A Look-Back to Jump Forward: From an Ancient Innovation Culture to the Exploration of Emerging Pedagogies in Engineering

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Abstract. From its inception, Universidad de Ingeniería y Tecnología (UTEC) has had the vision of causing a disruptive change in society by educating a new generation of holistic engineers. The university has recently embarked on a radical transformation of its educational model, in order to deliver its promise. A flexible curriculum provides students not only with a strong STHEAM backbone imparted in a student-centered, active-learning format, but also exposes them to real engineering challenges and promotes the acquisition of professional skills from the onset. For this radical change to be implemented successfully, UTEC has decided to design and launch a Laboratory for Educational Innovation, called Moray. Moray has been conceived as an open platform, consisting of a common space and a set of protocols through which faculty, students, staff, and experts from top universities worldwide can work interdisciplinarily and collaboratively, towards the enhancement of learning experiences in higher education.

Keywords: Educational innovation · Engineering education
Emerging pedagogies · Student-centered teaching · T-shaped engineers

1 Introduction

The founders of Universidad de Ingeniería y Tecnología (UTEC) conferred one main mandate to both the university's administrative and academic teams: to cause a disruptive change in society by educating a new generation of holistic and T-shaped engineers. The university launched in 2012 as a non-for-profit organization under the premise of giving Peruvian youth access to a world-class and future-proof educational model in Engineering, regardless of each individual's socioeconomic status, and only dependent on his or her talent, disposition, creativity and intellectual capacity.

To be able to truly live up to this vision and deliver its promise to students and society at large, the university has recently embarked on a radical transformation of its educational model. It has now instituted a more flexible and project-based curriculum, that provides students not only with a strong scientific, disciplinary and technical backbone, but also exposes them to "real life" engineering challenges, thus promoting the acquisition of professional skills from the very first day. All of the content transmission and

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skill-building dynamics are carried out in student-centered, active-learning formats that promote student engagement and the development of intrinsic motivation. This structural change should create the conditions for the formation of the T-shaped professionals the world is in such high demand for.

Furthermore, in order to facilitate the "structural re-engineering" of the traditional engineering program and a successful implementation, UTEC has decided to launch a Laboratory for Educational Innovation named "Moray", after an archeological site in Cusco, Peru, which is considered to have been a controlled environment for hydraulic and agricultural experimentation for the Inca civilization. This paper describes the design and implementation process of this laboratory, whose main purpose is to provide faculty with the training and support before, throughout and beyond this change process.

2 Background and Motivation

The learning sciences have significantly evolved in the last few decades, highlighting the deficiencies in traditional Engineering Education [1]. Diverse entities have told Engineering Schools across the globe that they should, on the one hand, strengthen and widen the scope of the fundamental sciences; and on the other, expose students to real-world engineering challenges, develop in them effective communication and teamwork skills, and also cultivate critical and ethical thinking [2]. All of this while reducing the number of hours in the curriculum, to allow most students to graduate in time. Traditional Engineering Education and its unrevised teaching methodologies cannot, as the record shows, fulfill these great expectations [1]. Today we count on proven theories on the science of learning (i.e. how people learn in a pedagogically-sound and relevant manner) and on the science of instruction (i.e. how teachers or mentors should help students learn), based on cognitive theory and neuroscience [3]. There is now an almost unanimous agreement that people learn by doing, experiencing and reflecting on the results, whereas they absorb and retain a rather small fraction of what they see and hear in a lecture format [4].

In addition, the digitalization of information and telecommunications has revolutionized the processes of knowledge production and transference. The mission of universities is to prepare their students for a modern professional career, encouraging them to actively engage with advanced technologies and develop functional skills in relation to new media, so that they can successfully integrate themselves into a society increasingly organized around these [5, 6]. Such developments have given rise to new scenarios of academic training, contents and processes of teaching and learning [7]. As a consequence, the adoption of a student-centered educational focus has led academic institutions to redefine the dynamics of teaching and learning that had previously been confined, predominantly, to the traditional classroom [8].

In view of these advancements in the learning sciences and the digital revolution, last year, and one year before graduating the first class, UTEC's higher administration and the Board of Directors decided to embark on a root-and-branch reform to be aligned with these changes and to ensure the preparation of holistic and T-shaped engineers. This disruptive change is embodied in what is now known as UTEC's Educational Model

(UEM), which in turn aims at ensuring that our students attain five main competencies. We consider these competencies necessary to truly become the holistic engineers that Peru and the world require:

1. Deep technical, disciplinary and interdisciplinary knowledge
2. Analytical reasoning and critical thinking for complex problem solving
3. Communication and collaboration skills across disciplines and cultures
4. Ability and will to lead the innovation and change processes
5. Ethical and socially responsible thinking and doing, both on a local and global basis

In short, UEM seeks to educate global professionals, able to understand, disaggregate and solve complex problems in a creative, innovative and ethical way; and communicate these solutions effectively. The model is highly student-centered and aims at awakening and empowering students' intrinsic motivation to deeply learn and arise with new solutions to the world's most pressing challenges. At UTEC, we believe that learning in a transdisciplinary and contextualized fashion and in connection with the real world, alongside the most important local and global industries, is a richer and more effective means for developing our students into adaptable, lifelong, flexible learners and change agents.

In this context, Moray has been thought-out as an open platform, consisting of both a common space and a set of flexible protocols through which faculty, students, staff and experts from top universities around the world can work interdisciplinarily and in a collaborative manner, towards the enhancement of teaching and learning dynamics and experiences both inside and outside UTEC's classrooms, fully embracing and harnessing the digitalization of the educational world. Moray crystallizes the innovative culture embedded in UTEC's DNA. This culture of innovation was, as mentioned before, first given as a mandate by UTEC's founders. It was later incorporated as one of three constitutive pillars – research, entrepreneurship, and educational innovation- during the university's design phase. Currently, it lies at the very core of the new educational model. This culture promotes experimentation, fosters a code of radical openness, is data-driven, and understands "failure" as something to be learned from and as an important step towards continuous improvement. Just like the Incas utilized Moray and its terraced depressions in concentric circles as an experimentation and testing station, the new curricular reform within UTEC has in the Educational Innovation Laboratory a platform from which to launch and monitor new initiatives. These initiatives can range from implementing technology-enhanced learning experiences to redesigning the underlying skill-building and knowledge-transfer activities, all of these with the objective of creating deep learning experiences in our students.

3 Design Process

The first step in the design process consisted of an initial (and mostly theoretical) benchmarking analysis, which allowed us to determine the key success factors for constituting an Educational Innovation Laboratory. Ten countries -USA, UK, Finland, Australia, Singapore, Korea, Uruguay, Colombia, Chile and Mexico- were covered in this analysis.

From the observations, it soon became clear that Moray had to become an overlay of physical and virtual spaces, serving as a focal point for the different actors and stakeholders of UEM. It had to be based on the following principles:

1. Be founded on a co-working and collaboration philosophy, a "radical openness" code of conduct and be staffed with a multi-disciplinary team, in order to eradicate blind spots and create communities and networks beyond the physical space or the confinement of the university.
2. Be user-centered (in this case, student-centered) and ensure the engagement of all actors within the ecosystem. The students should be co-creators of the experiences and changes.
3. Behave as an incubator or accelerator of educational projects, implementing a culture of rapid prototyping, testing, iteration and continuous improvement; always aiming to scale and replicate successful projects in other -larger- contexts.
4. Be research-based and data-driven as well as prone to incorporating new technologies and digital media into projects in order to communicate more efficiently, catalyze otherwise tedious processes, capture as much data as possible and produce relevant information models to guide the ulterior decision-making processes.
5. Provide constant mentoring and feedback to establish best practices that could later be effectively communicated to and shared with diverse audiences.

Taking these key principles into account, the following sequence of steps was pursued for the implementation of Moray:

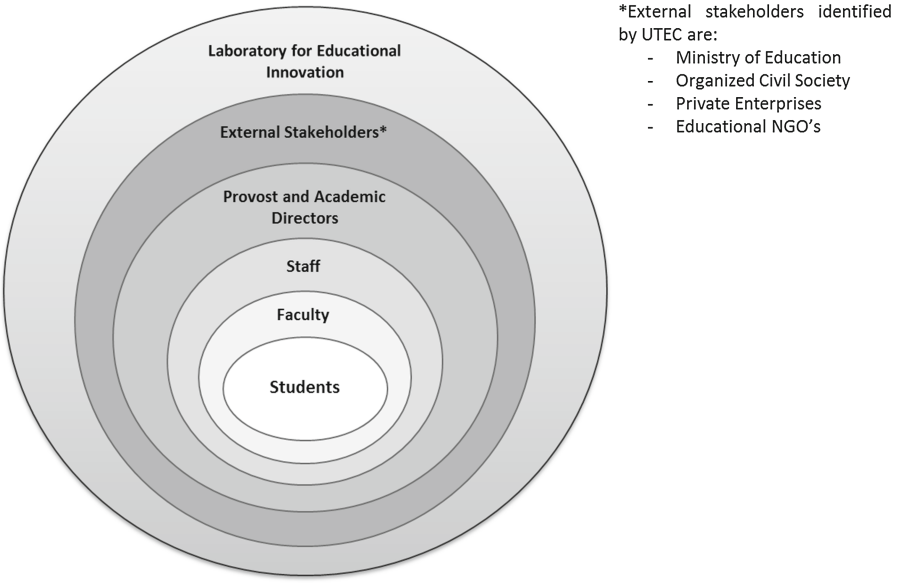

Fig. 1. Onion Map showing the different stakeholders that are being brought together by the Laboratory for Educational Innovation. At the heart of the map are UTEC students, whose experience of the new UEM is critical when it comes to orienting the Laboratory's efforts.

1. Identification of main stakeholders and possible contributors, participants and collaborators. The first step consisted of appointing the Director for the Laboratory, who would plan and supervise the initial and all subsequent processes in the establishment and governance of Moray. Moray is now being led by the Director of Educational Innovation and Quality at UTEC, and supported by two Coordinators (for Educational Quality and Digital Innovation) and two interns. In addition to the permanent staff, the champions (i.e. change leaders) and ambassadors within the organization were identified early on in the curricular transformation process, sent to specific "train-the-trainers" workshops and are now an integral part of the Laboratory. Furthermore, UTEC's Provost and the Heads of Departments have contributed to the design and launch, and now collaborate with Moray on a regular basis (Fig. 1).
2. *In-situ* contrasting of benchmarking analysis. After having carried out the benchmarking analysis based on available literature, an important step was to corroborate our theoretical findings on-site. Thus, Moray's Director and UTEC's Provost embarked on a journey that allowed for the exchange of ideas with the leaders of the most reputable Teaching and Learning Laboratories around the world (USA, UK, Denmark, Sweden, Finland, and Netherlands) and also hosted such leaders at UTEC. The main goal of these visits was to procure intensive knowledge-transfer dynamics and a bi-directional sharing of good practices with these experts.
3. Development of a strategic plan, with clear objectives, prioritized tasks, responsibilities and success metrics (Fig. 2).
   This strategic planning process had to take into account the following aspects:
   (a) Main activities: the initial focus areas would determine the activities to be developed and would take into account existing gaps and available resources. These would range from pedagogical workshops, rapid prototyping with sharebacks, presentations, one-on-one sessions, co-teaching dynamics, peer reviews, faculty exchange programs, content production (such as consolidating a problems/challenges bank), portfolio building, among others.
   (b) Personnel: the focus areas of the personnel would be based on the main educational themes and problems that the Laboratory would be focusing on with the option of calling in external talent for pedagogical consultancies.
   (c) Space: the focus areas and main functions of the Laboratory would also determine the type of space needed. Aspects to take into consideration here include location, flexibility of the given space, and the atmosphere to be created with the furniture, equipment and lighting.
   (d) Budget: the budget should be divided into four main pillars: personnel, equipment and tools, space, and operating costs by project.
4. Selecting and launching pilot project(s) that should evaluate the possible benefit to the final user and describe the concrete strategy to attain an objective. In this phase, it was important to ensure that the innovation served as enough of a proof of concept to merit the scale-up; otherwise, more pilot projects or prototypes would be necessary.

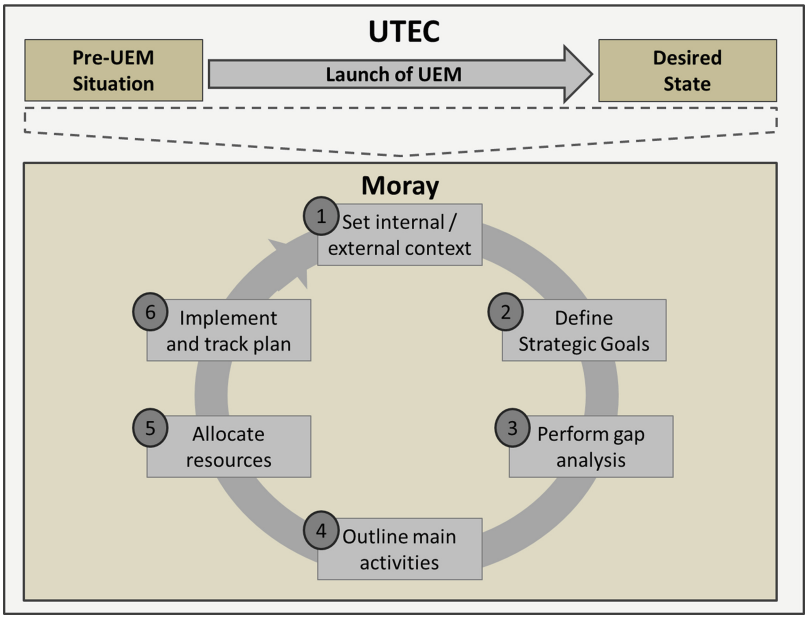

Fig. 2. Moray's strategic planning process as key support for the implementation of UEM. The benchmarking analysis and internal diagnosis (step 1) led to the definition of goals (step 2) and a follow-on gap analysis (step 3). The initial main activities (i.e. pilot projects) were focused on bridging these gaps (step 4) and were planned carefully by allocating the necessary resources to attain quick wins (step 5). The final step (6) consisted of implementing the initial plan and tracking the impact and results on the implementation of UEM. The process is iterative for continuous improvement of Moray and UEM at large.

4 Preliminary Results

To mention a few pilot projects, each faculty member has already been tasked with revising and redesigning his/her course, taking into account and introducing the newest tools and methodologies to foster student engagement, motivation, knowledge-transfer and long-term retention. In addition, UTEC's higher academic administration has created multi-disciplinary task-forces for the development or re-design of the different core courses (i.e. calculus, physics, chemistry, computer science, and communications), to ensure that foundational needs are being met. These faculty members gather at Moray every Friday for the "F3 - Faculty Feedback Fridays" meetings, a roundtable discussion and feedback session that aims at aligning on the overall objectives, iterating and improving these critical courses on the go.

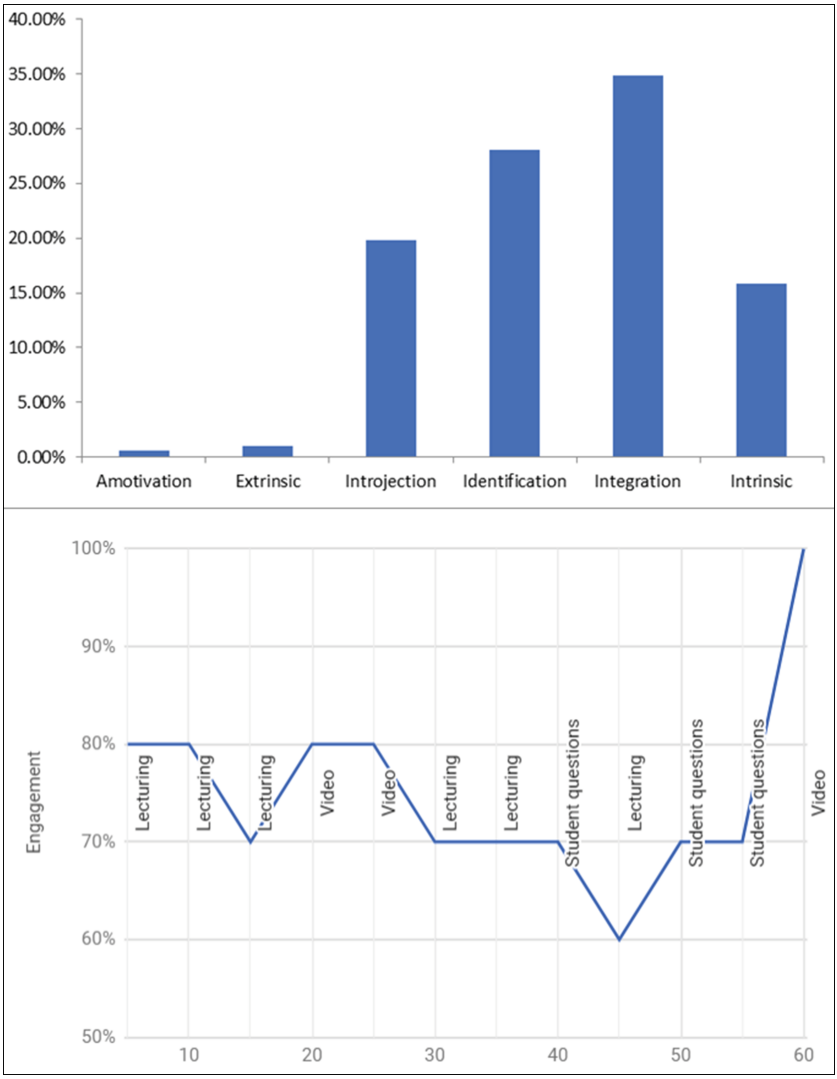

Fig. 3. Samples of data dashboards illustrating the level of achievement of two UEM-specific goals: student motivation, as accounted for by the students themselves through a student perception survey (top graph), and student engagement during classes as per an adaptation of The Classroom Observation Protocol for Undergraduate STEM [9] (COPUS; bottom graph).

The Laboratory has also launched a "Fellows Program" that chooses and supports 3-4 faculty members throughout a semester to backwards-design and innovate either the entirety of their courses or a significant portion of them, based on hand-picked literature that is read and discussed in an applied and reflective manner. Additionally, Moray is conducting several data-gathering assessments and surveys with both students and faculty. For instance, it is disseminating a student survey at two points during the term,

to measure motivation, relatedness, autonomy, perception of competence and overall satisfaction with each course (Fig. 3). A rigorous classroom observation protocol has also been implemented to allow the Laboratory to capture the level of student engagement during classes, which is regarded as a direct reflection of the teacher's ability to implement emerging pedagogies successfully. In addition, Moray's staff is holding regular focus groups with faculty, staff and students, to identify areas of development and continuous improvement for UTEC as a whole.

Moray has already organized two main faculty-wide, week-long teaching and learning workshops to prepare each and every member of the academic department for the new educational approach. The faculty will continue to have several training opportunities offered by external experts in the field of emerging pedagogies, as well as receive scientific literature, research papers and other tools and resources each week, which can be reviewed individually and later discussed at Moray's Journal Club. Finally, UTEC's faculty is also encouraged to work across-fields at Moray, to devise new transdisciplinary content and explore co-teaching opportunities. Some of these initiatives have already been rolled out; examples include courses like Art and Technology, Geopolitics of Water, and Global Challenges. These courses are meant to be a platform for students to approach a specific topic from different disciplinary perspectives while making sense of these diverse approaches as a whole.

The Laboratory is also designing new classroom spaces that are more suited to promote collaboration and creative thinking than a traditional classroom format, replacing the layout, equipment, and furniture which correspond to the "sage on the stage" model, with a new set-up that instead sparks a "guide on the side" take on didactic practices [10]. In addition, Moray has also been involved in the re-shaping and re-tasking of some areas within our campus to facilitate the "design-build-implement-test" process in proper engineering workspaces [11]. Accordingly, UTEC now has a large workspace, called UTEC Garage, where students gather, exchange ideas, think them through in a hands-on approach and test them in a safe environment (Fig. 4). Likewise, UTEC's FabLab allows students to 3D-print and prototype any idea very quickly, under the guidance of experts in relevant fields. More advanced ideas that have been matured over several semesters will have the chance to be incubated in UTEC's very own business accelerator, UTEC Ventures. The university also holds over 30 laboratories with different field-specific resources and equipment that are open to students and faculty for research projects or prototyping exercises. All these spaces are thought to be spatial extensions of Moray and work in close interaction with this Laboratory.

Finally, and as an umbrella program to all these initiatives, Moray has adapted and is piloting a framework for the evaluation of teaching achievement that has been put forth as part of a study commissioned by the Royal Academy of Engineering (RAE) to a leading pedagogical consultancy. This Career Framework for University Teaching [12], proposes a standardized and transparent -therefore, portable- method for evaluating and evidencing teaching achievement. The metrics proposed by the Framework have been designed with input from sixteen universities from around the globe -one of them being UTEC- and is already being used here to evaluate teaching performance at different stages: appointment, promotion and professional development. At Moray (and UTEC at large), we view this change in mindset and focus on teaching and learning (as

Fig. 4. UTEC Garage as a MakerSpace lying at the heart of Moray. This 250 m^2-large space is open around the clock to allow students, faculty and external people to gather in groups and develop prototypes of different fidelities for their diverse projects. It is also a space for transdisciplinary workshops and roundtable discussions

opposed to mainly on research performance) as instrumental for the success of the new educational model.

5 Conclusions and Future Work

UTEC has embarked on a major transformation of its education model, to fulfill its promise of causing a disruptive change in society through the education of a new generation of engineers. This new model is based on two main, interrelated pillars: a novel curricular structure and a teaching and learning–focused Faculty Development Model. We truly believe that the early adoption, enthusiasm and active participation of the faculty in this transformation have been catalyzed by the fact that the Faculty Development Model was designed and is being launched simultaneously with UEM. It helped faculty understand and make sense of the process and allowed them to grasp the need and the sense of urgency for a shift from a highly research-focused to a holistic perspective, which truly values teaching/mentoring – and rewards them accordingly. One of the main early findings from our design and implementation process was that faculty needs to be involved from the initial stages, be part of the change process and be supported throughout. That is how the idea of Moray, UTEC's own Educational Innovation Laboratory, was born. Having both a physical and digital space, dedicated personnel and a clear strategic plan for the implementation and change management process underlying the UEM, clearly helped all the involved parties align with the overall goal.

Today, Moray is already fulfilling the promise of serving as an open platform for UTEC and the higher education community to design and test innovative pedagogical initiatives in order to improve engineering education in Peru. There are five foundational competencies that have shaped the new educational model at the university. How to help students develop these throughout their experience at UTEC has been the guiding question and the connecting thread to which this model is the answer. Every course targets specific skills that are meant to percolate to a variety of other topics and that are meant to be exercised by students and translated into a wide range of contexts of practical application. Therefore, we expect students to be able to connect the dots between their engineering education and the complexity of the world they will face as professionals, which will demand from them the ability to navigate scenarios where leadership, ethical behavior, and teamwork, among other skills, will be crucial. Faculty at UTEC are the key players for this model to be implemented successfully and Moray should continue its path toward becoming the underlying support system for them to feel backed, motivated and empowered throughout and beyond this process.

A challenge that is yet to be resolved is finding the appropriate physical location for Moray. We have a temporary space at UTEC, but it doesn't present the necessary features we believe will help spark the disruptive atmosphere that is so necessary in an innovation laboratory. Furthermore, additional work is yet to be done regarding metrics to measure Moray's impact on the change management process and on the implementation of the educational model. To this means, the Laboratory needs to continue conducting focus groups, interviews and surveys with both students and faculty, to assess the level of satisfaction with and support perceived from Moray through the preparation, launch and implementation of UEM. Also, other ICT-driven processes such as the integration of additional tools and resources (our recently purchased smart-boards, VR equipment, 360° gear, augmented reality modules and "Clickers"), the path toward a blended or inverted model of instruction, and a more powerful drill-down on Business Intelligence tools to increase student retention rates need to be assessed by Moray. All of this in order to make sure technology is properly leveraged so as to enable student-centered learning. Finally, Moray's role in integrating the initiatives of UTEC's Finance and IT departments to think about and prepare for the future of education in new media and digital formats needs to be further assessed.

References

1. Besterfield-Sacre, M., Cox, M.F., Borrego, M., Beddoes, K., Zhu, J.: J. Eng. Educ. **103**, 193 (2014)
2. Felder, R.M.: **34**, 238 (2000)
3. Ambrose, S.A., Lovett, M., Bridges, M.W., Dipietro, M., Norman, M.K.: How Learning Works: Seven Research-Based Principles for Smart Teaching, San Francisco, CA (2010)
4. Felder, R.M., Woods, D.R., Stice, J.E., Rugarcia, A.: Chem. Eng. Educ. **34**, 26 (2000)
5. Claro, M.: La Incorporación de Tecnologías Digitales En Educación. Modelos de Identificación de Buenas Prácticas, Santiago de Chile (2010)
6. Khazaal, H.F.: J. Coll. Teach. Learn. **12**, 1 (2015)
7. Correa, J.M., De Pablos, J.: Rev. Psicodidáctica **14**, 133 (2009)

8. Santiago Campión, R., Navaridas Nalda, F., Andía Celaya, L.A.: Estud. Sobre Educ. **30**, 145 (2016)
9. Smith, M.K., Jones, F.H.M., Gilbert, S.L., Wieman, C.E.: CBE-Life Sci. Educ. **12**, 618 (2013)
10. King, A.: Coll. Teach. **41**, 30 (1993)
11. Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D.R., Edström, K.: Rethinking Engineering Education: The CDIO Approach. Springer, Cham (2014)
12. Graham, R.: Template for Evaluating Teaching Achievement, London (2016)