New Orleans JAZZED about Engineering Education
ASEE's 123rd Annual Conference & Exposition
New Orleans, LA
June 26-29, 2016
Paper ID #17483

Triple-Helix and International Collaboration to Design and Implement an Outcomes Based Engineering Curriculum to Better Serve Stakeholders in Valparaíso-Chile

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Triple-Helix and International Collaboration to Design and Implement an Outcomes Based Engineering Curriculum to Better Serve Stakeholders in Valparaíso, Chile

Abstract

Following an approach that has been pursued by many engineering programs that are outcomes based accredited, this paper describes the process of designing and implementing the curricula in the College of Engineering of the Universidad de Valparaíso in Chile, using a backwards design approach and also focusing on addressing stakeholders' needs through students' outcomes. Driven by the Chilean government through funding from MINEDUC (its educational development branch), this University has undertaken the task to completely revamp its engineering curricula by engaging faculty, students and industry, together with international collaborators from Argentina, Puerto Rico and Spain. A specific challenge for this redesign is the low performance of Chilean secondary students in international science and mathematics tests, that is tackled by putting an S.T.E.M. emphasis in the overall process. Using the mentioned backwards design approach, the multi-disciplinary, multi-national, multi-stakeholder team will share the process of establishing University-wide learning outcomes, as well as specific outcomes for the engineering program benchmarked through a very novel method and validated by industry and employers' representatives.

The authors will describe their motivations, aspirations and work currently being implemented in the College of Engineering that has also cascaded through the whole University, as well as the lessons learned, challenges, and successes along the road. In addition, the approach for faculty buy-in and capacity building of the new learning/teaching methodologies, outcomes assessment and continuous quality improvement strategies and the internal sharing of the most effective practices will be described.

The authors believe that the process outlined in this paper can help worldwide institutions adopt similar strategies for better serving their constituents.

Keywords

Curriculum innovation, triple helix, STEM, Chile, outcomes assessment

1. Introduction

The University of Valparaíso, is a Chilean state institution with 15.000 students and more than 1.800 faculty. The educational project[1] of the University of Valparaiso, reformulated in 2012, has been defined as "learning outcomes oriented", which is a nuanced interpretation of the learning outcomes educational model. This approach was undertaken to allow the initial introduction of the learning outcomes model in a public and traditional university, where resistance to change and administration formalism are serious threats to a massive curricular transformation. Hence this definition does not necessarily force to completely change all curricula, but rather a conceptual change that involves four key elements[2]:

1. Graduate profiles are formulated in terms of learning outcomes

2. Curricular design must be driven by the graduate profile.

3. Upon graduating, the student must have acquired all the learning outcomes considered in the graduate profile.

4. The achievement of the learning outcomes must be assessed at any time.

The School of Engineering ("Facultad de Ingeniería", or "FACING") of the University of Valparaíso, was established in 2011, gathering engineering careers formerly scattered between Science, Business and Architecture Schools: Construction Engineering, Civil Engineering, Computer Engineering, Oceanic Engineering, Biomedical Engineering, Industrial Engineering and Environmental Engineering. FACING's strategic plan for the period 2012-2016, defines a focus on quality assurance of the science subjects, curriculum innovation, and development of teaching skills. Curriculum innovation has been executed in the context of a state funded project since 2012, which engaged the School in a process of reflection and homogenization of the curriculum of the careers that compose it, leading to the accreditation of their careers by the National Accreditation Commission (CNA), and the certification of their administrative processes (ISO9000).

While this project has achieved the goals set, it was necessary to incorporate specific strategies to address problems of global scope: the development of skills in science, technology, engineering and mathematics (STEM). A new project named MECESUP UVA1409 "Design and implementation of a strategy for evaluation and continued strengthening of STEM skills", funded by the Chilean Government, embraces the challenge of changing teaching practices in order to introduce active learning methodologies for the initial two years of the program, which are intensive in science subjects. Its objectives are to motivate, empower, assess and monitor the development of learning outcomes which are transversal to all the engineering programs, and that are critical to the development of STEM skills. This project was started in March 2015, just after the final implementation's activities of the educational model at the Faculty UV, which led to the launch of the innovated curricula in 2016. In this context, the linkage between both initiatives was relevant and necessary in order to tackle the main problems of the Engineering School: high desertion rates and in time graduation.

	FACING	**UV**
First year retention rate	72%	82%
In time graduation	4,20%	19,90%

Table 1: Retention and in time graduation rates for the school of engineering.

Due to the FACING's recent creation, it also lacks of connection with the relevant society stakeholders and local industry.

The following sections present a triple-helix and international collaboration approach to design and implement an outcomes based engineering curriculum, to better serve stakeholders in Valparaíso, Chile. Section 2 presents the methodological framework of this approach, while section 3 presents main steps of the innovation process. Section 4 presents the conclusions and preliminary results of the curriculum design.

2. Background

2.1 Backwards design

As a field, instructional design is historically and traditionally rooted in cognitive and behavioral psychology, though recently constructivism (learning theory) has influenced thinking in the field. Instructional Systems Design (ISD) or simply instructional design[3] is the practice of creating "instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and appealing"[4]. Thus, ISD focuses on the learning experience. The process consists broadly of determining the needs of the learner, defining the end goal of instruction, and creating some "intervention" (the “catalytic process”) to assist in the transition, and thus, resulting in learning. Ideally the process is informed by pedagogically (process of teaching) and andragogically (adult learning) tested theories of learning and may take place in student-only, teacher-led or community-based settings. There are many instructional design models. Many involve five basic phases: analysis, design, development, implementation, and evaluation. This instructional design approach is very much like engineering problem solving! The newly established New Engineering University in Silicon Valley (now GalvanizeU in San Francisco, California) used this design approach for its curricula[5]. We are using a combination of instructional systems and “Backwards Approach (BA)” to re-design UV curricula.

BA design[6,7] is a method of designing curriculum by choosing learning outcomes before instructional methods or assessments. This means one chooses the outcome of the learning experience first, and let’s that guide the teaching/learning and the assessment/evaluation. This method challenges "traditional" methods of curriculum planning in which a list of content that will be taught is created and/or selected first and teaching/assessment methodology usually are lectures and laboratories, with written exams as assessment of learning. In backward design, the educator starts with goals, creates or plans out assessments and finally makes lesson plans. Supporters of backward design liken the process to using a "road map"[8]. In this case, the destination is chosen first and then the roadmap is used to plan the trip to the desired destination. In contrast, traditional curriculum planning has no formal destination identified before the journey begins.

2.2 Triple Helix

The concept of the Triple Helix of university-industry-government relationships (Figure 1) initiated in the 1990s by Etzkowitz[9,10] and Etzkowitz and Leydesdorff[11], encompassing elements of precursor works by Lowe[12] and Sábato and Mackenzi[13], interprets the shift from a dominating industry-government dyad in the Industrial Society to a growing triadic relationship between university-industry-government in the Knowledge Society. The Triple Helix thesis is that the potential for innovation and economic development in a Knowledge Society lies in a more prominent role for the university and in the hybridization of elements from university, industry and government to generate new institutional and social formats for the production, transfer and application of knowledge. This vision encompasses not only the creative destruction that appears as a natural innovation dynamics[14], but also the creative renewal that arises within each of the three institutional spheres of university, industry and government, as well as at their intersections.

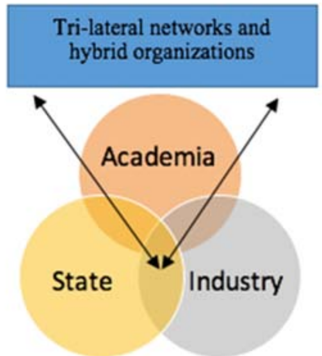

Figure 1. The Triple Helix Model of University–Industry–Government Relations.

In this particular environment, at the Universidad de Valparaiso, this Triple Helix concept has been conscientiously developed and promoted because:

1. There is the University itself,
2. but this is a public, state funded university which follows the state mandates and guidelines and,
3. has effectively involved not only the state, but also the industry in the process, particularly through the External Advice Committee which review the ongoing strategic process (Figure 2)

Figure 2. Review/Advice circle involving the External Advice Committee.

2.3 International Collaboration Team Conformation

As essential as the previously described process is, it is to receive the proper advice and training from external international experts which may add to this process not only their knowledge and experience, but a “non contaminated” vision. And when we say “non contaminated”, we are trying to describe in words the fact that these international experts should provide ideas and visions from outside the University and the Country without the bias of local experiences and points of view. As it is usually said, “No One is a Prophet in their Own Land” and, for all the previously explained reasons, an international group of experts has been invited to participate.

This group – formed by members of InnovaHiEd (www.innovahied.com) – includes three engineers who have strong background and experience in universities, both in the academic and management aspects. Lueny Morell, Director and Founder of the consulting firm, has been an Academic for almost 30 years at the Universidad de Puerto Rico and has also have an important experience in HP Labs, leading the University Relations Dept. for almost 10 years. Eduardo Vendrell-Vidal is currently the Dean at the School of Informatics of the Universitat Politècnica de València, Spain, and he is also the President of EQANIE, the European Quality Assurance Network for Informatics Education. Finally, Uriel Cukierman, Associate Director of InnovaHiEd, is currently the President of the IFEES, the International Federation of Engineering Education Societies and also have more than 30 years of academic and management experience at the Universidad Tecnológica Nacional in Argentina. This group of experts has visited the University in several occasions and has offered not only advice, but training workshops for faculties and staff that have helped them to effectively go through this process as it was evidenced in the surveys completed by the attendees.

3. Innovation Implementation

3.1 Innovation Process

In BA the educator is able to focus on addressing what the students need to learn, what data can be collected to show that the students have learned and how to ensure the students will learn. The UV's curriculum design phases are very similar to NEU's process, namely[5]:

Analysis – Understand regional and national economic development needs, technology trends and employer needs. The engineering/technology competencies for UV's Engineering Programs were captured through three ways: 1) conversations with the College of Engineering Advisory Council, which was established in early 2015, considering industry representatives and government representatives, 2) institutional and program accreditation committees that ensure the fulfillment of the accreditation requirements and entanglement with the curricular innovation process, and 3) by benchmarking successful programs worldwide, performing semantic analysis of the competencies and graduate profiles, looking for the most required skills and learning outcomes. This analysis also included the professional engineering profile required by important engineering Chilean and international organizations.

Design – Led by the Engineering Dean and the STEM project team, competencies were distributed across the curriculum ("roadmap") as shown in Appendix 1, and establishing the desired depth of learning the competencies, in terms of three Domain Levels. Each Domain Level covers 2 years of the engineering careers curricula. With the assistance of academic and industry experts, more specific learning objectives and desired outcomes were written for each of the individual courses. The courses' syllabi include specific learning objectives and outcomes, weekly course plan, weekly learning experiences, and outcomes assessment for all the competencies assigned to the course, as well as traditional information like title, description, textbooks/references and other logistics. We used the Felder-Brent definition of learning objectives (or instructional objective): "A statement of something observable and clear that students should be able to do after receiving instruction, plus (optional) conditions under which they would do it and/or what would constitute acceptable performance."[15]

Development – for each learning experience (course), faculty refined learning objectives, defined topics, resources needed, active learning experiences and assessments. Research shows that students learn better when they know why/what they are learning, when they see applications on how the knowledge is used, when having enough time to think and share thoughts with others, and when they engage in active learning. Thus, to design the learning experience we asked course designers to answer the following questions:

- How will students learn?
- What resources are needed?
- When and where will the learning take place?
- Who is responsible?
- What experiences will help students learn the knowledge and develop the skills, attitudes and values?
- How can we address different learning styles?

The teaching/learning strategy should be aligned with course objectives, should also balance facts with concepts, and include a variety of delivery modes. Therefore, all courses have a blended mix of, for example, short lectures (15-20 min) with any activity that keeps students alert, engaged and motivated in the learning process, such as student discussions, in-class demonstrations, laboratory experiences, team projects, and student oral presentations. At the time of preparing this paper, proposals are being sought from experts in industry and academia to develop laboratory/active learning experiences to support the program. All courses will include learning objectives and outcomes assessment (see section below for more details).

3.2 Innovation Results

After being agreed by program managers, the curricular innovation committee and the academic FACING coordination, the proposed STEM competencies were included in the bachelor's degree profile of the FACING careers. The proposed competencies were incorporated into the innovated curriculums of all programs included in the process of curricular innovation. Considering different programs states of progress, the impact on the curriculum is as follows:

- Four programs that have already developed the competencies for curricular innovation, a mapping table is to be drawn between the competencies proposed for each career and STEM competencies.
- The other three programs that were in the process of formulating their competencies, adhere to the Faculty transversal competences (professional ethics and STEM), adding only a limited number of specific competencies, relevant to their discipline.

In both cases, the recommendation is that the specific elements that each career should add to the transversal competences are explicit as learning outcomes indicators, which are ultimately associated with each subject of the new curricula. These activities are currently being deployed among the programs of the School of Engineering, by supporting teacher with three strategies: co-design of learning activities, elaboration of teaching guides including learning activities that are explicitly linked to learning outcomes, and support for teachers in their classroom activities.

4. Conclusions and Preliminary Results

The Triple Helix model has been implemented by means of an External Advice Committee, namely an Advisory Council. While these committees are not so common in certain regions for academic purposes, there are a lot of examples where an Advisory Council is an excellent resource for industry/society – university partnership[16]. By means of a well-defined mission statement and a correct choice of its members, universities can get feedback for programs, goals and strategic planning, taking into account external recognized views. This way, assessment of outcomes, suggestions for new competences or professional profiles, or development of new programs are usual issues that can be discussed in a set of regular meetings held by the Advisory Council. This committee must be compound by external members, including former students that can share a holistic view for the University, but it is important that university leaders will attend all meetings in order to know and assume all comments and advices issued and discussed. Starting from this point, new opportunities for industry partnership could be developed, mainly because members of this external committee could act as a link between the university and society, promoting university capabilities through their commitment. This approach has strengthened the proposed competences, leading to a widespread approval by the faculty. Evidence of a robust and inclusive discussion on the relevance and necessity for STEM competences has established a reliable basis for the next challenge: the intervention of teaching practices to connect learning outcomes with the detailed design of the learning activities.

BA designs requires that competences derive in a learning outcomes definition and assessment. This concept is directly assumed by teachers as they can define low level goals for the students that can be measured and assessed conveniently. These learning outcomes must be well defined, according to a well-known taxonomy, so further analysis can help to verify and re-adjust the syllabus in some iterations. This way, using convenient verbs and nouns when defining learning outcomes can evidence if a course is well oriented or not. For example, while a basic course should be focused on outcomes that lead to learn and assume basic concepts, an elective course, usually organized and taught in last years of the degree, must be oriented to apply and develop concepts. FACING's STEM team is currently training teachers and co-designing learning activities to ensure a properly low level goals definition and evaluation, derived from the competencies roadmap designed.

Finally, it is important to highlight here that several countries are implementing outcome based educations systems and active learning. Some examples to mention in which we were involved are: India (Walchand College of Engineering in Sangli and BVB College in Hubli). Also, there are several institutions that are moving towards this approach in Mexico (several institutions), Colombia (Universidad del Norte), Peru (PUC Lima) and some others. The approach and process described in this paper could be a helpful benchmark for other institutions seeking to re-engineer programs to better serve their stakeholders.

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Appendix 1: STEM Competencies Roadmap

Competence	Domain Level	Learning Outcomes
Apply knowledge of mathematics, science and engineering in solving engineering problems	I.- Solve problems using scientific or mathematical models and formulations that express a simplified engineering problem	Relate the mathematical formulation and the grammatical description of an engineering problem
		Express problems using graphics and mathematical models
		Solve problems using graphics and mathematical models
	II.- Solve problems using scientific or mathematical models and formulations that express a real engineering problem	Implement solutions to problems using graphics and / or mathematical models in real contexts
Design and implement validation activities of engineering proposals for obtaining quantitative and qualitative evidence, for further analysis and interpretation of results	I.- Apply experimental models for empirical validation of solutions to engineering problems	Identify the steps and features of a the design of experimental or empirical validation activities
		Relate the experimental design steps with laboratory experience
	II.- Select the input and output variables to the empirical validation of solutions to engineering problems	Designing an empirical validation activity to answer a research question
Design engineering solutions, such as systems, models and processes in real contexts and under real constraints	I.- Recognize and apply methodologies and tools to design engineering solutions	Identify methods , methodology , tools, techniques , standards applied in the design process engineering solutions .
		Analyze, select and use methods, methodologies, tools, techniques and standards to produce partial results in the engineering design process .
	II.- Build models and systems that can provide solutions to engineering problems in real contexts	Run and evaluate a engineering design process using methods, methodology, tools, techniques and standards
Identify, formulate and solve engineering problems	I.- Develop and implement a model that solves a disciplinary problem	Extract relevant information for understanding and solving the problem
		Understand the objective of the problem
		Establish relationships through information provided by the problem
		Apply different techniques to solve the problem
	II.- Design strategies for solving problems of discipline	Select different techniques to solve the problem according to their suitability to the discipline restrictions
Using techniques, methods and modern engineering tools	I.- Recognize and use the techniques and tools of modern engineering	Identify technical and engineering tools and understand their uses and applications.
		Using techniques and engineering tools in solving problems and / or projects
	II.- Select appropriate techniques and tools to solve problems of modern engineering	Select appropriate techniques and tools to solve problems of modern engineering
	III.- Designing and develop methods, techniques and tools for engineering	Design and develop methods , techniques and tools for engineering
		Build or develop methods , techniques and tools for engineering
Understand the impact of engineering solutions in the global, social, economic context and the environment.	I.- Interpret the impact of engineering solutions in the global, social, economic context and the environment	Infer and explain the impact of engineering solutions in the global, social , economic context and the environment
Knowing political and economic aspects of the context of the engineering performance	I.- Relate the engineering processes in the political, economic and environmental context of the engineering performance	Identify the political, economic and environmental context of the engineering performance