the DES imperative program reform that was at that moment overdue. This program reform was a clear opportunity to incorporate the CDIO standards in the curriculum.

The success of the CS program rests in the soul of its design. Since the CS program was conceived in the late 1980's, it had a strong emphasis in learning by doing, and in project based learning. Some other important characteristics are that students need to learn to learn by themselves, since technology changes so fast and there is no way that any university can provide the 100% of the corpus of knowledge in CS or Information Technology; the program has an inherent global market focus, training and education is always done considering that the students should be able to work anywhere in the world with their degree. Since its conception the program has had a capstone project (senior project) where every students must show that they have acquired the necessary skills to enter the job market. Currently, students can choose from capstone project or internship, depending on their preference. Another important trait of the program is that UNITEC has always tried to train entrepreneurs, so there is a entrepreneurship component in all undergraduate programs in the university. This shows that, even when it was not explicit, the CS program is inherently competence driven.

UNITEC's mission statement is: "To develop leaders renowned for their global vision and social responsibility through an educational model based on competences, values, entrepreneurship, academic and technological innovation, internationality, research and social outreach".

The recently revised mission statement of the university considers explicitly that all programs must be competence based, and should also include several features that align to the global economy that every day becomes more a reality. This mission guarantees that the leadership of the institution will support changes in the curricula and in the teaching philosophy to comply with a student centered – competence based education, a step forward to the complete inclusion of the CDIO initiative in the rest of engineering programs.

This paper will present the experience in the 2014-16 CS program reform where CDIO standards and competence based curriculum design played a significant role in the process of this curricular revision. The paper will present a brief background on the CDIO initiative, curriculum design and the challenges faced by engineering programs in Honduras. After the background is presented, there will be a description of the steps followed to achieve the 2016 CS program, then the achieved results of this reform to this date. Finally conclusions and future work is discussed.

BACKGROUND

CDIO Initiative

Technology is advancing at an accelerated pace, permeating all aspects of modern life. Engineering is the area of knowledge that provides the professionals that build and maintain this technology. Thus engineering is passing through a period of unprecedented change (Parashar & Parashar, 2012). To cope with this reality, the Massachusetts Institute of Technology in collaboration with Chalmers University of Technology, Linköping University and the Royal Institute of Technology founded de CDIO Initiative.

Engineering education traditionally was theoretical, and teaching was teacher centered (Kuang & Han, 2012), the result was producing graduates from the university that lacked practical experience and required further training to be able to produce in their jobs. Lecturers focused on the delivery of contents to fulfill their courses objectives without consideration of providing professional skills to the students. The effect was that engineering program was unable to provide the expected outcome from society.

CDIO Initiative comes to find convergence between theoretical knowledge and professional skills, both important in the job market. The heart of the initiative rest in its first standard that states that an engineering program needs to adopt the principle that "product, process and system lifecycle development and deployment use the model of Conceive, Design, Implement and Operate" (Bao, Gu, Lu, Xiong, & Chen, 2013; CDIO, 2017). The correct implementation of this model assures that engineering students will acquire the knowledge and skills needed for the job market.

Sometimes CDIO meaning is oversimplified to think that it is just project-based learning, when it actually means much more. For instance it considers the changes in curricula and courses design, the effects and impact in teaching, learning and assessment, and also the fact that the implementation should be continuously evaluated for improvement and sustainability (Bao, Gu, Lu, Xiong, & Chen, 2013). In addition to the impact in curricula, structure and teaching styles, CDIO goes even deeper, it proposes a new perspective in the student – industry approach (Bai, et al., 2013).

CDIO efforts are by no means isolated to other quality education improvements endeavor HEI pursue, by following the initiative, curricula places emphasis in graduates capabilities instead of qualifications thus becoming competence based. In addition to this advantage, by working towards the CDIO standards, the programs also get closer to accreditation standards (Bao, Gu, Lu, Xiong, & Chen, 2013; Soare, 2015).

Curriculum Design and Competence Based Curriculum

Designing a curriculum for any higher education program is a complex task that involves several parties and information. It is a delicate endeavor since it will have impact in the lives of the students that enroll in the program, and will affect also the industry where the graduates are going to serve once they finish the program.

The curriculum brings together several stakeholders: industry, students and alumni, state or accreditation agencies, politics and universities. Industry demands skilled workers that bring value to their companies, students want to land in "good" jobs when they graduate, politicians want to decrease unemployment and help create wealth, universities want to optimize the use

of resources, lastly professors want to provide lifelong and meaningful education to their students (Schlingensiepen, 2014). Some additional issues that should be factored in are globalization, technology advances, social inequality and environmental changes (Parashar & Parashar, 2012). To successfully assemble all these factors is to come close to a successful higher education program that will satisfy all stakeholders.

Traditionally education has been teacher – centered and content – oriented, however recent advancements in teaching and learning have shown that it is better to change the focus of education from the teacher to the student (Parashar & Parashar, 2012). This means that bringing together all the stakeholders demands is not enough to have a favorable program, especially for the students. This is where competence based design comes in. Competence is defined as: "complex kind of learning outcome that is often related to skills, abilities, personality traits, capacities, knowledge, attitudes, values, etc." (Soare, 2015). Competence based education closes the breach between the needs of the market and the outcome of education systems. The focus of this paradigm is on producing a professional that knows "how to do", instead of only "knowing the theory". Students have the pressure to find a job at the moment of graduation (Zhang, Wang, Li, & Shi, 2016), by switching to a competence based education, there is a higher chance that the future professionals will find job in the industry.

The goal of competence based education is to provide a hands – on experience to the student transferring focus from the books to projects (Bai, et al., 2013), to make the training relevant to the student, this way the information and skills will be "locked" in the brain of the student.

Engineering Challenges

Since technology is changing so fast, especially in information technology, it is difficult to update the course contents and academic programs to cope with these changes (Kuang & Han, 2012; Zhang, Wang, Li, & Shi, 2016). Some higher education regulations allow for some flexibility in their programs, thus letting them update up to certain point their contents and even overall program structure. In the case of Honduran regulations, programs do not have this flexibility. This reality forces curriculum designers to become creative in the definition of courses, in such way that some flexibility is gained, and updates can be done by professors without failing to conform to the official structure of the program. A consequence is that professors need to periodically update their courses to renovate according to the most recent advancements of their specialty.

Professors need to be motivated to engage with the new philosophy of continuous update, and competence based education; this challenge can be confronted with periodic workshops by professors in engineering that share hands-on experience about these issues. This brings up another bigger problem, that is, to be able to have this frequent professional development with professors, and in UNITEC case is difficult since more than 90% of the professors are part time.

Zhang, Wang, Li, & Shi (2016) state that it is the responsibility of the HEI to train and educate students with the demands of the employers, this poses another issue, particularly in CS programs; it is very difficult to teach all of the employers demand with the four year time constraint of undergraduate programs. Some employers want students to graduate with specific tools training, and other employers with other different tools. A way to handle this problem is to have elective courses, and to provide extracurricular workshops on topics and tools that are popular at a given time.

METHODOLOGY AND RESULTS

Overview of Computer Science Program Curricular Reform

As it was mentioned, the key is to bring all information from the stakeholders together, and then formulating a meaningful program that will help create value to all. Figure 1 depicts the process that took part for the reform of de CS program. There are four sets of stakeholders shown in four layers: foreseeable future, global market, local market and students, faculty and alumni. These layers represent the different levels of information used to collect all relevant information for the reform. Starting from the latter one: faculty, students and alumni were interviewed and surveyed to gather data about the advantages and shortcomings of the previous CS program, three goals were sought: what needed to be kept or improved, what needed to disappear for lack of relevance, and what new things needed to be added to the program. At this level the most common suggestion was to add web and mobile development courses, and to add agile development methodology.

The next layer includes the national market and industry expectations. A meeting was held with industry representatives from companies that recruited a significative number of CS graduates. At this meeting it was discussed a proposal of the new program, and representatives had the opportunity to suggest changes that would help graduates provide value to their companies in shorter time. As it was expected, industry requested that specific products were taught: Visual Basic, Oracle, etc. Another topic of discussion was about the professional skills that they expect from CS professionals. Industry manifested that graduates needed to improve: communication skills, both oral and written, and teamwork. On the other hand industry requested more system administration and datacenter management courses and training. It is important to remember that companies are always looking for graduates that require the minimum amount of additional training, knowing this fact helps to trim their requirements and to synthesize them into competences that would serve most of them when they hire a graduate from the CS program. In contrast, most companies stated that UNITEC graduates needed the least time of additional training before becoming productive in their positions.

The next level of stakeholders represent the global market. Considering the constraint that it was not possible to visit international companies, a study was made using the ACM curricula report (ACM & IEEE CS, 2013) to seek clues on the demand of the global market of CS graduates. In addition to this report, some alumni working abroad were interviewed to gather information about the demands of international companies. It was found that, in general, some courses of the UNITEC CS program had questionable relevance like compilers, algorithm analysis, theory of computation and the sort. However at this reform the designers decided to keep these courses as they provide competitive advantage to the graduated professionals. The international input supported the requests from local market to improve the web and mobile development subjects in the program. Skills were also confirmed, and there was an addition: language skills, working in the global market requires that professionals are proficient in English.

The World Business Forum published a report where the top 10 skills for the future jobs are: Complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgement and decision making, service orientation, negotiation and cognitive flexibility (Leopold, Ratcheva, & Zahidi, 2016). Even though the reform was done before this report was published most of these skills where identified supporting the information given by the stakeholders.

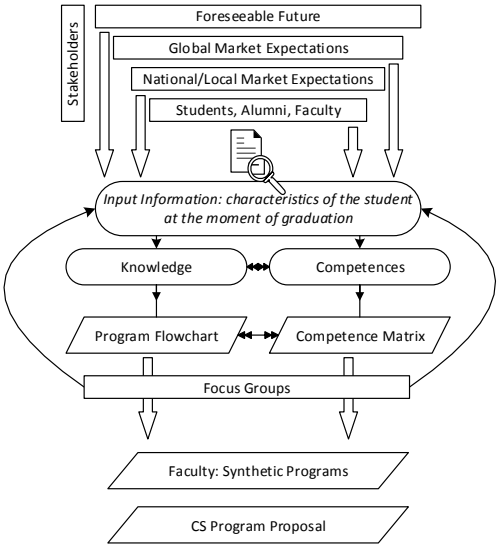

Figure 1. Overview of Curricular Revision Process

The last layer: foreseeable future, represents an attempt to predict the changes in the following five to ten years, this is to keep the program in the vanguard in the universities market and to have courses that will be relevant before the next reform. It is arguable that this layer is based on guessing, but it is informed guessing using all available information about the tendencies of technology.

Once all the above mentioned data is collected, it must be analyzed and synthesized to produce the set of topics (knowledge) and the set of competences (skills) all graduates must have by the time they complete the program. Then, the flowchart of the courses is outlined and the set of competences is mapped into a competence matrix. This is revised later by focus groups that provide feedback for minor adjustments. By the time the flowchart and competence matrix is improved, the faculty is asked to write the synthetic program of each of the courses. The synthetic program is an official document that formally describes each of the courses in the academic program. At this moment the reform can go for official review at the higher education authority the DES.

Identification of Professional Competences

To determine the professional competences, a document was written with an initial list of competences that a CS graduate should have. This document was shared among several people around the world (US, Taiwan, Honduras, etc.) to contribute to the list, and to describe any suggestions if it was considered appropriate. After several months of revision the identified professional competences are as follows:

- Programming
- Systems Integration (3rd Party Libraries usage)
- API Development
- Unit tests and integration
- Operating Systems and Platforms
- Information Systems Development
- Web Application Development
- Mobile Application Development
- Math and Statistics
- Project Management
- Database design and management
- Computer Networks and Communication
- User Interface Design
- Software Engineering
- Information and Computer Security

Table 1. Excerpt of Competences Matrix

Course	CDIO	Professional Competences																		Generic Competences								
Quarter	Name	Knowledge Block	Conceive	Design	Implement	Operate	Programming	Systems Integration (3rd Party Libraries usage)	API Development	Information Systems Development	Web Application Development	Mobile Application Development	Math and Statistics	Database design and management	Computer Networks and Communication	User Interface Design	Software Engineering	Unit tests and integration	Operating Systems and Platforms	Information and Computer Security	Project Management	English	Oral Communication	Writen Communication	Business Communication	Leadership	Entrepreneurship	Creativty	Teamwork	Professional Practices
2	Introduction to CS	Application Development			L1		K							K			K					R1	L1	L1				L1	L1	L1
3	Programming I	Application Development		L1	L3		C									K	K	K				R1	L1	L1				L1	L1	L1
4	Programming II	Application Development	L1	L3	L3		C	C	C							C	K	C				R1	L1	L1		L1		L1	L1	L1
5	Programming III	Application Development	L3	L3	L3		C	AP	AP								K	AP				R1	L1	L1		L1		L1	L1	L1
6	Data Structures I	Computer Science	L1	L3	L3		AP	AP	AP								K	AP			K	R1	L1	L1		L1		L1	L2	L1
7	Data Structures II	Computer Science	L1	L3	L3		AP	AP	AP	K				K			K	AP			K	R1	L2	L2		L1		L2	L2	L1
9	Database Theory I	Infrastructure	L3	L3	L3	L3	AP	AP		C				AN	K	K	K			K	K	R1	L2	L2				L2	L1	L2
10	Computer Architecture	Computer Science	L3	L3	L3		AP	K											K			R1		L2				L2		
10	Programming Languages	Computer Science	L3	L3	L3		S											AN				R1						L2		
10	User Experience	Application Development	L3	L3	L3		AN	AP	AP	C	AP	AP		AP	K	S	C	AP	K	K	K	R1	L1	L1		L1	L1	L2	L2	L2
10	Database Theory II	Infrastructure	L3	L3	L3	L3	AP	AP		C			AP	S	K		K			K	K	R1	L2	L2				L2	L1	L2

Legend

L1	Level 1: Basic
L2	Level 2: Medium
L3	Level 3: Medium
R1	Reading Level 1: Basic Reading skills

K	Bloom taxonomy level 1: Knowledge
C	Bloom taxonomy level 2: Comprehension
AP	Bloom taxonomy level 3: Application
AN	Bloom taxonomy level 4: Analysis
S	Bloom taxonomy level 5: Synthesis
E	Bloom taxonomy level 6: Evaluation

Identification of Generic Competences

As discussed previously, the CS program needed to be explicitly competence based, so there was an imperative on the identification of generic competences, also known as soft skills. The process was similar than the identification of professional competences, but there was an inclusion of input from professionals of other areas of knowledge, to have a more round up idea of what generic skills should the graduates have. The generic competences identified are:

- English
- Oral Communication
- Written Communication
- Business Communication
- Leadership
- Entrepreneurship
- Creativity
- Teamwork
- Professional Practices

The Competence Matrix

The heart of this curricular reform is the competence matrix, other authors have developed similar approaches to the mapping of competences. For instance (Schlingensiepen, 2014) proposed a Boolean matrix using competences as modules and showed where each competence should be activated. The experience of this curricular reform is that a Boolean matrix can be improved by using different levels of cognition or intensity.

Table 1 shows an excerpt of the matrix used to map the competences to each of the courses determined by each of the knowledge blocks. The matrix has four parts: the courses, the CDIO implementation, the professional competences, the generic competences. Notice that for each course a level of implementation of CDIO is indicated, where L1 means that only basics are introduced and L3 means that the course should give the full intensity of that skill. For instance the Data Structures courses have a low level of conception and high level of design, implementation and operation. The next part of the table shows professional competences, for each of the identified competence a cognitive level is defined. The cognitive level is chosen from the six cognitive levels expressed in the Blooms Taxonomy. As an example, in the Introduction to CS course, the course should train in Programming, Database and Software Engineering at the most basic level: Knowledge. The final part of the matrix shows generic skills, also mapped for each of the courses. The different levels mean the different level of demand on each of the courses, for instance in this excerpt English level of competence should be Basic Reading, as it is expected that students are able to gather information from English written references.

After carefully working with the competences matrix, it was time to write the formal description of each of the courses. To do so, all faculty received training in competence based education, and on the whole methodology used to design the CS program. This way each of the faculty would be able to write the synthetic program of the courses related to their area of expertise.

Synthetic Program Definition

Competence based curriculum design has three components: description of the competence (skill), means to assess it, and a standard to cast judgment of compliance with the acquired competence (Soare, 2015; Jones, Voorhees, & Paulson, 2002). It follows that this components need to be taken into account when writing the synthetic program. UNITEC`s format to write the synthetic program of each course includes information as competences, conceptual and procedural concepts, attitudes, values and regulations, assessment methodology and indicators of accomplishment, among other general information.

Using the competence matrix each professor is able to determine the actual competences that need to be developed in the course. Then by using the Bloom Taxonomy verbs related to the cognitive level defined for each competence, it was easy to select the appropriate verbs to describe the competences and sub-competences that each course required, and the appropriate delivery method of each competence.

The other issue to discuss is that based on the new competence based education, the assessment methodology needed to be updated to reflect that the actual competences are being assessed and not the traditional list of contents the course requires.

To successfully write all the courses synthetic programs, a small team of faculty helped all of the rest on a one-on-one basis. This way all the documents were aligned to same tone using the experts in every subject.

CONCLUSIONS

The use of a scientific method for curricular reform has shown how to integrate the demands of all stakeholders in the design or reform of an academic program. At this moment the CS program has been granted approval by the higher education authority and is currently operating since the second semester of 2016.

Thanks to the usage of the competence matrix, it was easy to map all the competences required by stakeholders into each and all of the courses, and then it became a simple task to map this into the required by law synthetic program for each course.

CDIO initiative is completely aligned with competence based education, the current paradigm chosen by UNITEC, and it helped the CS program reform to come closer to the next accreditation process with ABET.

FUTURE WORK AND CHALLENGES

This work has brought more challenges to the CS department in UNITEC. Starting 2017 the chairman will need to start to train all faculty on the changes of paradigm. So far the program has been implicitly competence-based, but now it needs to explicitly take into consideration the changes in the way things are done. Starting 2017 the CS department is going to record the experience of taking this program design into the classrooms. It is believed that the major impact will be in the way that projects and practices are assessed, using indicators that help measure the acquisition of the demanded competences.

After the faculty is trained, there is a plan of creating a community of practice so that faculty – that in majority is part time – have the opportunity to share their problems and lessons learned.

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BIOGRAPHICAL INFORMATION

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