Learning Outcomes for Engineering Education Programs

Dr. Kseniya Zaitseva, Tomsk Polytechnic University/ Association for Engineering Education of Russia

Associate professor at Tomsk Polytechnic University faculty member, Accreditation Center director in Association for Engineering Education of Russia. PhD in Pedagogical Sciences, graduate degree in "Mathematical Methods in Economics". Also holds a Management degree. Her research focus is in Quality Assurance, active learning and international academic mobility. Has experience in coordinating several TEMPUS, Erasmus+ projects as well as organizing joint international partnerships in educational and research areas, including national and international projects, organizing conferences, seminars, workshops and training courses.

Prof. José Carlos Quadrado P.E., Porto Polytechnic Institute

Jose Carlos Quadrado, is an international leader in engineering education.

He is a tenured full-professor at the Porto Polytechnic Institute (P.Porto), one of the leading and most prestigious engineering institutes in Portugal, where he is also currently the Pro-President for Internationalisation. He holds a BSc in Energy and Power Systems, a diploma degree in Electrical Engineering, Automation and Industrial Electronics, a MSc and a Doctor degree in Electrical Engineering and Computers from Lisbon University. He also holds the Habilitation degree (Aggregation) in Electrical Engineering from Beira Interior University.

He is currently the past-President of the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI). Holds the position of past-President of the International Federation of Engineering Education Societies (IFEES) and the position of past president of the Ibero-American Engineering Education Association (ASIBEI). He is also a past-Vice President of the European Society for Engineering Education (SEFI) and past-President of Instituto Superior de Engenharia de Lisboa (ISEL). Innovative, good communicator and experienced in the field of Engineering he leads the Portuguese Observatory on European and Latin-American University management strategy best practices (TELESCOPI Portugal). Being a former member of the National Bologna Expert Group, he is the past-President of the Portuguese association of engineering deans (APDI2E).

As a current Vice President of the European Network for Accreditation of Engineering Education (ENAEE), he has been actively supporting the development of new accreditation agencies in Central Asia, Africa and Latin America. He is also a Kazakhstan Society of Engineering Education (KazSEE) accreditation board member. Being a member and senior member of several engineering societies and engineering education societies in several continents, he is also a visiting professor in many universities around the world and board member of several technological societies and technological companies.

He has been involved in more than 200 international publications, patents and has been the recipient of international technical awards and scholarships. He is the Peter I 2017 medallist from the Russian Engineering Education Association. He has also occupied editorial positions in scientific journals. His academic work is mostly related to the fields of renewable energy, fuel cells, electric vehicles and intelligent control.

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LEARNING OUTCOMES FOR ENGINEERING EDUCATION PROGRAMS

Abstract

Since the Bologna Declaration was signed in 1999, higher education institutions throughout Europe launched vast curriculum reforms including transition to the concept of learning outcomes often determined as specific statements of what students should know and are able to do as a result of learning. Being a nice complement to different qualification frameworks, quality assurance and accreditation systems, the outcome- based approach has become increasingly popular at international level. Although specific features, different ways and levels of implementation appear depending on the country.
This paper presents a summary of learning-outcomes development in Latin America, and particularly in Colombian technical universities, describes the state-of-art and gives recommendations on further steps of curriculum design and quality improvements.

Introduction

In recent decades, the way of understanding engineering university education has been reinforced. On the one hand, globalized world demands highly professional qualified engineers with specific characteristics, which alters the demands of society to the university: it is no longer enough for students to assimilate the knowledge developed so far, but, due to the continuous and rapid scientific and technological advances, the university education is requested from students to be prepared to assimilate the foreseeable future transformations and, even, have a significant role in them.
On the other hand, the university itself, is impacted and has to change under technical and economic transformations as well as globalization, new technologies or internationalization in all areas of activity, it must undergo profound modifications that also affect its relations with society. Again, it is proposed that students have to be able to work and contribute to a world in permanent change and very open, from multidisciplinary perspectives and multicultural, for a future that today is uncertain.
In any case, the formative challenge is important and can not be ignored. Therefore, it is vital that students keep getting knowledge and skills linked to a certain set of disciplines, but also have all conditions to develop transversal competences that ensure the ability to follow learning and being updated throughout life, hand in hand with new advances and discoveries, according to the needs that arise. At the same time the ability to communicate and work in multidisciplinary and multicultural teams and, of course, to best use all the available resources has to be developed within the learning process.

State-of-art

One of the main educational challenges is that the university has to train students to be good professionals and citizens in an uncertain future and also help to create it. If this is the case, it follows that the students must work in diverse and varied environments, so that they are able to perceive regularities through this diversity of contexts, as well as the relevance and limitations of knowledge.
This means that throughout their training they have to face with diverse situations and problems, which force them to make decisions under conditions of uncertainty, as is likely to happen often in their professional life.
The approach, the orientation, that emerges from the documents of the European Higher Education Area, as well as the contributions of numerous authors highlight the need that the university education revises its constituent pillars and center its teaching work in the deepening the learning of university students, as well as improving their hands-on practice.

When we think of innovative curricula that leads professors to act with a focus on learning and encourage students to use their training in the best way, we must also think of the elements in the curriculum design which will achieve these purposes. In this way, one of the key elements of the engineering curricula are the learning outcomes. “Learning outcomes represent what is formally assessed and accredited to the student and they offer a starting point for a viable model for the design of curricula in higher education which shifts the emphasis form input and process to the celebration of student learning” [1]. Their appropriate definition becomes an essential element of the curricular design that helps to describe what you want to achieve with a training program or part of it.

The European Commission, in its document Using Learning Outcomes, points out that its use has an impact on education, training practices and policies, accentuating the learning of student by making it explicit [2]. Learning outcomes represent one of the basic principles for the transparency of higher education systems and make it possible to carry out the recognition of the qualifications of professionals in different fields.

The establishment of the European Credit Transfer System (ECTS) for undergraduate and master programs has led to the introduction of a new training model in higher education focused on the student [3]. This fact has supposed a methodological change in recent years: from a content-based (input-based) approach - focused on what the professor teaches to another focused on results or outcome-based approach -that is focused on what a student is capable to understand and do when successfully completing an educational program.

The learning outcomes offer greater clarity and transparency for the systems of higher education and its qualifications. They are important clarification tools for the students, citizens, employers and the educators themselves [4].

For the university it is a very useful tool for planning and organizing learning since it makes evident the expected results of the teachings and allows them to be easily understood by professors, students, employers and other stakeholders of the educational system. On the one hand it helps the professor to guide his teaching towards the achievement of certain objectives that have been made explicit in terms of knowledge and skills. On the other, allows the student to know in advance the challenges that he or she will face throughout his/her training, that is, what is expected of him/her at the end of studies and how the achievement of the learning results will be evaluated. In addition, the use of learning outcomes increases the coherence of the teaching-learning model centered on the student since it establishes a link between content of learning, training activities and techniques, evaluation methodologies and final outputs.

In this way, learning outcomes are of interest: a) for universities when they carry out the definition of their qualifications and the training of their students, essentially through their subjects; b) at the national level when the definition of the framework for qualifications or external evaluation and quality assurance; and c) in the international arena with the purpose of promoting recognition, mobility, and transparency of titles between different countries.

The idea of compatibility, comparability and competitiveness in higher education is not an exclusively European aspiration. As we have seen the concept of learning outcomes in Europe is not new, but Latin America universities are still not very familiar with all its characteristics when trying to implement it.

One of the features of the modern globalization process is the growing mobility of students, and this requires reliable and objective information about the available educational programs. In addition, we also need to take into account staff mobility. Current and future employees inside and outside Latin America will need to have reliable information about what this qualification or educational program actually means.

Today Latin America is making steps forward towards international recognition of their educational degrees, but at country level the speed and motivation are quite different.

It took Europe several decades to consolidate the integration process. Although Latin America has made significant headway in recent years, its achievements and progress need to be further strengthened [5]. As far as the academic community concerned, it is necessary to bridge the gap

between a ‘traditional education’ — based on disciplinary knowledge and transmission — and an outcome-based education required for the new global job market and the new knowledge and technology based society [6].
As in the majority of developing countries, higher education institutions in Latin American are still dominated by the concept of a ‘traditional education’ that emphasize the transmission of disciplinary contents and the paramount role of professors inside the classroom. This model focuses more on what is it taught (contents and topics of different subjects), and less on what student will be able to do and how will be able to use acquired knowledge and skills in his or her professional life after graduating the program.
To switch the traditional focus from teaching to learning is not easy since it implies the assumption of new curriculum concepts that should lead and assure an effective learning [7].
It is worth noting, for example, that in some Latin American countries where academic credits are in place these have been implicitly conceptualized keeping in mind the teaching process performed by professors in the classroom or in direct contact with students through supervised activities. In practice, the central element of this approach are the contact hours with professors and not a real student’s workload. Thus, although the definition of credit does not formally declare it, institutions have been using credits as a means to estimate professors’ workload rather than students' [8].
One evidence that this reality is changing, one can look into the recent developments in Colombia. Under the new law in Colombia for degree registry (law 1280 of 25th July 2018) the institutions define the organization of academic activities autonomously [9].
For the first time the academic credits are the unit of measurement of academic work to express all the activities that are part of the curriculum that must be met by students. An academic credit is defined as a 48-hour academic work that includes the hours with direct accompaniment of the professor and the hours of independent work that the student must dedicate to the realization of study activities, practices or other tasks that are necessary to achieve the learning goals.
Although this law was designed for facilitating the national and international mobility of students and graduates, and curricular flexibility, among other aspects, also the academic activities associated with research training that may be developed in contents or options of degree (monographs, degree works, thesis or equivalents) were to be molded with the same approach within the curriculum.
The major change described by this law was that the number of credits to which corresponds each activity. must be accurate, so that “The student can know the time that must be available for the proper development of each activity”. Also, it is for the first time clear that “the number of credits of an academic activity in the curriculum will be that which results from divide by 48 the total number of hours the student must use to meet satisfactorily the learning goals.”
In practice this law introduces in the Colombian Higher education as mandatory the learning outcome-based approach.

How the curriculum is designed

The basis of this methodological approach corresponds to a major change, from a content-based approach focused on what the professor teaches to a focus on learning outcomes, on what the student is able to understand and do when successfully completing his learning process.
The learning outcomes therefore become the centerpiece of this change since they can be used as a director element in the design and in the teaching-learning process, as well as a descriptor of what is intended to be carried out in a curriculum, also as a facilitator for the elaboration of other elements of the curricular design, such as the training activities and the evaluation system, and as an element of link and analysis with other curricula, facilitating the fundamental objectives such as transparency, mobility, accountability, and employability.
The learning outcome-based approach is based on the educational conception decided by the university and uses the prospective diagnosis to assess critically the need for a specific graduate. Based on the needs of the market namely for the engineering profession, the design of the

educational program defines its aim. It is important to stress that the aim of the educational program is only achieved several years after the graduation from the referred program.
To achieve the educational program's aim, it is important to define the profile and the competences of the graduate on the moment of graduation, also known as the educational program learning outcomes.
Once the educational program learning outcomes are set, then, by using the educational concept of the university, the study plan is designed to achieve the referred learning outcomes. This will induce the planning of each subject of the educational program which will incorporate several methodological strategies.
As a final reference it should be clear that the evaluation strategies should be adapted to this new reality since they are aiming to evaluate above all in each subject the learning outcomes that contribute to the educational program learning outcomes.

Methodology and Results

In order to support Latin American HEIs Association for Engineering Education of Russia (AEER) together with Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) in the period 2016-2018 organized and held 6 training workshops for academic staff of different Latin American countries with 25-30 participants each. The training sessions aimed at quality assurance and professional accreditation of engineering education programs took place in Costa Rica, USA, Colombia, Chile, Ecuador and Peru. Within the training a great focus was made on the learning outcomes of the study programs. Following active learning mode within the training sessions participants had to complete different tasks working in teams and individually:

- description and analysis of of the curricular is currently designed;
- expert evaluation of criteria and indicators to evaluate the quality of curricular design;
- adjusted problem analysis in accordance with the state of art;
- identification of limitations and barriers to improve the curricular design;
- searching for solutions and recommendations to solve the problem.

At the first stage an individual assessment of current state of the problem was made by seminar participants based on their experience and expert opinion as shown in figure 1.

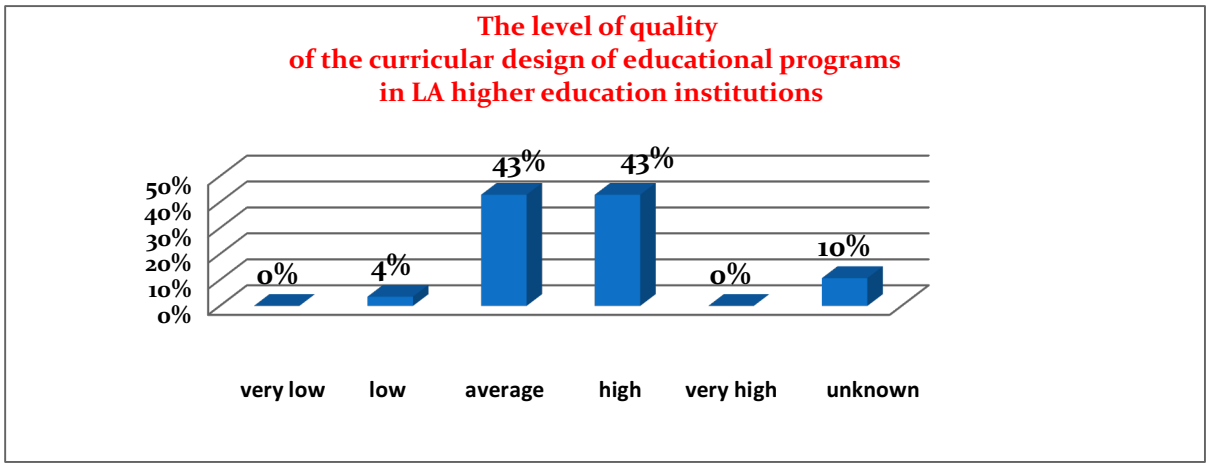

Figure 1. The level of quality of the curricular design of educational programs in LA higher education institutions

To clarify the results obtained, experts were asked to divide into teams (4-6 people in each team) and make a brainstorm session searching up to five criteria defining the problem. Team leaders (elected in each team) had to present teamwork results and defend the criteria proposed by the team. During the general discussion identical criteria were excluded and those approved by all participants were left.

At the end of this stage participants commonly identified the following criteria that characterize the quality of the curricular design of educational programs:

1. Relevance
2. Continuous improvement
3. Infrastructure (educational environment)
4. Coherence
5. Internationalization

After individual and team expert evaluation of the problem participants of the seminar completed one of the most time-consuming tasks: Build the matrix to measure the quality of the curricular design of educational programs in LA higher education institution (Table 1). Participants defined their own indicators (giving a quantitative estimate) to each criterion. After being processed responses of all participants were transformed in average rating for each criterion and introduced into the appropriate cell of the matrix.

Level / **Criterion**	**Very low**	**Low**	**Average**	**High**	**Very high**
1. Relevance (% of plan compliance)	0-34	34-47	47-64	64-80 65	80-100
2. Continuous improvement, (% of plan compliance)	0-32	32-46	46-61	61-76 70	76-100
3. Infrastructure (educational environment),%	0-33	33-47	47-65 50	65-81	81-100
4. Coherence, (% of alignment with market)	0-31	31-43	43-60 45	60-77	77-100
5. Internationalization (% of the program internationally available)	0-14 12	14-23	23-35	35-51	51-100

Table 1. The matrix to measure the quality of the curricular design of educational programs in LA higher education institutions

Searching for current indicators defining the real state of the art (marked in red) demonstrated that the initial perception of participants was aligned with the obtained results (based on first four criteria) except for the last one, where the real indicator corresponds to the low level of the created scale.

One of the objectives of the next step is to get participants' opinion on the challenges one could face dealing with the defined problem situation. In this case participants defined, after using a crowd source discussing method, a list of main limitations for high quality curricular design of educational programs:

- Resistance to change
- Lack of national / international references
- Economic limits / lack of resources
- Professional interest of professors
- Disarticulation between the objectives and the curriculum.

Finally, participants had to work in teams and suggest solutions how to improve the curricular design, taking into consideration the criteria, the scale and limitations from the previous tasks. Summarizing various measures proposed to improve the quality of curricular design, the following list of recommendations was obtained:

- To carry out shared processes that reduce the resistance of academic community to change (awareness plan, spaces for reflection)
- To share good practices at national and international level (international benchmarks)
- To develop strategic plan of improvement measures
- To define training purposes for the 21st century
- To define teacher training policy
- To make closer connection with market and industry
- To manage efficiently the search of resources (not only externally but internally)

Conclusions

Undoubtedly, the application of the outcome-based approach has become an integral part of the transformations taking place in the system of higher engineering education in Latin America, and in particular in Colombia, taking into account the new law.

However, in order for ensure that these changes have a systemic nature and bring real benefits, significantly improve the quality of future engineers training, the academic community, and ultimately professors and students have to undergo this modernization process consciously, with the necessary degree of motivation and inner understanding of the importance of the ongoing transformations.

To do this, as was mentioned above, it is important to make the first steps towards major transformations. In particular, educational program managers, together with members of the teaching staff, need to perform a critical analysis of existing educational programs: evaluate and make the goals of the educational program correspond to the mission of the university. At the same time, it is important to remember that the goals of the educational program must be sufficiently ambitious, have unique characteristics (distinguishing them from other similar programs in order to be competitive), and be achievable by graduates of the engineering educational programs after 3-5 years after graduation.

Together with the main stakeholders (for example, employers), select and describe key learning outcomes that first of all have to be aligned with the previously defined goals of the educational program, taking into account employers' requests and international requirements for the competence of engineers, i.e. well-known internationally recognized quality assurance and

accreditation of engineering educational programs systems, such as EUR-ACE [10] and the Washington Accord [11]. And only after this, to design or modernize the curriculum, selecting the necessary set of disciplines, teaching and learning techniques, adequate evaluation methods that can ensure the achievement of the stated learning outcomes.

At current stage of transformation that is taking place in the system of higher engineering education in Latin America, it was visible through the training workshops held in the region that is necessary to support universities seeking to make the necessary changes, while making every effort so that these updates do not become just a formal requirement, but lead to real changes developing an internal culture of quality improvement that can be recognized internationally. This will allow to meet the challenges of globalization, giving an opportunity to increase the share of both academic and professional mobility in the field of engineering and technology, ensuring the exchange of best practices, and ultimately meeting the requirements of the modern society.

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