International Journal of Engineering Education Vol. 34, No. 5, pp. 1451–1466, 2018
Printed in Great Britain
0949-149X/91 $3.00+0.00

How Do We Teach? A Practical Guide for Engineering Educators*

ERIC FORCAEL[1], GONZALO GARCÉS[1], PETER BACKHOUSE[2] and ELENA BASTÍAS[3]
[1] Universidad del Bío-Bío, Department of Civil and Environmental Engineering, Concepción, Chile.
E-mail: eforcael@ubiobio.cl, ggarces@alumnos.ubiobio.cl
[2] Universidad del Bío-Bío, College of Engineering, Concepción, Chile. E-mail: pbackhou@ubiobio.cl
[3] Universidad del Bío-Bío, Pedagogical and Curriculum Development Unit, Concepción, Chile. E-mail: ebastias@ubiobio.cl

For centuries, engineering has been taught based on diverse educational paradigms, with a remarkable predominance of traditional approaches. During the last decades, new educational paradigms and didactic strategies have arisen. Nevertheless, it was not always the case that engineering educators had a clear understanding of a paradigm or a strategy being used. Thus, after an exhaustive review of literature, this paper presents a guide for engineering educators that shows how the multiple didactic strategies are classified within the four educational paradigms found in engineering education (positivism, constructivism, socio-critical and communicative-critical).

Keywords: educational paradigms; didactic strategies; positivism; constructivism; socio-critical; communicative-critical

1. Introduction

For centuries, diverse teaching methods have evolved to improve learning of engineering. However, one of the shortcomings in training engineers has been the predominance of traditional teaching-learning methodologies, with an emphasis on decontextualized teaching and rote learning [1].

That is one of the reasons why universities and educators have paid a greater attention to carry out a constant search to develop and adapt new pedagogical-didactic strategies, that could allow training engineering professionals with the competences demanded by more dynamic working and social environments [2, 3], through adapting the teaching processes according to the needs and characteristics of each student [4, 5]. These didactic strategies seek to promote the development of generic competences such as learning to learn, organizing and planning, analyzing and synthesizing, applying knowledge to practice, expressing oral and written clearly, developing critical ability and self-criticism, and working collaboratively with initiative and leadership among others [6]. In this way, it is essential for the educator to learn how students can internalize and incorporate new contents into their mental structures, especially in engineering programs, where a high academic performance is required [7].

Therefore, an urgent need for change not only in contents but also in methods and approaches to engineering education has emerged. However, one of the obstacles to progress in this regard is the lack of confidence and knowledge about different pedagogical approaches or learning streams, where some educators see them as a challenge not always easy to address [8].

2. Paradigms in education

Kuhn [9] argues that a paradigm is a general thought of the object of study of a science, of the problems to be studied, of the method to be used in research, and of the ways of explaining, interpreting or understanding the results obtained in a research. Therefore, a paradigm is a guide to all justified, valid and reasonable knowledge. In other words, it helps to see the reality in a certain perspective, and consequently, to determine to a great extent how to develop a research process and how to acquire knowledge [10, 11].

A large number of authors refer to four approaches to educational reality or paradigms: Positivism or Rationalist; Constructivist or also known as Interpretive current (hermeneutic-phenomenological); the Socio-Critical perspective; and the most recent Communicative-Critical that contributes to the overcoming of educational and social inequalities [12]. These paradigms have different ways of seeing and understanding the reality of the current education and differ in the approach of construction and obtaining of knowledge.

2.1 Positivism

Positivism is a current of thought whose beginnings is usually attributed to the approaches of Auguste Comte, who only considered the knowledge from the empirical sciences valid. This paradigm, also known as Quantitative or Rationalist, establishes the existence of a certain uniformity and order in nature, which means that the natural world has its own existence, independent of who investigates it [13]. Based on this, it is governed by laws that allow explaining, predicting and controlling phenomena.

* Accepted 17 April 2018.

This paradigm is particularly predominant in engineering education, where students are passive throughout the learning process, and depend on the educator as a source of information and not on themselves as constructors of knowledge [14].

From an epistemological point of view, Positivism has an objective position, a distant and non-interactive attitude between the subject and the peers [15]. Assuming that reality is given and can be absolutely known by the subject (e.g., an engineering student), and therefore requires finding the right and valid method to discover that reality. Consequently, positivist science is based on the assumption that the subject has an absolute possibility of knowing reality through a specific method. This is the type of problems that engineering students often encounter in classrooms, by using this traditional approach, which do not necessarily prepare them for the real problems that they will find as future engineers [16].

Positivism, as mentioned above, was originally established by Comte but complemented by a number of authors; one of them was John Stuart Mill. Despite the most progressive approach of Mill, both visions converge, even going backwards until reaching David Hume and the philosophy of the Enlightenment [17]. Beyond different points of view of Comte and Mill, they are considered some of the most relevant supporters of positivist science and precursors of this paradigm [18]. Fig. 1 shows how they contributed to build this paradigm.

Hence, Positivism emphasizes verification, based on observation and opposing any science that is constructed without any empirical correlates [19]. The most important characteristic of positivist theory is the search for a systematic, verifiable and measurable knowledge, focusing on the cause of phenomena that occur, from observation, measurement and statistical procedure. In this way, this paradigm leads the students to answer tests in the most accurate way possible in terms of either what educator has taught or study books establish, getting much better academic grades but not necessarily a better understanding [1].

2.2 Constructivism

Constructivism argues that learning is essentially active [20], where each student structures his/her knowledge through his/her unique pattern. In other words, while a student learns he/she incorporates the knowledge acquired to his/her previous experiences, thus modifying his/her mental schemes. That is, the previous experiences related to the subject as well as new information are assimilated and stored in the mind. Therefore, learning is neither passive nor objective; rather, it is a subjective process that each person continuously modifies by incorporating new experiences [21]. It is therefore important to note that learning is generated through an event, experience or understanding in a structure that grows subjectively, leading the learner to establish rational and meaningful relationships with the environment.

Having said that, constructivism affirms that the student, both in the cognitive and social aspects of behavior as in affective ones, is not a mere product of the environment, nor the result of his/her internal abilities, but a self-construction that is constantly produced as a result of interaction of such aspects [22]. That is, the construction of knowledge is generated gradually and progressively [23]. In other words, each student is a constructor of knowledge in the classroom, having the possibility of reflecting about the content, investigating and creating new concepts, exposing educator his/her point of view about the solution of problems. In this way, Constructivism is quite effective in engineering education, because instead of solving exercises objectively exposed by the educator, real engineering problems could be solved subjectively and the knowledge built among the participants [16, 24].

Thus, Constructivism is an epistemological and philosophical trend that starts from a framework of social consideration of classroom education,

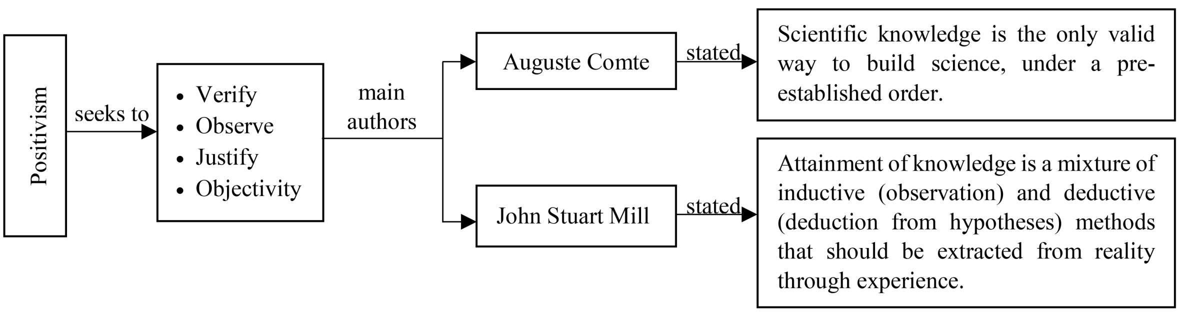

Fig. 1. Positivism according to Auguste Comte and John Stuart Mill.

attempting to explain how the human being is able to construct all concepts [25]. The student filters out all the information that he/she receives through his/her cognitive structure in relation to a specific topic, and if he/she does not internalize that this is a meaningful or important matter, his/her learning structure is not modified [26].

Next contributions of the main authors of constructivism will be analyzed, namely: Jean Piaget, Lev Vytgosky, David Ausubel and Jerome Bruner. The first theorist, Piaget, considered by many as the author of Constructivism, divided into stages the way in which the human being learns, conducting researches even with his own children [23, 27]. Then, Vygotsky proposed that the subject learns through interaction with others. That is, the construction of knowledge is produced through social interaction, giving the teacher a new purpose: a mediator of learning [28–30]. Later, Ausubel stated the concept of learning by reception, to distinguish it from the memoristic, allowing the student to understand, retain and transfer knowledge [25, 26, 31]. Finally, Bruner, known by his contributions about learning by discover, established that the student will organize what he/she finds, in a way not only intended to discover the relationship of concepts, but also to filter out the information, avoiding its accumulation [32, 33]. These constructivist theorists marked a historical precedent in educational matters and their contributions are summarized in Fig. 2.

During most of the 20th century, engineering education was mainly focused on hands-on practice; however, as the century progressed, the engineering education evolved towards teaching the engineering science, while teaching engineering practice was increasingly de-emphasized [34, 35]. As a result, in recent years, industry has found that students receiving an engineering degree, although technically competent, lack many skills required in real-world engineering situations [36]. This is why institutions such as the Accreditation Board for Engineering and Technology (ABET) created a list of skills which engineers must have [34, 37, 38], with the aim of encouraging universities to rethink their educational strategies to meet those real-world needs that engineers have to face. Later, in the late 1990s, the CDIO initiative emerged, originally developed by the Massachusetts Institute of Technology [39], which corresponds to an educational framework that provides students with an education based on Conceive-Design-Implement-Operate of systems and products for the real world [39, 40]. Today, the MIT and other leading US, European, Canadian, British, African, Asian and New Zealand leading engineering schools utilize this CDIO initiative as a framework for curriculum planning and assessment based on the results [41, 42]. Also based on a constructive approach and with the objective of bridging the gap between scientific and practical training, new initiatives have emerged such as Rapid Prototyping, which is a manufacturing technique that allows rapid manufacture of 3D computer models, achieving functional prototypes, shortening design time, and leading to successful finished products [43]. In summary, during the last years, engineering educators have been taking on the challenge of reforming engineering education towards a constructivist approach, being able to identify, formulate and solve real engineering problems immersed in a globalized and social world.

Hence, constructivist ideas about learning have raised a direct challenge to more traditional educational precepts, since unlike Positivism; student controls the development of knowledge, skills and attitudes of the student facing real engineering problems. The constructivist model clearly has

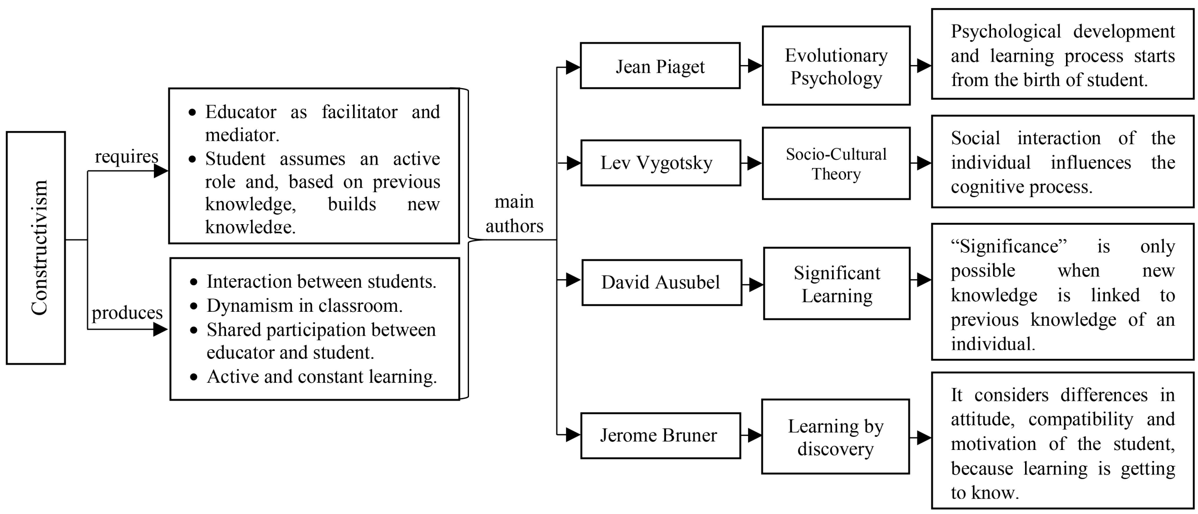

Fig. 2. Constructivism and its main authors.

profound social implications as it produces changes in the relationship between educator and student, and in learning, which depends on how thought works at different levels of the educational process [44].

2.3 Socio-Critical theory

The origins of this paradigm goes back to the 1920s, when in the School of Philosophy and Social Sciences at the Institute of Social Research in Frankfurt, Germany, Max Horkheimer and Theodor Adorno developed a concept focused on the emancipation of the human being [45, 46], where this theoretical conception was firstly known as Critical Theory [47].

Subsequently, Socio-Critical paradigm emerged in response to positivist and interpretative traditions that have had little influence on social transformation. This new approach is based on the basic assumption of education and research are not neutral. That is, it asserts the impossibility of obtaining unbiased knowledge, since the neutrality of science is false [48]. Therefore, this paradigm seeks to establish the existence of a social science that is neither purely positivist nor purely constructivist [49, 50], aiming a change or a social transformation through the participation of the members of communities [47, 51].

In other words, Socio-Critical theory is characterized by developing subjects rather than just objects, making it possible for the oppressed to participate in the socio-historical transformation of their society. According to [52], the way to carry out this process is a liberating education, which allows people to become active subjects of their own learning processes. This Socio-Critical paradigm, therefore, is characterized by being emancipatory [47] since it invites the subject to a process of reflection and analysis about the society in which is involved and the possibility of generating changes. For this reason, this approach would lead student to reflect and criticize the contents in a collective way [51]. This would change students' ways of thinking, help them to solve engineering problems not for their own benefits, but for the improvement in the environment and society, through an objective and subjective involvement of the participants in the classroom, both educator and students.

In addition to the works of Max Horkheimer and Theodor Adorno, many other authors have contributed to this paradigm belonging to the tradition of social thought. Fromm, Brecht, Marcuse, Wilhelm Reich, Pollak and Habermas make up this broad list of contributors [45, 47, 50]. Despite a large number of authors who have worked on this paradigm, for the purposes of this research only two fundamental authors have been considered: Max Horkheimer, a pioneer of Critical Theory; and the world-known sociologist, political scientist and philosopher Jürgen Habermas, who is still contributing to the socio-critical paradigm. The contributions of these two renowned thinkers are summarized in Fig. 3.

In summary, the Socio-Critical paradigm emerges from the problems of everyday life and is constructed through solutions [53]. This is why the critical researcher tries to discover what objective and subjective conditions restrict the search for new alternatives, opinions and results. In this way, it

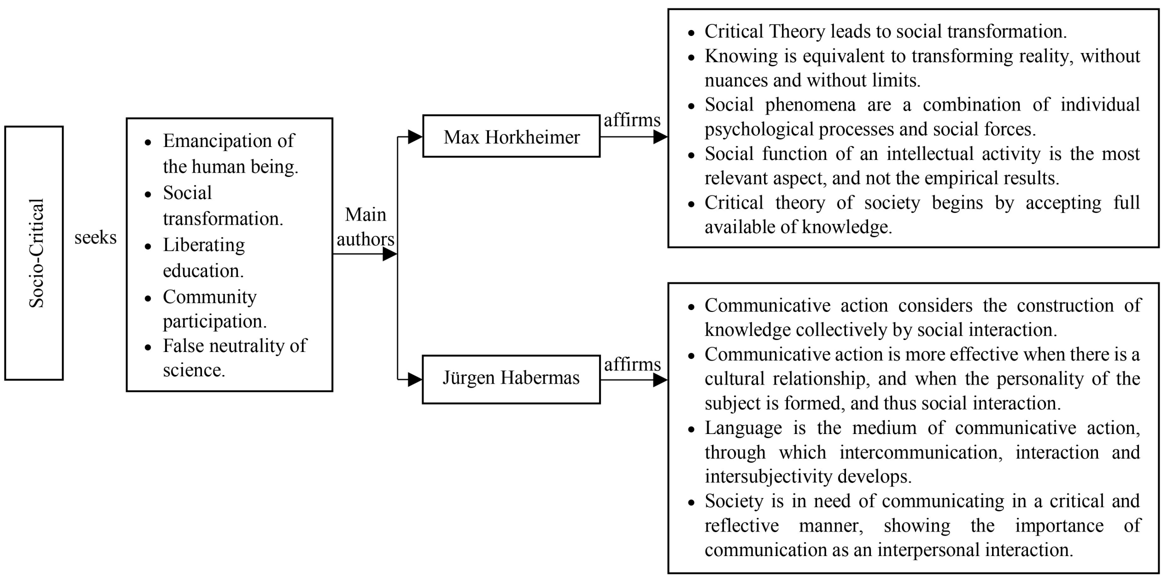

Fig. 3. Socio-Critical paradigm according to its main thinkers.

leads to a collaborative and participative process of self-reflection, which takes place in communities committed to a better society.

2.4 Communicative-critical theory

This theory also considers a change in how scientific knowledge is created, where the figure of expert or educator has undergone a profound transformation, since he/she does not have all the necessary information to make contributions that are useful to all people. Therefore, from an educational perspective, this paradigm establishes that decision-making processes increasingly depend on dialogue and consensus [54–56]. In other words, this current of thought affirms that it is possible to do science and construct new concepts, but this has to be done based on what really matters for this communicative-critical perspective: the evidences contributed by participants in the teaching-learning process through dialogue and consensus. In this way, this paradigm encourages students to be more participatory in class, looking together with their peers for concrete solutions, analyzing exercises, engineering problems given by the educator, and building knowledge through critical and reflective dialogue.

On the other hand, this paradigm is based on a series of postulates established by Gómez et al. [12] who affirmed that the conception of social reality is built by people through interactions between individuals, where the success of this approach is based on studying and analyzing current social and educational problems. That is why this new trend incorporates the opinions of all people included in a research, from the beginning to the end of it, creating scientific knowledge through validating both the opinions of experts and novices. Thus, this paradigm encourage educator to teach not only real engineering problems, but also to present challenges to the students that require designing and solving complex problems with a clear social approach [57, 58]. This inclusion of all people for the generation and the transformation of knowledge is known as dialogical turn [12].

From an epistemological point of view, this paradigm agrees that scientific statements are result of dialogue. For this reason, the critical communicative approach focuses on the intersubjective aspect of knowledge creation. Consequently, the creation of knowledge according to this perspective is a product of dialogue, discussion, reflection, and exchange of ideas of a group of people, in which they justify and demonstrate their affirmations based on arguments and evidence, thus forming the vision of the world and the current society [54, 55].

Despite the fact that some other authors have explored and studied this paradigm exhaustively, their perspectives are aligned to those stated by their seminal author Jesús Gómez, distinguished professor and researcher at the University of Salamanca in Spain, and the previously mentioned world-known sociologist and philosopher Jürgen Habermas. Therefore, based on the researches of Gómez and Habermas, Fig. 4 shows the postulates of the Communicative-Critical paradigm.

Summarizing, this paradigm is based on the dialogical turn, incorporating all the voices, in which dialogue is the generator of knowledge. Simply speaking, this approach integrates scientific principles, but also experience of the daily life of

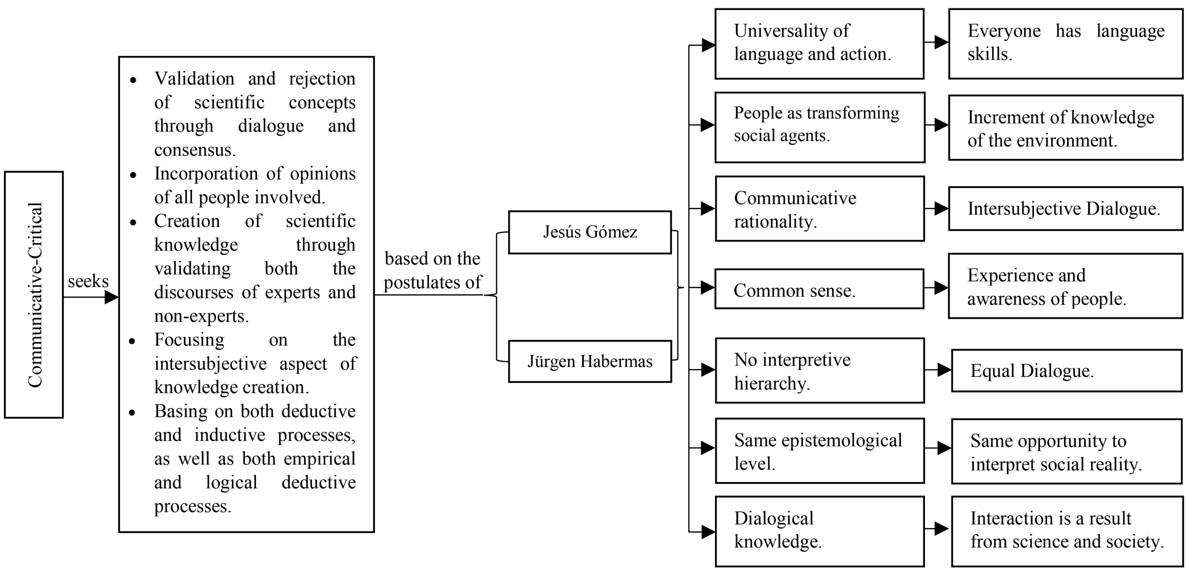

Fig. 4. Communicative-Critical paradigm thinkers.

people. In this way, results are obtained from both deductive and inductive processes, or from both empirical and logical-deductive ones.

2.5 Other educational approaches

As previously mentioned, there are educational paradigms related to how realities and knowledge are constructed. However, other alternative pedagogical approaches or methods have been present for decades. Some of those approaches have been based on multidisciplinary and integrative strategies, which contribute to the development of the human being from the doing and living together. Furthermore, other approaches have studied the way to form the students' behavior by manipulation of environmental stimuli [59], and how those approaches may be related to behaviorism, as the philosophy of the science of human behavior [60]. To name but a few, authors such as Maria Montessori, John Locke and John Dewey devoted a great extent of their works to explore these approaches.

Maria Montessori (Italy, 1870–Holland 1952), for example, put forward an educational proposal, worldwide recognized as the Montessorian method, which consists of solving problems of education, based on principles and scientific orientations emanated from medicine mainly [61], giving much importance to personal, family and social aspects. The method also proposes an adequate setting for learning, considering construction materials with dimensions not only adequate but suggestive, to promote what would be considered the axis of its method: self-management of learning as a spontaneous internal process [62]. Another important aspect of Montessori's work is the characterization of the student, whom she describes in adolescence as someone with physical and psychic changes, with an unstable and undisciplined character, who does not yet form his/her will and his/her discernment, and who learns from experience and work [63].

On the other hand, John Locke (1632–1704), and his Lockean thought, was a great contribution to the pedagogy of that time, being one of his best known theoretical pieces "Some Thoughts Concerning Education" [64]. His work focused primarily on philosophy and the art of education. His contributions include a wider conception of education, not only as the acquisition of knowledge for the formation of bourgeois, but also as the preparation for interacting in the world, where the pedagogical purpose was the formation of the individual morally and socially [65]. Another interesting aspect of his approach was the appreciation of the physical aspects of the human being, to face the absolute valuation of the intellect, alluding to that a healthy and strong body could guarantee a strong spirit.

Another interesting example is John Dewey (1859–1952), a philosopher whose prolific work influenced several areas of education sciences, such as didactics, philosophy of education, educational psychology and educational policy [66]. He can be considered the most influential philosopher of education within the 20th century in the United States. The greatest contribution of Dewey's work is characterized by his on-site researches, which helped him out to assign particular value to pragmatism, pointing out that knowledge was instrumentally focused [67]. According to his approach, the validity of a theory had to be determined by means of practical examinations, in which concepts, ideas, and knowledge were understood as learnings, and the evaluation tools were developed to solve problems.

And last but not least is the Waldorf method born in Germany amid the social and economic chaos that preceded the First World War [68, 69]. This pedagogical approach seeks to achieve an education focused on freedom and the renewal of society. Its efforts are put on developing creative environments, with the collaboration of parents and educators, placing the student at the center of learning. It is intended to enhance in the individual both cooperative development and individuality, avoiding the pressure of examinations and grades.

The different perspectives mentioned up to here, from Positivism to the last approaches presented, allow a relational analysis, integrating authors, approaches and didactic strategies, as will be shown in the following sections.

3. Relationships of educational paradigms and didactic strategies of learning

Didactic strategies are defined as organized, formalized and oriented procedures to obtain an established learning objective. In other words, it is the planning of the teaching-learning process for which the educator adopts techniques and activities that he/she can use in the classroom, in order to reach the proposed goals and the decisions that he/she must take in a critical and reflexive way to achieve the expected learning outcomes [70, 71]. As each didactic strategic is part of an educational paradigm, the idea is to link them in order to give engineering educators a guide to determine what paradigm is related to the didactic strategies that they are using. Before showing those relationships, a brief explanation about the main didactic strategies used in engineering education is shown in Table 1.

Next, relationships between the paradigms presented in this paper with their respective authors, and the didactic strategies commonly used in engineering education (Table 1) are shown in Table 2,

Table 1. Didactic strategies in engineering education

Didactic Strategies of learning	Description
Traditional Teaching [72, 73]	Educator is a provider of knowledge elaborated and studied previously. Student is only a recipient of this knowledge, which is presented in an objective and rarely questionable way.
Teacher Tutoring [74]	Student is guided to support his/her learning process, carrying out a personalized and detailed follow-up of weaknesses and strengths that are presented in topics taught.
Demonstration Technique [75, 76]	Practical or theoretical verification of a concept that is not easily understandable, with the aim of highlighting and convincing when there is possibility of doubts, responding to a need for demonstration.
Symposium [77].	A team of experts develops different aspects of a theme or problem in a successive way before the audience, supported by empirical data from researches. Finally, a time is given to ask questions and answer them.
Expository Teaching [78, 79]	Participation of students is limited but not null, which makes evident by questions or comments asked to educator, activating the learning process.
Workshop [80]	Students apply their knowledge, abilities, skills and attitudes into practical learning experiences, facilitating problem solving and critical thinking development.
POL: Project-oriented learning [81, 82, 83]	It is based on applying and integrating knowledge. Students plan, implement, evaluate and solve real projects beyond the classroom, developing long-term interdisciplinary learning activities.
PBL: Problem-based learning [1, 84]	It consists of obtaining knowledge, as a result of an exploring process towards new concepts through problem solving, facilitating the acquisition of professional knowledge.
Simulation strategy [84, 85]	Students learn through their participation in activities that simulate real situations, by using a series of tools that allow creating multiple scenarios of variable complexity.
Student debate [86]	It is oriented to teach students to receive affective-social interaction, performed in an atmosphere of respect and cordiality. They develop communicative, cognitive and social abilities.
Critical questions [87]	It consists of questions that encourage students to examine ideas, notions and problems related to a case given by the educator, stimulating deep reflection on problems.
Portfolio [88, 89]	It is a compilation of activities and key works carried out by students, allowing educator and student to reflect on the achievements and difficulties found along a training period.
Logbook [90, 91]	It consists of a research conducted by students through books, readings, news, happenings and research experiences, having a shorter duration than the Portfolio, reporting to educator the progress and results of such research.
Interview [92, 93, 94]	It is a scientific technique that uses verbal communication to gather information in relation to a certain purpose, through a closed conversation of reciprocal exchange.
Brainstorming [95, 96]	It is a group technique that looks for generating original ideas in a relaxed atmosphere, where the best ideas are selected by participants.
Virtual forum [97]	It facilitates the creation of environments that stimulate learning and critical thinking, where virtually everyone is part of the learning process and the dynamics of group as a basis for relevant analyses.
Role Play [98]	Students assume roles within some work or situation raised, allowing discovering new facets of their imagination and helping them to think of multiple alternatives for a problem.
Observation technique [99]	It requires students to search, from a descriptive perspective, objects, processes, either phenomena or natural or social behaviors, to later apply the knowledge acquired to solve real problems.
Service Learning [100, 101]	Educational proposal that combines learning processes and community service in a single well-articulated project, in which participants learn while working in real needs of surroundings with the purpose of improving them.
Case study [102]	It focuses on students' research on a real and specific problem, which helps them to acquire the basis for an inductive study.
Discussion 66 [103]	It consists of forming groups of six members, in order to discuss or analyze a topic, trying to give a common response in six minutes to the topic initially proposed.
Round Table [104, 105]	Communicative mode in which groups of students are met to discuss on a particular topic. There is a coordinator per group who introduces the topic and orders conversation. At the end of sessions, the whole audience of students opines and asks groups.
Conceptual Map [25, 106]	Students should link and record concepts in a hierarchical order. It is characterized by starting from a main topic, extending branches that indicate the relationships between concepts.
Mental Map [107]	Graphic way of expressing the student's thoughts according to the knowledge that he has been stored. Its application allows generating, organizing, expressing the learnings and associating ideas more easily.
Cooperative learning [20, 108, 109]	It is considered a philosophy of interaction widely applied in diverse didactic strategies, where students work together to ensure that all members of the group achieve learning goals.
K-W-L: what we know, what we want to find out, we learned and still need to learn [110]	It allows exploring the previous knowledge that students own, inquiring what they know (K); what they want to know (W), and finally what they learned (L).
PMI: Plus, Minus, Interesting [111]	It allows generating a great number of ideas about an event or observation, leading students to list all points concerning a situation, and then ordering them into plus, minus and interesting points.

Table 1. (*cont.*)

Didactic Strategies of learning	Description
KPSI: Knowledge and Prior Study Inventory) [112, 113]	It provides students with an instrument for self-regulation, in which the alternatives of answers are: (1) I don't know, don't understand, cannot do; (2) I am not sure if I know, or understand, or can do; (3) I think I know what it means, I think I can do; (4) I know, I understand, can do well; and (5) I can explain, show how to do, to others.
Ideograms [114]	It consists of synthetic or schematic description of a text through prioritizing concepts and defining relationships between them.
V-Diagram [115, 116]	A "V" is drawn, in which the question to be investigated is placed in the center. The right side of "V" indicates the methodology to collect, interpret and assess the information needed to answer the central question. In the left side related concepts are defined.
Learning by discovery [117]	Students should explore through didactic experiments and research, according to the objectives that educator presents to them, promoting metacognition in the learning process.
Student seminar [118]	It is characterized by the active participation of small groups under direction of the educator, within an environment of dialogue and flexible research, which encourages participants' reasoning and metacognition.
Survey [119]	It is a strategy where students perform a survey on a sample of subjects representing a large population, by using standardized interrogation procedures, in order to obtain quantitative and qualitative information about a great variety of topics.

classifying those strategies in terms of participation of the individuals (i.e. student, educator, or both) in the generation of knowledge. Table 2 also shows the percentage in which each didactic strategy is a part of a paradigm, and this provides information about the degree of influence of a paradigm on a strategy according to literature.

Because of each didactic strategy is part of one or more of the paradigms mentioned—which have sought to build an educational reality throughout history—, these were linked to the strategies in order to give engineering educators a guide on how paradigms and strategies are related. Thus, the educator can decide if he/she wants: (a) to be the protagonist in the classroom; (b) to be a mediator and facilitator, promoting equal dialogue for the construction of knowledge; or rather (c) to be a passive actor in the classroom, transferring prominence to the students. To do so, the educator must identify the educational paradigm that better fits his/her teaching style, and then cross it in Table 2 with the didactic strategy that he/she is using, with the aim of knowing the role he/she is playing in the classroom.

As an example, when entering Table 2, if the educator realizes that he/she teaches according to the positivist approach and wishes to emigrate towards the constructivist approach, he/she should apply strategies such as: PBL; Case study; Portfolio; Workshop; Simulation; among others. On the contrary, if he/she wants to develop critical and reflective thinking of students (i.e. the Socio-critical approach), then he/she should apply strategies such as: Student debate; Critical questions; Round table; or Expository teaching, for mentioning just a few. Finally, if he/she wants to contribute to overcoming educational and social inequalities, promoting social inclusion (i.e. the Communicative-critical approach), then he/she should apply strategies such as: Service Learning; POL; Brainstorming; Discussion 66; among others. Simply speaking, Table 2 shows a map and the educator must choose the route.

Therefore, as seen in Table 2, these didactic strategies can be classified in terms of the participation of the educator, the student or both in a sharing way [120]. Therefore, if the main participant is the educator, then he/she undertakes tasks of explanation, orientation, encouragement, help, correction, etc.; however, if the protagonists are the students, activities are performed where they are the builders and creators of knowledge, in which they can act individually or in groups. Also, participation can be a combination of these two approaches, where the educator fulfills the role of mediator and facilitator of knowledge and the students interact with the object of knowledge and with their peers in a critical and reflective way.

4. ABET and CDIO

Over time, the role of the engineer and his/her training have been redefined, including now skills of a professional nature, such as: leadership, communication, team work and an understanding of ethics and professional issues, within a global and social context, encouraging lifelong learning and a knowledge of contemporary matters [145, 146]. Thus, the objective is nowadays to form a trained engineer to identify, formulate and solve real problems of society.

That is why modern engineering education programs seek to provide students with a broad base of knowledge, skills and attitudes, whose make them

Table 2. Relationship between educational paradigms and didactic strategies

	Educational paradigms / Didactic strategies	Positivism						Constructivism												Socio-Critical						Communicative Critical						
		Auguste Comte			John Mill			Jean Piaget		Lev Vygotsky				David Ausubel			Jerome Bruner			Max Horkheimer		Jürgen Habermas				Gómez, Latorre, Sánchez & Flecha						
	Didactic strategies	[121]	[122]	[123]	[124]	[125]	[126]	[127]	[72]	[128]	[129]	[130]	[131]	[132]	[25, 133]	[134]	[135]	[136]	[137]	[138]	[139]	[49]	[140]	[141]	[142]	[54]	[143]	[144]	Positivism (%)	Constructivism (%)	Socio-Critical (%)	Communicative Critical (%)
Participation and control of educator	Traditional teaching	•	•	•	•	•	•													•		•							100	0	33	0
	Teacher tutoring				•	•	•	•			•	•	•				•	•						•	•				50	50	33	0
	Demonstration technique	•	•	•	•	•	•		•																				100	8	0	0
	Symposium		•	•	•	•	•					•	•							•		•		•	•	•			83	17	67	33
Participation and control shared	Expository teaching													•	•	•			•	•		•	•	•	•				0	33	83	0
	Workshop							•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	0	100	83	100
	POL							•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	0	100	50	100
	PBL							•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	0	100	50	100
	Simulation										•	•	•	•	•	•	•	•	•					•	•	•	•	•	0	75	33	100
	Student debate								•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0	83	100	100
	Critical questions						•	•		•	•		•	•		•			•	•	•	•	•	•	•		•		17	58	100	33
	Portfolio							•	•	•	•	•	•	•	•	•	•		•			•							0	92	17	0
	Logbook							•	•	•	•	•	•	•	•	•	•					•							0	83	17	0
	Interview									•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	0	83	83	100
	Brainstorming									•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	0	83	83	100
	Virtual forum								•		•	•	•	•		•	•	•	•				•	•	•	•	•	•	0	75	50	100
	Role play									•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	0	83	50	100
	Observation technique				•	•	•	•	•	•	•	•			•		•				•	•	•		•				50	58	67	0
	Service learning									•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	0	83	50	100
	Case study									•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	•	•	0	83	67	100
Participation and control of student	Discussion 66							•		•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	0	92	50	100
	Round table							•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0	100	100	100
	Conceptual map				•	•		•	•	•			•	•	•	•	•		•										33	75	0	0
	Mental map							•	•	•				•	•	•	•		•										0	67	0	0
	Cooperative learning										•	•		•			•	•	•		•	•	•	•	•	•	•	•	0	50	83	100
	K-W-L				•		•	•	•	•				•	•	•	•	•	•										33	75	0	0
	PMI							•	•	•				•	•	•			•			•							0	58	17	0
	KPSI				•			•	•	•			•	•	•	•			•										17	67	0	0
	Ideograms					•	•	•	•	•				•	•	•	•		•										33	67	0	0
	V-Diagram				•		•	•	•	•						•	•	•	•			•							33	58	17	0
	Learning by discovery																•	•	•				•	•	•	•	•	•	0	25	50	100
	Student seminar									•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	0	83	83	100
	Survey				•		•	•	•	•	•	•	•	•	•	•	•		•	•		•	•	•	•	•	•	•	33	92	83	100

successful engineers. These skills have been integrated by means of the CDIO initiative, as an attempt to create a set of rational, complete, coherent and generalizable goals for undergraduate engineering education. The objective of the CDIO syllabus is to formally summarize a set of knowledge, skills and attitudes that students, industry and academic world desire for future generations of engineers [147]. In addition, it can be used to define the student outcomes, in terms of learning objectives of the personal, interpersonal and systems understanding skills, necessary for the practice of modern engineering. In this sense, it can be used to design new educational initiatives, and then as the basis for a rigorous evaluation process focused on outcomes, as required by ABET. The Student Outcomes of ABET and Syllabus Levels of CDIO are summarized in Table 3, assigning for each skill and competence a nomenclature.

Table 4 links the skills and competences established by ABET and CDIO, and the didactic strategies included in this research, in order to provide the educator with a clear understanding of what strategic is recommended, to achieve those abilities needed for the future engineers.

In summary, a number of universities around the world are today teaching and reinforcing diverse didactic techniques, aimed at stimulating active learning in engineering education [148, 149,150], to train qualified engineers who will work immersed in a more complex and globalized context than ever, where initiatives such as CDIO and institutions such as ABET are playing an important role.

5. Discussion

Clearly, it can be observed that Positivism is the paradigm that embraces fewer didactic strategies, promoting passive, static and repetitive learning, being the educator the protagonist in the classroom, with little or no interaction with the student. In addition, despite Comte and Mill share a similar positivist approach, it is possible to observe differences between them. Comte is more conservative, accepting and validating all justified knowledge with empirical results, whereas Mill incorporates a more progressive vision based on the inductive method (based on observation and experimentation), and the deductive method (abstraction and deduction from hypotheses that are extracted from reality through experience, so that from a generalized idea to a specific concept).

On the other hand, Constructivism has a greater relationship with didactic strategies, promoting student control and autonomy, where he/she actively builds new ideas or concepts based on

Table 3. Expected results of students according to ABET and CDIO [42, 147, 151]

Skills and Competencies of the Student		
Student Outcomes[a]		
ABET	SO1	Ability to apply knowledge of mathematics, science, and engineering.
	SO2	Ability to design and conduct experiments, as well as to analyze and interpret data.
	SO3	Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
	SO4	Ability to function on multidisciplinary teams.
	SO5	Ability to identify, formulate, and solve engineering problems.
	SO6	Understanding of professional and ethical responsibility.
	SO7	Ability to communicate effectively.
	SO8	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
	SO9	Recognition of the need for, and an ability to engage in life-long learning.
	SO10	Knowledge of contemporary issues.
	SO11	Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
Syllabus Levels[b]		
CDIO	SL1	Disciplinary knowledge and reasoning. Knowledge of underlying mathematics and science. Core fundamental knowledge of engineering. Advanced engineering fundamental knowledge, methods and tools.
	SL2	Personal and professional skills and attributes. Analytical reasoning and problem solving. Experimentation, investigation and knowledge discovery. System thinking. Attitudes, thought and learning. Ethics, equity and other responsibilities.
	SL3	Interpersonal skills: teamwork and communication. Teamwork and communications; and communications in foreign languages.
	SL4	Conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context External, societal and environmental context; and enterprise and business context. Conceiving, systems engineering and management; and designing, implementing and operating.

[a] SO = Student Outcomes. [b] SL = Syllabus Levels.

Table 4. Relationship of skills and competences expected with didactic strategies

Didactic strategies	Student Skills and Competencies	ABET											CDIO			
		SO1	SO2	SO3	SO4	SO5	SO6	SO7	SO8	SO9	SO10	SO11	SL1	SL2	SL3	SL4
Participation and control of educator	Traditional teaching	•	•										•			
	Teacher tutoring	•	•			•						•	•			
	Demonstration technique	•	•			•						•	•	•		
	Symposium			•			•		•		•		•			
Participation and control shared	Expository teaching	•							•				•	•		
	Workshop	•	•	•	•	•	•	•	•		•	•		•	•	•
	POL	•	•	•	•	•	•	•	•	•	•	•		•	•	•
	PBL	•	•	•	•	•	•	•	•	•	•	•		•	•	•
	Simulation	•	•	•	•	•		•	•	•		•		•	•	•
	Student debate			•	•		•	•	•		•			•	•	
	Critical questions			•				•	•					•	•	
	Portfolio		•	•				•		•			•	•		•
	Logbook		•					•		•			•	•		
	Interview			•	•		•	•	•	•				•	•	
	Brainstorming		•	•	•		•	•	•					•	•	
	Virtual forum			•	•			•	•		•	•		•	•	
	Role play			•	•		•	•		•	•			•	•	•
	Observation technique		•			•				•		•		•		
	Service learning			•	•	•	•	•	•	•	•	•		•	•	•
Participation and control of student	Case study		•	•	•	•	•	•	•	•	•	•		•	•	•
	Discussion 66		•	•	•		•	•	•					•	•	
	Round table		•	•	•	•	•	•	•					•	•	
	Conceptual map		•	•				•	•				•	•		
	Mental map		•					•	•				•	•		
	Cooperative learning			•	•	•	•	•	•	•		•		•	•	•
	K-W-L	•							•	•				•		
	PMI	•							•	•				•		
	KPSI	•							•	•				•		
	Ideograms													•		
	V-Diagram									•				•		
	Learning by discovery		•	•	•	•	•	•	•			•		•	•	•
	Student seminar			•	•			•	•	•	•			•	•	
	Survey		•	•			•	•	•		•	•		•		

present and previous knowledge. It also stimulates to a greater degree the shared participation between educator and student, evidencing that knowledge acquisition can be subjective, and not purely objective as Positivism states. Additionally, it can be observed that Vygotsky, unlike Piaget, focuses mainly on strategies based on teamwork, thus affirming that it gives more importance to social interaction, through which learning improves significantly. Hence, for Vygotsky, social interaction when acquiring learning, plays a fundamental role, students not only learn with the educational setting, but also with their peers; where culture leads directly to the social development of man [29]. On the other hand, authors such as Ausubel and Bruner emerge developing and contributing more ideas and concepts to this paradigm, such as the significant learning by reception of Ausubel—considering that knowledge occurs when it is significant for the subject—, and the learning by discover of Bruner—considering that it is necessary to discover and describe formally the meanings for human beings, and how they create new knowledge from their experiences and proposing hypotheses about the processes of meaning construction—[33]. Therefore, Constructivism is an epistemological conception, which highlights the contribution of the individual in the acquisition of knowledge, through interaction with the environment and between educator and student.

In consequence, the Socio-Critical paradigm arises in response to positivist and constructivist traditions, encompassing strategies that propose the integration of all participants but stimulating critical and reflexive thinking, through a social transformation. In this way, despite Horkheimer is considered the father of this paradigm, Habermas, with a less conservative thinking, considers that the construction of knowledge is produced by social interaction through consensus and the egalitarian dialogue between student and educator, establishing the fundamentals of the most recent educational paradigm, the Critical Communicative promoted by Gómez.

As a summary, Table 2 shows each didactic strategy as part of an educational paradigm, giving the educator necessary information about which of them to apply in the classroom for the construction and obtaining of knowledge. This is according to the current of learning that he/she wants to stimulate in the educational setting: objective, subjective or intersubjective way; oriented to the process or the result; passive or dynamic environment; to explain and control or to promote equal dialogue for the construction of knowledge; or to promote a balanced and shared way between educator and student.

The use of new didactic strategies induces the educator to move towards a new role as a facilitator, since it is the learning that brings to the student the skills shown in Table 3 (ABET and CDIO), necessary to solve real problems in a globalized world. Nowadays, future engineers are required not only as professionals, but also as citizens in search of a social transformation, through critical and reflexive communication.

In other words, the way as engineering educator teaches requires a change, and therefore, the lecture itself must be different. The role of the educator will move from a traditional instructor to a facilitator of the learning process. The traditional classroom will become a workshop, with the aim of integrating the student little by little to the real world. It is according to this perspective that the educator will have to become a follower of these new tools, taking into account new actors, in a new scenario. For this reason, engineering educators must understand what the industry demands from future engineers, going over from the language they use up to the way they transmits knowledge, in order to motivate the student and make learning happen effectively.

6. Conclusions

Finally, the paradigms included in this research have had the purpose of clarifying and offering solutions to the challenges posed by education through history, where each one has a different way of seeing and understanding educational reality, and a different epistemological dimension. That is, they differ in the model of relationship between participants, and the way that the knowledge is obtained. For that reason, this paper does not pretend to be a categorical and absolutist view about educational paradigms and strategies, but also it is just a contribution to guide educators in the complex path of understanding how engineers teach and how different approaches may help improve engineering students' learning.

Acknowledgements—This work was partially supported by the Chilean National Commission for Scientific and Technological Research (CONICYT) under grant No.1171108/Fondecyt Regular.

References

1. M. J. Prince and R. M. Felder, Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases, *Journal of Engineering Education*, **95**(2), 2016, pp. 123–138.
2. G. L Gray, F. Constanzo, D. Evans, P. Cornwell, B. Self and J. L. Lane, The dynamics concept inventory assessment test: A progress report and some results, *American Society for Engineering Education Annual Conference & Exposition*, Portland, Oregon, 12 June 2005.
3. P. S. Steif, A. Dollár and J. A. Dantzler, Results from a Statics Concept Inventory and their Relationship to other Measures of Performance in Statics, *Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference*, IEEE, Indianapolis, 19–22 October 2005, pp. T3C5-T3C10.
4. R. M Felder and L. K. Silverman, Learning and teaching styles in engineering education, *Engineering Education*, **78**(7), 1988, pp. 674–681.
5. K. Eishani, E. Saa'd and Y. Nami, The Relationship Between Learning Styles And Creativity, *Procedia—Social and Behavioral Sciences*, **114**(1), 2014, pp. 52–55.
6. J. Walther, N. Kellam, N. Sochacka and D. Radcliffe, Engineering Competence? An Interpretive Investigation of Engineering Students' Professional Formation, *Journal of Engineering Education*, **100**(4), 2011, pp. 703–740.
7. M. Meyer and S. Marx, Engineering Dropouts: A Qualitative Examination of Why Undergraduates Leave Engineering, *Journal of Engineering Education*, **104**(4), 2014, pp. 525–548.
8. D. Bourn and N. Sharma, Global and sustainability issues for engineering graduates, *Proceedings of the Institution of Civil Engineers—Municipal Engineer*, **161**(3), 2008, pp. 199–206.
9. T. Kuhn, Tradition mathématique et tradition expérimentale dans le développement de la physique, *Annales. Économies, Sociétés, Civilisations*, **30**(5), 1975, pp. 975–998.
10. M. Borrego, E. P. Douglas and C. T. Amelink, Quantitative, qualitative, and mixed research methods in engineering education, *Journal of Engineering Education*, **98**(1), 2009, pp. 53–66.

11. M. Patton, *Qualitative Evaluation and Research Methods*, Sage Publications, Beverly Hills, USA, 1990.
12. J. Gómez, A. Latorre, M. Sánchez and R. Flecha, *Metodología Comunicativa Crítica*, El Roure editorial, 2006.
13. J. Tribe, Research Paradigms and the Tourism Curriculum, *Journal of Travel Research*, **39**(4), 2001, pp. 442–448.
14. T. J. Moore, S. S. Guzey, G. H. Roehrig, M. Stohlmann, M. S. Park, Y. R. Kim, H. L. Callender and H. J. Teo, Changes in Faculty Members' Instructional Beliefs while Implementing Model-Eliciting Activities, *Journal of Engineering Education*, **104**(3), 2015, pp. 279–302.
15. D. Montfort, S. Brown and D. Shinew, The Personal Epistemologies of Civil Engineering Faculty, *Journal of Engineering Education*, **103**(3), 2014, pp. 388–416.
16. J. R. Savery and T. M. Duffy, Problem based learning: An instructional model and its constructivist framework, *Educational Technology*, **35**(5), 1995, pp. 31–38.
17. G. H. Von Wright, *Explanation and Understanding*, Cornell University Press, New York, USA, 2004.
18. T. Heyd, Mill and Comte on psychology, *Journal of the History of the Behavioral Sciences*, **25**(2), 1989, pp. 125–138.
19. I. Hacking, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science*, Cambridge University Press, Cambridge, UK, 1983.
20. K. A. Smith, S. D. Sheppard, D. W. Johnson and R. T. Johnson, Pedagogies of Engagement: Classroom-Based Practices, *Journal of Engineering Education*, **94**(1), 2005, pp. 87–101.
21. J. Abbott and T. Ryan, Constructing Knowledge, Reconstructing Schooling, *Educational Leadership*, **57**(3), 1999, pp. 66–69.
22. A. Johri and B. M. Olds, Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences, *Journal of Engineering Education*, **100**(1), 2011, pp. 151–185.
23. J. Piaget, Piaget's theory, in P. Mussen (ed), *Carmichael's Manual of Child Psychology*, **2**, Wiley, Nueva York, USA, 1970.
24. D. Jonassen, J. Strobel and C. B. Lee, Everyday problem solving in engineering: Lessons for engineering educators, *Journal of Engineering Education*, **95**(2), 2006, pp. 139–151.
25. J. D. Novak, *Learning, Creating, and using Knowledge: Concept Maps as Facilative Tools in Schools and Corporations*, Routledge, New York, USA, 1998.
26. D. Ausubel, *The Psychology of Meaningful Verbal Learning*, Grune Stratton, New York, USA, 1963.
27. D. Montfort, S. Brown and D. Pollock, An Investigation of Students' Conceptual Understanding in Related Sophomore to Graduate-Level Engineering and Mechanics Courses, *Journal of Engineering Education*, **98**(2), 2009, pp. 111–129.
28. L. Vygotsky, *Mind in Society: The Development of Higher Psychological Functions*, Harvard University Press, Cambridge, USA, 1978.
29. H. Mahn and V. John-Steiner, Vygotsky and Sociocultural Approaches to Teaching and Learning, in I. Weiner (ed), *Handbook of Psychology*, 2nd edn, John Wiley & Sons, Inc., 2012, pp. 117–145.
30. M. G. Levykh, The affective establishment and maintenance of Vygotsky's Zone of Proximal Development, *Educational Theory*, **58**(1), 2008, pp. 83–101.
31. K. P. Cross, On College Teaching, *Journal of Engineering Education*, **82**(1), 1993, pp. 9–14.
32. J. S. Bruner, *Acts of Meaning*, Harvard University Press, Cambridge, USA, 1990.
33. R. J. Kelly, Jerome Bruner: The Tireless Explorer, *Journal of Social Distress and the Homeless*, **7**(4), 1998, pp. 289–302.
34. J. D. Lang, S. Cruse, F. D. McVey and J. McMasters, Industry expectations of new engineers: A survey to assist curriculum designers, *Journal of Engineering Education*, **88**(1), 1999, pp. 43–51.
35. A. Rugarcia, R. M. Felder, D. R. Woods and J. E. Stice, The future of engineering education I. A vision for a new century, *Chemical Engineering Education*, **34**(1), 2000, pp. 16–25.
36. R. M. Felder and R. Brent, Designing and teaching courses to satisfy the ABET engineering criteria, *Journal of Engineering Education*, **92**(1), 2003, pp. 7–25.
37. Accreditation Board for Engineering and Technology (ABET), *ABET 1993–94 Accreditation Yearbook*, New York, July 1993.
38. L. D. Feisel and A. J. Rosa, The role of the laboratory in undergraduate engineering education, *Journal of Engineering Education*, **94**(1), 2005, pp. 121–130.
39. K. F. Berggren, D. Brodeur, E. F. Crawley, I. Ingemarsson, W. T. Litant, J. Malmqvist and S. Östlund, CDIO: An international initiative for reforming engineering education, *World Transactions on Engineering and Technology Education*, **2**(1), 2003, pp. 49–52.
40. E. Crawley, J. Malmqvist, S. Ostlund, D. Brodeur and K. Edström, *Rethinking Engineering Education: The CDIO Approach*, 2nd edn, Springer International Publishing, 2014, pp. 60–62.
41. Z. Jianzhong, On CDIO model under learning by doing strategy, *Research in Higher Education of Engineering*, **3**, 2008, pp. 1–6.
42. History of the Worldwide CDIO Initiative, http://www.cdio.org/cdio-history, Accessed 5 Octuber 2017
43. W. Y. Yeong, C. K. Chua, K. F. Leong and M. Chandrasekaran, Rapid prototyping in tissue engineering: challenges and potential, *TRENDS in Biotechnology*, **22**(12), 2004, pp. 643–652.
44. H. Gash, Knowledge Construction: A Paradigm Shift, *New Directions for Teaching and Learning*, **2015**(143), 2015, pp. 5–23.
45. R. Wiggershaus, *The Frankfurt School: Its History, Theories, and Political Significance*, MIT Press Cambridge, USA, 1995.
46. I. Gur-Ze'ev, Adorno and Horkheimer: Diasporic Philosophy, Negative Theology, and Counter-education, *Educational Theory*, **55**(3), 2005, pp. 343–365.
47. R. C. Solomon and D. Sherman (eds), *Critical Theory, in The Blackwell Guide to Continental Philosophy*, Blackwell Publishing Ltd, Padstow, UK, 2003.
48. P. Reason (ed), *Human Inquiry in Action. Development in New Paradigm Research*, Sage Publications, London, UK, 1998.
49. S. D. Brookfield, *The Power of Critical Theory for Adult Learning and Teaching*, Open University Press, Maidenhead, England, 2005.
50. H. Joas, An underestimated alternative: America and the limits of "Critical Theory", *Symbolic Interaction*, **15**(3), 1992, pp. 261–275.
51. A. Basden, Enabling a Kleinian integration of interpretivist and socio-critical IS research: the contribution of Dooyeweerd's philosophy, *European Journal of Information Systems*, **20**(4), 2011, pp. 477–489.
52. P. Freire and D. Macedo, *Alfabetización. Lectura de la palabra y lectura de la realidad*, Paidós-MEC, Barcelona, Spain, 1989.
53. W. Carr and S. Kemmis, *Teoría crítica de la enseñanza*, Ediciones Martínez Roca, S.A., Barcelona, Spain, 1988.
54. A. Gómez, L. Puigvert and R. Flecha, Critical communicative methodology: Informing real social transformation through research, *Qualitative Inquiry*, **17**(3), 2011, pp. 235–245.
55. A. Gómez and J. Díez-Palomar, Metodología comunicativa crítica: transformaciones y cambios en el S. XXI, in R. Flecha and S. Steinberg (eds), *Teoría de la Educación. Educación y Cultura en la Sociedad de la Información*, **10**(3), 2009, pp. 103–118.
56. J. Habermas, *The Theory of Communicative Action*, Beacon Press, Boston, USA, 1984.
57. M. W. Apple and J. A. Beane, *Democratic Schools: Lessons in Powerful Education*, Heinemann, Portsmouth, NH, 2007, p.174.
58. A. Aubert and M. Soler, Dialogism: The dialogic turn in the social sciences, in J. Kincheloe and R. Horn (eds), *The Praeger Handbook of Education and Psychology*, Greenwood Press, Westport, USA, 2006, pp. 521-529.
59. J. O. Cooper, Applied behavior analysis in education. *Theory Into Practice*, **21**(2), 1982, pp. 114–118.

60. B. F. Skinner, *About Behaviorism*, Vintage Books, 1976, New York, USA.
61. R. Kramer, *Maria Montessori: A Biography*, Diversion Books, New York, USA, 2017.
62. I. Clark, Formative assessment: Assessment is for self-regulated learning, *Educational Psychology Review*, **24**(2), 2012, pp. 205–249.
63. M. Montessori, *The Montessori Method*, Transaction publishers, New Jersey, USA, 2013.
64. J. Locke, *Some Thoughts Concerning Education: Including Of the Conduct of the Understanding*, Dover Publications, New York, USA, 2007.
65. W. Hayes, *The Progressive Education Movement: Is it Still a Factor in Today's Schools?* Rowman & Littlefield Education, Blue Ridge Summit, 2006.
66. J. Dewey, *How We Think*, Dover Publications, New York, USA, 1997.
67. J. Dewey, *Experience and Education*, Simon & Schuster, New York, USA, 1997.
68. M. Ashley, Can one teacher know enough to teach year six everything? Lessons from Steiner-Waldorf pedagogy, *British Educational Research Association, Annual Conference*, Pontypridd, UK, 14th–17th September 2005, pp. 1–14.
69. P. Q. Uceda, Waldorf Teacher Education: Historical origins, its current situation as a higher education training course and the case of Spain, *Encounters in Theory and History of Education*, **16**, 2015, pp. 129–145.
70. K. C. Sloat, R. G. Tharp and R. Gallimore, The incremental effectiveness of classroom-based teacher-training techniques, *Behavior Therapy*, **8**(5), 1997, pp. 810–818.
71. R. J. Marzano, D. Pickering and J. E. Pollock, *Classroom Instruction that Works: Research-Based Strategies for Increasing Student Achievement*, Association for Supervision and Curriculum Development, Alexandria, USA, 2001.
72. J. I. Pozo, *Teorías cognitivas del aprendizaje*, Ediciones Morata, Madrid, Spain, 1997.
73. E. Mazur, Farewell, lecture? *Science*, **323**(2), 2009, pp. 50–51.
74. A. Lázaro and J. Asensi, *Manual de orientación escolar y tutoría*, Narcea, Madrid, Spain, 1987.
75. G. Beal and J. Bolhen, *Planificación de la enseñanza*, Paidós, Buenos Aires, Argentina, 1996.
76. S. J. Lou, W. Y. Dzan, C. Y. Lee, C. C. Chung, Learning Effectiveness of Applying TRIZ-Integrated BOPPPS, *International Journal of Engineering Education*, **30**(5), 2014, pp. 1303–1312.
77. J. H. Pimienta, *Estrategias de enseñanza-aprendizaje*, Pearson Educación, México, 2012.
78. D. Ausubel, J. D. Novak and H. Hanesian, *Educational Psychology: A Cognitive View*, Holt, Rinehart and Winston Eds, Nueva York, USA, 1986.
79. J. Biggs, *Calidad del aprendizaje universitario*, Narcea, Madrid, Spain, 2006.
80. G. Wiggins and J. McTighe, *Understanding by Design*, Association for Supervision and Curriculum Development, Virginia, USA, 2005.
81. W. Blank and S. Harwell (eds), *Promising Practices for Connecting High School to the Real World*, University of South Florida, Tampa, FL., 1997, pp. 15–21.
82. K. P. Dickinson, S. Soukamneuth, H. C. Yu, M. Kimball, R. D'Amico and R. Perry, *Providing Educational Services in the Summer Youth Employment and Training Program. Technical Assistance Guide*, Office of Policy and Research, Employment and Training Administration, Washington, D.C., 1998.
83. G. Bottoms and L. D. Webb, *Connecting the Curriculum to "Real Life". Breaking Ranks: Making it Happen*, National Association of Secondary School Principals Reston, USA, 1998.
84. H. S. Barrows, A Taxonomy of Problem-Based Learning Methods. *Medical Education*, **20**(6), 1986, pp. 481–486.
85. W. M Butler, J. P. Terpenny, R. M. Goff, R. S. Pant and H. M. Steinhauer, Improving the aerospace capstone design experience through simulation based learning, *International Journal of Engineering Education*, **28**(2), 2012, pp. 492–500.
86. M. Garrett, L. Schoener and L. Hood, Debate: a teaching strategy to improve verbal communication and critical-thinking skills, *Nurse Educator*, **21**(4), 1996, pp. 37–40.
87. S. Wassermann, *El estudio de casos como método de enseñanza*, Amorrortu Editores, Buenos Aires, Argentina.
88. J. Arter, *Curriculum-Referenced Test Development Workshop Series, Addendum to Workshops Two and Three: Using Portfolios in Instruction and Assessment*, Northwest Regional Educational Laboratory, Portland, USA, 1990.
89. C. Danielson and L. Abrutyn (1997). *An Introduction to Using Portfolios in the Classroom*, Association for Supervision and Curriculum Development, Virginia, USA, 1997.
90. H. Azh, Evaluation of midwifery students in labor and delivery training: comparing two methods of logbook and checklist, *Iranian Journal of Medical Education*, **6**(2), 2006, pp. 123–128.
91. F. A. Korthagen, Linking reflection and technical competence: The logbook as an instrument in teacher education, *European Journal of Teacher Education*, **22**(2–3), 1999, pp. 191–207.
92. R. Mayer and F. Ouellet, *Métodologie de recherche pour les intervenants sociaux*, Gaëtan Morin Éditeur, Boucherville, Canada, 1991.
93. I. Mohedas, S. R. Daly and K. H. Sienko, Design ethnography in capstone design: Investigating student use and perceptions, *International Journal of Engineering Education*, **30**(4), 2014, pp. 888–900.
94. S. J. Taylor and R. Bogdan, *Introducción a los métodos cualitativos de investigación*, Paidós, Barcelona, Spain, 1987.
95. A. Osborn, *Applied Imagination: Principles and Procedures of Creative Thinking*, Charles Scribner's Sons, New York, USA, 1953.
96. N. Roozenburg and J. Eekels, *Product Design: Fundamentals & Methods*, Wiley, Chichester, UK. 1995.
97. B. Wilkins, *Facilitating online learning: training ta's to facilitate community, collaboration, and mentoring in the online environment* (M.Sc. thesis), Brigham Young University, Utah, USA, 2002.
98. F. R. Shaftel and G. A. Shaftel, *Role-Playing for Social Values: Decision-Making in the Social Studies*, Prentice-Hall, New Jersey, USA, 1967.
99. R. Jinks, Developing experimental skills in engineering undergraduates, *Engineering Science and Education Journal*, **3**(6), 1994, pp. 287–290.
100. B. Jacoby, *Service-Learning in Higher Education.* Jossey-Bass, San Francisco, USA, 1996.
101. D. E. Schaad, L. P. Franzoni, C. Paul, A. Bauer and K. Morgan, A perfect storm: Examining natural disasters by combining traditional teaching methods with service-learning and innovative technology, *International Journal of Engineering Education*, **24**(3), 2008, 450–465.
102. J. Boehrer and M. Linsky, Teaching with Cases: Learning to Question, in M. Svinick (ed), *The Changing Face of College Teaching. New Directions for Teaching and Learning*, Jossey-Bass, San Francisco, USA, 1990.
103. J. Moran, *Queuing For Beginners: The Story of Daily Life From Breakfast to Bedtime*, Profile Books, London, UK, 2007.
104. S. T. Boghici and C. Boghici, C. The Interactive Methods and Techniques Stimulating Creativity-Crucial Components of the Didactic Strategies, *Bulletin of the Transilvania University of Braşov. Series VIII: Performing Arts*, **6**(2), 2013, pp. 23–28.
105. M. Delgado and A. Solano, Estrategias Didácticas Creativas en Entornos Virtuales para el Aprendizaje, *Actualidades Investigativas en Educación*, **9**(2), 2009, pp. 1–21.
106. J. M. Walker and P. H. King, Concept Mapping as a Form of Student Assessment and Instruction in the Domain of Bioengineering, *Journal of Engineering Education*, **92**(2), 2003, pp. 167–178.
107. T. Buzan, *Cómo crear mapas mentales*, Ediciones Urano S.A., Barcelona, Spain, 2002.
108. K. A. Smith, (1995). Cooperative learning: effective teamwork for engineering classrooms, *Proceedings Frontiers in Education 1995 25th Annual Conference. Engineering Edu-*

cation for the 21st Century, Atlanta, USA, 1 November 1995, pp. 2b5.13–2b5.18.
109. D. W. Johnson and R. Johnson, *Cooperation and competition: Theory and researc*, Interaction Book Company, Edina, USA, 1989.
110. D. M. Ogle, KWL: A teaching model that develops active reading of expository text, *The Reading Teacher*, **39**(6), 1986, pp. 564–570.
111. M. Portmann and S. Easterbrook, PMI: Knowledge elicitation and De Bono's thinking tools, in T. Wetter, K. Althoff, J. Boose, B. Gaines, M. Linster, F. Schmalhofer (eds), *Current Developments in Knowledge Acquisition—EKAW* '92, vol. 599, Springer, Berlin, Heidelberg, pp. 264–282.
112. D. B. Young and P. Tamir, Identifying what students know, *Science Teacher*, **44**(6), 1977, pp. 26–27.
113. P. Tamir and R. Amir, Retrospective curriculum evaluation: An approach to the evaluation of long-term effects, *Curriculum Inquiry*, **11**(3), 1981, pp. 259–278.
114. I. Iglesias (1999). La creatividad en el proceso de enseñanza-aprendizaje de ele: caracterización y aplicaciones, *Actas del X Congreso Internacional de ASELE*, Cádiz, Spain, 22 September 1999, pp. 941–954.
115. J. D. Novak and D. B. Gowin, *Learning How to Learn*, Cambridge University Press, Cambridge, UK, 1984.
116. D. B. Gowin and M. C. Alvarez, *The Art of Educating with V Diagrams*, Cambridge University Press, Cambridge, UK, 2005, pp. 17–19.
117. J. S. Bruner, Some elements of discovery, in L. Shulman and E. Keislar (eds), *Learning by Discovery: A Critical Appraisal*, Rand McNally & Co, Chicago, USA, 1966, pp. 101–113.
118. A. C. Estes, R. W. Welch, S. J. Ressler, N. Dennis, D. Larson, C. Considine, T. Nilsson, R. J. O'Neill, J. O'Brien and T. Lenox, Ten years of ExCEEd: Making a difference in the profession, *International Journal of Engineering Education*, **26**(1), 2010, pp. 141–154.
119. F. Hasson, S. Keeney and H. McKenna, Research guidelines for the Delphi survey technique, *Journal of Advanced Nursing*, **32**(4), 2000, pp. 1008–1015.
120. G. Brown and M. Atkins, *Effective Teaching in Higher Education*, Routledge, London, UK, 1988.
121. T. Ward, De Auguste Comte a Émile Zola: la teoría literaria modernista de Manuel González Prada. *Bulletin of Spanish Studies*, **87**(4), 2010, pp. 485–508.
122. M. Pickering, Reviewed Work: Auguste Comte, an Intellectual Biography, *Archives de Philosophie*, **2**(3), 2011, pp. 320–322.
123. L. Lacroix, *La sociologie d'Auguste Comte*, Presse Universitaires de France, Paris, France, 1956.
124. S. Bernatene, M. B. Dall'Aglio and M. B. Sbrancia, *De la teoría a la práctica en J.S. Mill*, Universidad del Cema, Buenos Aires, Argentina, 2004.
125. W. J. Ashley, *Introducción a los Principios de economía política de John Stuart Mill*, Fondo de Cultura Económica, Ciudad de México, México, 1996.
126. J. Skorupski, *John Stuart Mill*, Routledge, London, UK, 1983.
127. C. Chadwick, *Teorías del aprendizaje para el docente*, Editorial Universitaria, Santiago, Chile, 1983.
128. J. J. Muntaner, *Consecuencias didácticas de la Teoría de J. Piaget*, Universidad de las Islas Baleares, Mallorca, Spain, 1988.
129. A. M. Anguiano, A. L. Clavo, C. Plascencia, A. Ruíz, E. García and R. Guerra, Andragogía, aprendizaje colaborativo y cooperativo. Intervención de Trabajo Social, *Margen–Periódico Digital de Trabajo Social y Ciencias Sociales*, **48**, 2008.
130. C. Coll, Constructivismo y educación escolar: ni hablamos siempre de lo mismo ni lo hacemos siempre desde la misma perspectiva epistemológica, *Anuario de Psicologia*, (69), 1996, pp. 153–178.
131. R. Baquero, A. Camilloni, M. Carretero, J. Castorina, *Debates Constructivistas*, Aique Grupo Editor S.A., Buenos Aires, Argentina, 1998.
132. C. Tünnermann, El constructivismo y el aprendizaje de los estudiantes, *Universidades*, **61**(48), 2011, pp. 21–32.
133. J. D. Novak, (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners, *Science Education*, **86**(4), 2002, pp. 548–571.
134. M. L. Rodríguez, *La teoría del aprendizaje significativo en la perspectiva de la psicología cognitiva*, Octaedro, Barcelona, Spain, 2008.
135. A. B. Cálciz, Metodologías activas y aprendizaje por descubrimiento, *Revista Innovación y Experiencias Educativas*, (40), 2011, pp. 1–11.
136. B. Restrepo, Aprendizaje basado en problemas (ABP): una innovación didáctica para la enseñanza universitaria, *Educación y Educadores*, **8**, 2005, pp. 9–19.
137. K. Takaya, Jerome Bruner's Theory of education: from early Bruner to later Bruner, *Interchange*, **39**(1), 2008, pp. 1–19.
138. I. R. Rojas, Theodor W. Adorno y la Escuela de Frankfurt, *Convergencia, Revista de Ciencias Sociales*, **6**(19), 1999, pp. 71–86.
139. D. Mora, Pedagogía y Didáctica Crítica para una Educación Liberadora, *Pedagogía y Didáctica Crítica*, **2**(1), 2009, pp. 25–60.
140. B. Solares, La teoría de la acción comunicativa de Jürgen Habermas: tres complejos temáticos, *Revistas UNAM*, **41**(163), 1996, pp. 9–33.
141. J. Kim and E. Kim, Theorizing Dialogic Deliberation: Everyday Political Talk as Communicative Action and Dialogue, *Communication Theory*, **18**(1), 2008, pp. 51–70.
142. S. Miedema, The Relevancefor Pedagogy of Habermas' "Theory of Communicative Action", *Interchange*, **25**(2), 1994, pp. 195–206.
143. A. Latorre, A. Gómez and L. Engel, Metodologia comunicativa crítica, transformació i inclusió social, *Temps d'Educació*, (38), 2010, pp. 153–165.
144. R. Flecha and I. Tellado, Metodología Comunicativa en Educación de personas adultas, *Cadernos Cede*, **35**(96), 2015, pp. 277–288.
145. L. J. Shuman, M. Besterfield-Sacre and J. McGourty, The ABET "Professional Skills"—Can They Be Taught? Can They Be Assessed?, *Journal of Engineering Education*, **94**(1), 2005, pp. 41–55.
146. E. Forcael, S. Vargas, A. Opazo and L. Medina, Role of the Civil Engineer in the Contemporary Chilean Society, *Revista de la Construcción*, **12**(2), 2013, pp. 72–87.
147. E. F. Crawley, J. Malmqvist, W. A. Lucas and D. R. Brodeur, The CDIO syllabus v2.0. An updated statement of goals for engineering education, *Proceedings of 7th International CDIO Conference*, *Copenhagen, Denmark*, 20 June 2011.
148. K. Bryden, K. P. Hallinan and M. F. Pinnell, A Different Path to Internationalization of Engineering Education, *32nd ASEE/IEEE Frontiers in Education Conference*, 6 November 2002, Boston, MA, p. S4B-2.
149. E. Graaff, S. Saunders-Smits and M. Nieweg (eds), *Research and practice of active learning in engineering education*, Pallas Publication—Amsterdam University Press, 2005.
150. C. J. Finelli, S. R. Daly and K. M. Richardson, Bridging the Research-to-Practice Gap: Designing an Institutional Change Plan Using Local Evidence, *Journal of Engineering Education*, **103**(2), 2014, pp. 331–361.
151. Accreditation Board for Engineering and Technology (ABET), *Criteria for accrediting engineering programs, 2017–2018*, http://www.abet.org/wp-content/uploads/2015/11/Proposed-Revisions-to-EAC-Criteria-3-and-5.pdf, Accessed 4 October 2017.

Eric Forcael is an Associate Professor in the Department of Civil and Environmental Engineering at the Universidad del Bío-Bío, Chile. He earned his BS in Civil Engineering from the Universidad del Bío-Bío, Chile, his MBA from the Universidad Politécnica de Madrid, Spain, and his MS and PhD in Civil Engineering from the University of Florida, USA.

His research interests include modeling and simulation in construction and civil engineering, and engineering education. His work has been published in high impact journals including Computer-Aided Civil and Infrastructure Engineering, Journal of Construction Engineering and Management, and Journal of Professional Issues in Engineering Education and Practice.

Gonzalo Garcés is a Research Assistant in the Department of Civil and Environmental Engineering at the Universidad del Bío-Bío, Chile. As a Civil Engineer (PE), he received a BS in Civil Engineering from the Universidad del Bío-Bío, Chile. His main research topic is engineering education. He is currently working, as a member of the Editorial team, on the first volume of a Latin American journal in engineering education and practice, sponsored by the College of Engineering at the Universidad del Bío-Bío, Chile.

Peter Backhouse is an Associate Professor in the Department of Industrial Engineering at the Universidad del Bío-Bío, Chile. He earned his BS in Mechanical Engineering from the Universidad de Concepción, Chile, his Master in Industrial Engineering from the Pontificia Universidad Católica, Brazil, and his PhD in Higher Education Management from the Universidad Pablo de Olavide, Spain. His research interests include engineering education, university management, and quality assurance in higher education. His research results have been presented and published in different congresses and journals.

Elena Bastías is a Researcher in the Pedagogical and Curriculum Development Unit at the Universidad del Bío-Bío, Chile. She holds a BEd and a MEd in Curriculum Assessment from the Universidad Católica de la Santísima Concepción, Chile. Her research interests are teaching in higher education, and curriculum assessment. Since 2008, her work has been presented and published in diverse congresses and conferences.