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Editorial

CROSS-SECTIONAL COMPETENCES IN ENGINEERING: AN APPROACH FROM THE PRINCIPLES OF GAMIFICATION

COMPETENCIAS TRANSVERSALES EN INGENIERÍAS: Una aproximación desde los principios de gamificación

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Abstract: Research on gamification has seen a growing trend in the last decade, withapplications of principles and elements of the game in non-recreational environmentsto motivate learning at different educational levels, from elementary school to businessenvironments. Given the potential of these strategies to make structural changes insideand outside the classroom, this research applies the gamification principles proposed byNoran (2016), for the design and prototyping of a gamified tool, which transversallysupports the teaching and learning processes in an engineering college. For this, thiswas done with 121 students and 166 graduates who participated in prioritizing relevantskills for engineers. The results indicate three priority skills for this exercise: 1) acquirenew knowledge and use it effectively, 2) identify and solve engineering problems, and 3)PANORAMA, 2021, vol. 15, núm. 28, Enero-Junio, ISSN: 1909-7433 / 2145-308XPDF generado a partir de XML-JATS4R por RedalycProyecto académico sin fines de lucro, desarrollado bajo la iniciativa de acceso abiertowork as a team. In addition, the tool was designed with three gamified games that seekto reinforce prioritized transversal skills

Keywords: Teaching, learning, gamification, competences, motivation.

Resumen: La investigación sobre gamificación reviste una tendencia creciente en laúltima década, con aplicaciones de principios y elementos propios del juego en ambientesno lúdicos para motivar el aprendizaje a diferentes niveles educativos, desde básicaprimaria, hasta entornos empresariales. Dado el potencial de estas estrategias pararealizar cambios estructurales dentro y fuera del aula, esta investigación aplica losprincipios de gamificación propuestos por Noran (2016), para el diseño y prototipadode una herramienta gamificada, que apoye transversalmente los procesos de enseñanza yaprendizaje en una facultad de ingeniería. Para ello se trabajó con 121 estudiantes y 166egresados que participaron en la priorizaron de competencias relevantes para ingenieros.Los resultados señalan tres capacidades prioritarias para este ejercicio: 1) adquirir nuevoconocimiento y usarlo eficazmente, 2) identificar y resolver problemas de ingeniería, y3) trabajar en equipo. Además, se diseñó la herramienta con tres lúdicas gamificadas quebuscan reforzar las competencias transversales priorizadas.

Palabras clave: Enseñanza, aprendizaje, gamificación, competencias, motivación, education, learning, skills.

1. INTRODUCTION

Games have existed since ancient times, they are related with human development and serve as tools for entertainment and as means to build relationships, to train other individuals and even as a means of survival (McGonigal, 2011). Nevertheless, the way we play radically changed with the appearance and consolidation of videogames, which have settled as one of the favorite modalities of leisure by people of all ages. In fact, the adoption of computer-based games has motivated its implementation in other areas and with other purposes, such as education. This aspect accelerated academic research on games as strategy to shape people's behavior in formal environments, such as industry and education, which in turn made way for a trend known as gamification (Acosta-Medina et al., 2020; Observatorio de Innovacion Educativa, 2016; Sailer et al., 2017).

In its most strict sense, gamification is defined as a technological tool with mechanics based on games, aesthetics and elements of play to engage people, encourage action, solve problems and promote learning (Bahji et al., 2013; Cozar & Saez, 2016; Sanmugam et al., 2015). The aim of gamification is to increase commitment, motivating users through techniques that resemble those used in games, such as scoreboards, rewards and quick and personalized feedback (Callaghan, 2016). Production of literature on gamification has significantly risen in the last decade, to the point that -nowadays- there is a polarized answer about its use and benefits, with some academics rejecting it as mechanism to support teaching and learning processes, others who explore it with interest, and others who incorporate it defending its efficacy (Callaghan, 2016; Pedroza et al., 2017; Soboleva et al., 2018). Anyway, gamification's popularity in education stems from its potential to engage and motivate students to participate in courses (Legaki & Assimakopoulos, 2018; Lobo-Rueda et al., 2020).

Higher education has not been oblivious to the context of gamification, it has adapted to the technical and social reality of its stakeholders and it has integrated ICT to the classroom, becoming a key driver for motivation, participation and creation of shared knowledge (Piñeiro-Otero & Costa-Sanchez, 2015), applying strategies such as gamification. In addition to this environment, there is a need to have teachers with pedagogical experience and trained in the use of ICT, who are capable of guaranteeing total and quality feedback in the gamification process (Becerra et al., 2017).

Thus, gamification strategies have a potential to be used in different areas of knowledge. This article explores the potential pertaining to cross-sectional competences in engineering, such as teamwork, solution of complex engineering problems, or the use of new knowledge as solution to real situations faced by engineers; these are formulated within a competence model with international recognition in the area of higher education.

2. THEORETICAL BASIS

2.1. Game and Human Beings

Games, challenges and competitions are engrained in human character, and thus, constitute a meaningful aspect of society's development. Throughout history, play and play therapy have been used to enhance the human condition (McGonigal, 2011; Nacke & Deterding, 2017). Game's concepts and mechanics have been used in different fields, including work (Fernandes et al., 2012), education (Landers, 2014), crowdsourcing (Mekler et al., 2017), data collection (Guin et al., 2012), health (Jones et al., 2014), marketing (Hamari, 2013, 2015), social media (Farzan & Brusilovsky, 2011), and protection of the environment (Gustafsson et al., 2009). In all of these contexts, gamification is expected to encourage certain behavior, such as motivation of the group of participants (Schunk & Mullen, 2012).

Games have taken different shapes depending on the area of application. For instance, in commercial or military areas, "serious game" (Jeana et al., 2018) is understood as a training tool that is based on computer devices. In marketing, the concepts of game may entail rewards, fidelity points and virtual currency that may be used in future purchases, strengthening the game's behavior. In education, there are two ways to apply games; the first is known as "game-based learning", which uses games or videogames as learning mechanisms (without necessarily being digital); and the second are "gamified courses", which try to engage students through the use of principles and elements that are typical of games with the aim of driving motivation amidst learning processes (Hsua et al., 2018; Observatorio de Innovacion Educativa, 2016; Sanmugam et al., 2015; Sousa & Rocha, 2019). In fact, for decades, teachers have used play mechanics in the classroom to encourage students and increase their interest and performance. An example of this situation is public recognition of students in class honor rolls; another example is fostering competition among students, challenging the development of an activity in a given timeframe.

Nowadays, with the success of digital games in the entertainment industry, gamification (applied in different contexts) is more likely to incorporate elements of games in learning situations. Also, advancements in information and communication technologies have provided a robust platform for the development of an evolving game industry and to further research about it, its effects and relevance in the framework of the current digital era (Noran, 2016; Seaborn & Fels, 2015; Stott & Neustaedter, 2013).

2.2. Competence-Based Models and its Role in the Job Market

The leap from an exclusive teaching-based approach to an approach based on the joint concept of "teaching-learning" has influenced a large percentage of programs in the past decades in higher education around the world (European Association for Quality Assurance in Higher Education -ENQA-, 2015), and in that sense, higher education institutions have modified their curriculums implementing competence-

based models, prioritizing the level of employability of their future graduates and shifting a teacher-centered approach for an approach centered on students and on desirable competences in the exercise of their profession (Barr & Tagg, 1995; IQM-HE, 2016).

This competence-based approach derives from fundamental social changes taking place, which comprise the way of living, how information is disseminated and how individuals relate to each other. As of today, there are numerous approaches to the concept of competition, at operationalization and measurement level (Blömeke et al., 2015). In this research, the term competence refers to a perspective that integrates cognitive and practical aspects at the same time (IQM-HE., 2016; Weinert, 2001), which are formulated depending on the context, using a medium level of abstraction. Accordingly, competences of citizens - university professionals in particular- must be related to communicative skills (Shamshina, 2014), and include competences in mathematics, scientific and technological culture (Zhurakovsky, 1997), information and digital treatment (Alam et al., 2018), competences to learn how to learn, social and citizen competences, personal autonomy and initiative, as well as competences in humanistic and artistic culture.

Although there are many classifications, there are two types of competences discernible in the academic field: specific and cross-sectional (see Table 1). "Specific competences are associated with concrete knowledge areas that require continuous training with different levels of intensity" (de Miguel, 2005, p.26). "Cross-sectional competences may be used in diverse situations in the professional sphere. Have been associated with the development of certain generic abilities put in practice and reused in other situations" (Safta, 2015. p.349).

N°	Basic Competences
1	Reading and writing competences
2	Competences in mathematic notions and in proficiency of basic concepts of science and technology
3	Competence in foreign languages
	Cross-Sectional Competences
4	An individual's overall capacity to adapt to a given situation, to give it a purpose being sensitive of its context.
5	An individual's skill to execute a task, his or her method, and the intellectual process that allow integrating knowledge and abilities to fulfill it.
6	Abilities and knowledge jointly put in practice, in the same scenario, making use of a capacity to manage the strong connection between the desire to solve the problem, its technical nature and previous skills amassed.

Table 1

Basic and Cross-Sectional Competences.

Source: taken from de Miguel (2005) and Safta (2015).

Cross-sectional competences are considered fundamental to incorporate individuals to the job market, they play a key role in social cohesion and are crucial for citizens' active exercise (Afriat et al., 2006), to the point that, in the European Union, Member States have been advised to include promotion and development of said policies in their national education policies. In other countries in Latin America, such as Colombia, Brazil, and Argentina, the competence-

based model is also enforced by government organizations. In the US, models of international accreditation have been devised based on competences, with cross-sectional competences playing an essential role (ABET, 2016; Koehn & Parthasarathy, 2005). This relevance makes sense when thinking about the fact that in a mature and well-developed job market, with geographic mobility conditions, an individual's cross-sectional competences may be used regardless of position or functions in a given moment in time, and can be taken from one job to another if needed, having an undeniable impact on the employability index.

2.3. ABET Competences

ABET (Accreditation Board of Engineering and Technology) is an international organization that accredits university programs in applied and natural sciences, computing, engineering and engineering technology (ABET, 2016; Koehn & Parthasarathy, 2005). The ABET model "comprises the development of skills, abilities and knowledge that students acquire as they make progress in their chosen program and are expected to be put in practice when they graduate" (Morales, 2018, p.28). The competences in the ABET model are summarized in Table 2.

	Competences
A	Capacity to identify, formulate and solve engineering problems using principles of engineering, science and mathematics.
B	Ability to generate solutions to satisfy specific needs, considering public health, safety, wellbeing, as well as global, cultural, social, environmental and economic factors.
C	Capacity to communicate efficiently.
D	Capacity to recognize ethical and professional accountability and to issue an informed judgement, taking into consideration the impact of engineering solutions.
E	Effectively working as a team, creating a collaborative and inclusive environment, in which objectives are set, tasks are planned and objectives are fulfilled.
F	Capacity to analyze and interpret data and use engineering judgement to draw conclusions.
G	Ability to acquire and apply new knowledge, using suitable learning strategies.

Table 2
Competencies of the ABET model.
Source: taken from ABET (2017, p. 4-5).

3. METHODOLOGY

The tool's development is divided in four stages (see). Initially, the interdisciplinary team was assembled following the principles of top-management project planning (Gilchrist et al., 2018). Work was conducted with Laboratorio de Innovacion Educativa, GALEA (Torres-Barreto et al., 2018), which is part of a Colombian university that is in the process of obtaining the international accreditation by ABET. In the second stage, the team designed a search equation that allowed identifying motivational didactics tools based on gamification, and the elements of gamification used by researchers in the area. In the third stage, a process to prioritize cross-sectional competences of the ABET model took place. Finally, in the fourth stage, the users interface of the gamified tool was designed, following formally-established principles for gamification.

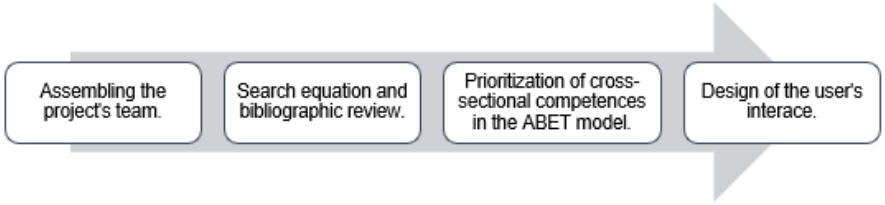

Figure 1
Stages of the methodology.
Source: compiled by the authors.

4. RESULTS

4.1. Assembling the Work Team

Members of highly-productive work teams are characterized for having joint accountability over the results to be attained instead of being exclusively responsible for individual duties (Aven, 2012; Katzenbach & Smith, 1993). This joint accountability implies team members discuss the aspects inherent to the project, provide input for the processes and support each other as part of their working routine. The interdisciplinary team was put together with the aforementioned characteristics, as follows: and industrial designer with extensive experience in developing man-machine interfaces, in charge of transforming users' needs into design requirements and of designing an interface for students and another one for teachers; a systems engineer with experience in videogame development, in charge of designing the architecture and of developing the tool based on the validated design; a systems engineer and an industrial engineer provided their expertise in the ABET model to assist the process of selecting the competences to prioritize with this gamified exercise; a business administrator, part of Laboratorio GALEA and knowledgeable in methodologies to develop games, helped in the design of the games in the gamified tool; finally, two industrial engineering students supported the operational development of the project, as well as the collection of results and the documentation. The team was coordinated by the director of GALEA. This team had the potential to produce different ideas and perspectives of problems to be dealt with, and to come up with solutions from the variety of knowledge disciplines within the group, thus providing an infrastructure to support reliable operations within the frameworks of the project.

4.2. Search Equation and Main Results

The search equation shown in Figure 2 was put together with the aim of identifying motivational didactic tools based on gamification to support teaching-learning processes in higher education. With this equation, the ISI Web of Science (WoS) and Scopus databases were consulted with the time frame of 2001-2018 in Web of Science and of 1976-2018 in Scopus. Restrictions or filters pertaining to language, types of document or areas or interest were disregarded.

Web of Science: TS= ((learn* AND teach*) AND (gamification OR "IT") AND (base* OR appl*) AND ("motivation feeling" OR "motivational teaching" OR "teaching tools" OR tool*) AND ("higher education" OR "university students" OR student*))
Scopus: TITLE-ABS-KEY ((learn* AND teach*) AND (gamification OR "IT") AND (base* OR appl*) AND ("motivation feeling" OR "motivational teaching" OR "teaching tools" OR tool*) AND ("higher education" OR "university students" OR student*))

Figure 2.
Search equation
Source: compiled by the authors.

The equation includes keywords that represent the aspects of interest intended to be encompassed by this research. Which is why the terms learn* and teach* are present, in this case the star (*) function is used to include different variations of these terms in the search (such as "learn" or "learning" and "teach" or "teaching"). The structure of the equation contains the following words: gamification, or IT, which refer to the gamification/game or to the use of ICT. The terms base* and appl* (based or applied/ applying) are also used and refer to the way in which topics are related in the search; terms such as: "motivation feeling", "motivational teaching", "teaching tools" y tool* appear and are related to the motivational didactic tools. Lastly, the words: "higher education", "university students" and "student*" were added.

The search resulted in 201 documents (articles, reviews, and proceedings), out of which 34 articles were deemed important for this research since these emphasize in the fact that gamification's objective is to encourage student motivation, and is related to positive impact in learning. Also, it promotes a more dynamic, innovative and playful environment in classrooms, and it is introduced as an effective tool for students and teachers to learn cooperatively and innovatively. Results also show that gamification in higher education is useful to disseminate academic content, even those of basic sciences (Legaki & Assimakopoulos, 2018); furthermore, it improves the educational process and students' performance with increased participation in the educational process (Li, Rothrock, & Pang, 2017).

Some research applies tools such as virtual reality, along with gamification, to teach basic science concepts (Becerra et al., 2017). Villagrasa et al., (2014) suggested an exercise to teach art in 3D, using gamification techniques in a higher education environment. This way, a gamified classroom is part of a dedicated exercise which requires research, interpretation, customization and the use of gamification principles relevant in learning and in the teaching practice. With gamification, the quality of teaching may be enhanced by aligning objectives, teaching styles and goals of the game proposed in the classroom. (Noran, 2016).

4.3 Prioritization of ABET Competences

In order to select the competences covered in this research, the prioritization matrix is selected, known "as tools to prioritize activities, topics, characteristics, products, services, and others, based on known weighted criteria. These are used in decision-making and are grounded on total quality management" (Camison et al., 2006, p.1270). The team

identified six prioritization variables in the prioritization matrix used in this research through a focus group.

The first four variables were taken from a survey designed by Laboratorio GALEA, which was electronically sent to 500 engineering students in the university of this study, and to 500 graduate engineers, in a time frame of sixteen years (as per available data). Participants were asked to rate from 1 to 5 the importance of seven competences in the ABET accreditation system (variables 1 and 3), as well as its shortcomings (variables 2 and 4), and to assign a score, to then be weighed per the weight granted by the project's team, illustrated in Table 3.

The survey's response rate was of 24.2% (students) and of 33.2% (graduates). It reflected that students consider the capacity to identify, formulate and solve engineering problems (A), and the skill to acquire and apply new knowledge (G) to be very relevant. While the capacity to communicate efficiently (C), along with the capacity to analyze and interpret data and use engineering judgement to draw conclusions (F) are the ones with the greatest failings. Moreover, despite the fact that competences A and B are the most important, these are not sufficiently developed by students, as results indicate.

In terms of the graduate's survey, the capacity to identify, formulate and solve engineering problems (A), the ability to communicate efficiently with a variety of audiences (B), and the skill to acquire and apply new knowledge (G) are the competences perceived as the most relevant. Also, the most important abilities for graduates (A and B) show lacking development, which would entail additional work in order to make them more robust.

Variable 5, related with gamification background, was used as the main input in the literature review conducted in the previous stage, which helped identify 34 texts that focused on a particular ABET competence, determining the amount of articles that were related to each competence; this result was weighted by the project's team in a scale of 1 to 7: 1 assigned to competences with zero articles and 7 to competences with fifteen articles. Results obtained show that the competences which have been studied the most in the literature were: capacity to identify, formulate and solve complex engineering problems and the ability to acquire and apply new knowledge.

Finally, variable 6 was scored using a technical concept issued by the systems engineer and the industrial designer who participated in the project, they allocated a score between 1 and 7, accounting for the technical feasibility to develop the gamified tool per each of the seven ABET competences. Thus obtaining the ability to acquire and apply new knowledge, capacity to apply engineering design to produce solutions that meet specific needs and capacity to analyze and interpret data, as the competences with the greatest technical feasibility to be developed in the gamified tool.

For this exercise, the group allocated a weight to each variable, which represents its relevance in connection with the project's object of study.

The first four variables were given a weight of 7.5% and the last two were given a weight of 35%, specified in the "percentage" column in Table 3

No.	Variable	Percentage
1	Importance for students	7,5%
2	Shortcomings for students	7,5%
3	Importance for graduates	7,5%
4	Shortcomings for graduates	7,5%
5	Gamification background	35%
6	Possibility in its development and creativity	35%

Table 3

Variables to prioritize the competences and relevance percentage.

Source: compiled by the authors.

On the other hand, Table 4 introduces the prioritization matrix with the corresponding result and weight of each of the variables. The analysis chose the competences with the highest score, additionally the project's team decided to include a third competence, given its relevance to develop and strengthen the educational environment and its indispensable nature for industries' adequate functioning.

The three selected competences will operate in the gamified exercise of this project, elucidated alongside its score in .

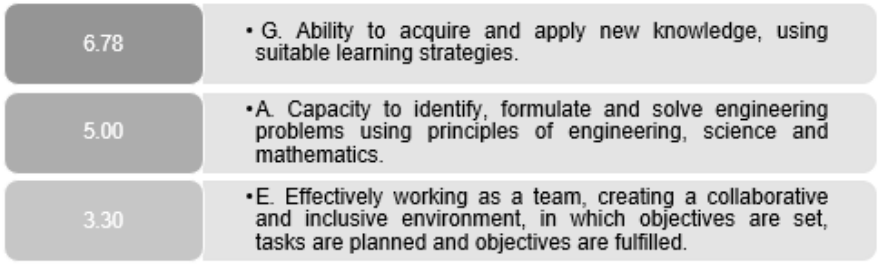

Figure 3.

Competences selected based on the prioritization matrix.

Source: compiled by the authors.

COMPETENCES	VARIABLES																		TOTAL
	IMPORTANCE FOR STUDENTS			SHORTCOMINGS FOR STUDENTS			IMPORTANCE FOR GRADUATES			SHORTCOMINGS FOR GRADUATES			GAMIFICATION BACKGROUND			POSSIBILITY IN ITS DEVELOPMENT AND CREATIVITY			
	Score	%	Weighting	Score	%	Weighting	Score	%	Weighting	Score	%	Weighting	Score	%	Weighting	Score	%	Weighting	
ENGINEERING PROBLEMS SOLVING	6	7.5%	0.45	3	7.5%	0.23	7	7.5%	0.53	4	7.5%	0.30	6	35%	2.10	4	35%	1.40	5.00
SOLUTIONS TO SPECIFIC NEEDS	5	7.5%	0.38	4	7.5%	0.3	6	7.5%	0.45	5	7.5%	0.38	1	35%	0.35	6	35%	2.10	3.95
EFFICIENT COMMUNICATION WITH AUDIENCES	4	7.5%	0.3	2	7.5%	0.15	4	7.5%	0.3	1	7.5%	0.08	1	35%	0.35	1	35%	0.35	1.53
ETHICAL ACCOUNTABILITY AND ISSUING JUDGEMENT	2	7.5%	0.15	5	7.5%	0.38	2	7.5%	0.15	6	7.5%	0.45	1	35%	0.35	3	35%	1.05	2.53
TEAMWORK	3	7.5%	0.23	7	7.5%	0.53	3	7.5%	0.23	3	7.5%	0.23	4	35%	1.40	2	35%	0.70	3.30
EXPERIMENTATION, ANALYSIS AND INTERPRETATION	1	7.5%	0.08	1	7.5%	0.08	1	7.5%	0.08	2	7.5%	0.15	4	35%	1.40	5	35%	1.75	3.53
ACQUIRING AND APPLYING NEW KNOWLEDGE	7	7.5%	0.53	6	7.5%	0.45	5	7.5%	0.38	7	7.5%	0.53	7	35%	2.45	7	35%	2.45	6.78

Table 4

. Prioritization matrix.

Source: compiled by the MOTIVATIC research team.

4.4 Users' Interface Design

The interface's design process went through a cycle illustrated in Figure 4. It began with the information compiled in the literature review and with an inquiry into the users' needs and requirements. The gamification elements used and exposed in study cases were identified, then the survey was applied to the engineering students at the university (which is the object of the study) to look into their knowledge on gamified tools and its application in classrooms, with the aim of establishing students' needs regarding the design of the tool based on the selected ABET competences.

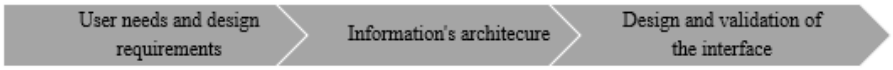

Figure 4.
Diagram of the users' interface design
Source: compiled by the authors.

Subsequently, the information's architecture was conducted taking the card sorting method into account, an instrument that according to Hassan-Montero et al. (2004) is based on:

Observation of how users group and associate with each other a predetermined number of cards labeled with different topic categories of the website. Thus, through users behavior, it is possible to organize and classify the information of a web space according to their mental model. (p. 94)

Open and closed card sorting were implemented to get to know the users' mental processes and organize the application's information in a way that adapts to students.

Finally, the interface's design incorporated the institutional logo, specific fonts appealing to students, the golden grid with a section for the logo design, institutional colors, multitasking between screens, functional buttons such as: search, dropdown menu, confirmation dialogs, designed images, satisfaction surveys, game design, purchase transactions in the system, and others. Based on these aspects, the tool's logo was designed the golden section, institutional colors and concepts such as networks and the hub component.

The tool has several functionalities, including: settings, user's profile, friendly browsing, confirmation dialogs that work as *poka-yokes* to prevent errors, customized user, among others. Also, the basic elements of a gamified tool were designed: character, levels reached, progress in terms of the entirety of the activity, points, measurements against the rest of the group and badges.

The tool will help students visualize the different courses they are enrolled in, it is meant to serve as a complement in classes. Figure 5 displays the tool's design with some of its characteristics.

Figure 5.
User interface with typical functions of the tool.
Source: Motivatic team.

Three games were designed to be used by a variety of courses in the tool, since its questions are subject to parametrization by teachers. Each teacher must include questions in the gamified tool aimed at strengthening the competences prioritized in the matrix.

The first game contains a series of multiple choice questions meant to be answered by the student with the help of different hints or wild cards (see). The second game introduces a series of cards with different concepts, which will be interactively evaluated (see Figure 8); lastly, the third game focuses on reinforcing collaborative work (see).

Figure 7
First game: multiple choice questions
Source: Motivatic team.

Figure 8
Second game: cards.
Source: Motivatic team.

Figure 9.
Third game: to be chosen by the teacher.
Source: Motivatic team.

5. CONCLUSIONS AND DISCUSSION

This article presents the results of a research exercise focused on designing a gamified tool as element of motivational didactic that supports a cross-sectional competence model devised for the area of engineering.

As demanded by gamification principles, the project's team was built with interdisciplinarity in mind, the team selected and prioritized cross-sectional competences for engineers with an evaluation matrix in which five weighted variables converge. The prioritization exercise was conducted with 121 students enrolled in engineering undergraduate programs and with 166 graduates, aside from focus groups with experts in teaching, design and educational models per competences. This prioritization revealed the need to work with the competences of solving complex engineering problems, acquisition and use of new knowledge and teamwork, as key competences in an engineer's future exercise.

Then, the design and prototype of a motivational didactic tool followed by specifically addressing those competences, with parametrization capabilities to be used aside from the subject, and embedded with basic gamification elements. Thus, the designed tool responds to the identified needs while using an innovative methodology (gamification), corroborated by numerous studies to date. The tool is supported on concrete elements of play to keep students engaged with learning, but it also demands teachers' accompaniment, meaning the teacher must also be updated and interested in learning about new educational models to instill and strengthen students' knowledge (Torres-Barreto et al., 2017).

In terms of the results obtained by the project, so far, gamification-based educational models have yielded positive results compared with conventional learning methods. In fact, several studies have illustrated the effects of the use of gamification, explicitly in learning levels, motivation, interest and concrete results of the designed gamified tool (Piñeiro-Otero & Costa-Sanchez, 2015; Villagrasa et al., 2014). In that regard, this research highlights the importance of integrating gamification supported in technologies into higher education institutions' classrooms, pursuing the development of cross-sectional competences.

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REFERENCES

ABET. (2016). *Aspectos generales ABET*. ACOFI. http://www.acofi.edu.co/wp-content/uploads/2016/12/2.-Aspectos-generales-ABET.pdf

ABET. (2017). *Criteria for accrediting engineering programs, 2018-2019*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/

Acosta-Medina, J., Torres-Barreto, M., & Alvarez-Melgarejo, M. (2020). Literature mapping about gamification in the teaching and learning processes. *Revista ESPACIOS, 41*(11), 26.

Acosta-Medina, J., Torres-Barreto, M., Álvarez-Melgarejo, M., & Paba-Medina, M. (2020). Gamificación en el ámbito educativo: Un análisis bibliométrico. *I+ D Revista de Investigaciones, 15*(1), 30-39.

Afriat, C., Gay, C., Loisil, F., & Gay, C. (2006). Mobilités professionnelles et compétences transversales. En *La Documentation française*.

Alam, K., Erdiaw-Kwasie, M., Shahiduzzaman, M., & Ryan, B. (2018). Assessing regional digital competence: Digital futures and strategic planning implications. *Journal of rural studies, 60*, 60-69.

Aven, T. (2012). *Foundations of risk analysis*. John Wiley & Sons.

Bahji, S., Lefdaoui, Y., & El Alami, J. (2013). Enhancing motivation and engagement: A top-down approach for the design of a learning experience according to the S2P-LM. *International Journal of Emerging Technologies in Learning, 8*(6), 35-41. https://doi.org/10.3991/ijet.v8i6.2955

Barr, R., & Tagg, J. (1995). From teaching to learning—A new paradigm for undergraduate education. *Change: The magazine of higher learning, 27*(6), 12-26.

Becerra, D., Quispe, J., Aceituno, R., Vargas, G., Zamora, F., Mango, J., Paulina, G., Figueroa, A., Vizcarra, A., & Chana, J. (2017). Evaluation of a gamified 3D virtual reality system to enhance the understanding of movement in physics. *CSEDU 2017 - Proceedings of the 9th International Conference on Computer Supported Education, 1*, 395-401.

Blömeke, S., Gustafsson, J., & Shavelson, R. (2015). Beyond dichotomies. *Zeitschrift für Psychologie, 223*(1), 3-13.

Callaghan, N. (2016). Investigating the role of Minecraft in educational learning environments. *Educational Media International, 53*(4), 244-260.

Camisón, C., Cruz, S., & González, T. (2006). *Gestión de la Calidad: Conceptos, enfoques, modelos y sistemas* (Cañizal Ed.). Pearson Educación, S.A.

Cózar, R., & Sáez, J. (2016). Game-based learning and gamification in initial teacher training in the social sciences: an experiment with MinecraftEdu. *International Journal of Educational Technology in Higher Education, 13*(1).

de Miguel, M. (2005). *Modalidades de enseñanza centradas en el desarrollo de competencias. Orientaciones para promover el cambio metodológico en el Espacio Europeo de Educación Superior*. Asturias, España. Servicio de Publicaciones. Universidad de Oviedo.

European Association for Quality Assurance in Higher Education (ENQA). (2015). *Standards and guidelines for quality assurance in the European Higher Education Area (ESG).*

Farzan, R., & Brusilovsky, P. (2011). Encouraging user participation in a course recommender system: An impact on user behavior. *Computers in Human Behavior, 27*(1), 276-284.

Fernandes, E., Dos Santos, C., & Milidiú, R. (2012). Latent structure perceptron with feature induction for unrestricted coreference resolution. *In Joint Conference on EMNLP and CoNLL-Shared Task*, 41-48.

Gilchrist, A., Burton-Jones, A., & Green, P. (2018). The process of social alignment and misalignment within a complex IT project. *International Journal of Project Management, 36*(6), 845-860.

Guin, T., Baker, R., Mechling, J., & Ruyle, E. (2012). Myths and realities of respondent engagement in online surveys. *International Journal of Market Research, 54*(5), 613-633.

Gustafsson, A., Katzeff, C., & Bang, M. (2009). Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment (CIE), 7*(4), 54.

Hamari, J. (2013). Transforming homo economicus into homo ludens: A field experiment on gamification in a utilitarian peer-to-peer trading service. *Electronic commerce research and applications, 12*(4), 236-245.

Hamari, J. (2015). Why do people buy virtual goods? Attitude toward virtual good purchases versus game enjoyment. *International Journal of Information Management, 35*(3), 299-308.

Hassan-Montero, Y., Martín-Fernández, F. J., Hassan-Montero, D., & Martín-Rodríguez, Ó. (2004). Arquitectura de la información en los entornos virtuales de aprendizaje. Aplicación de la técnica card sorting y análisis cuantitativo de los resultados. *El profesional de la información, 13*(2), 93-99.

Hsua, C.-L., Chen, M.-C., Hsu, C., & Chen, M.-C. (2018). How gamification marketing activities motivate desirable consumer behaviors: Focusing on the role of brand love. *Computers in Human Behavior, 88*, 121-133.

IQM-HE. (2016). *Handbook for Internal Quality Management in Competence-Based Higher Education* (pp. 1-116). http://www.enqa.eu/indirme/IQM-HE Handbook.pdf

Jeana, S., Medemaa, W., Adamowskia, J., Chewb, C., Delaneyb, P., & Wals, A. (2018). Serious games as a catalyst for boundary crossing, collaboration and knowledge co-creation in a watershed governance context. *Journal of Environmental Management, 223*, 1010–1022.

Jones, B., Madden, G., & Wengreen, H. (2014). The FIT Game: preliminary evaluation of a gamification approach to increasing fruit and vegetable consumption in school. *Preventive medicine, 68*, 76-79.

Katzenbach, J., & Smith, D. (1993). *The Wisdom of Teams Harvard Business School Press*. Boston, Mass.© McKinsey & Coy Inc.

Koehn, E., & Parthasarathy, M. (2005). Practitioner and employer assessment of ABET outcome criteria. *Journal of Professional Issues in Engineering Education and Practice, 131*(4), 231-237.

Landers, R. (2014). Developing a theory of gamified learning: Linking serious games and gamification of learning. *Simulation & Gaming, 45*(6), 752-768.

Legaki, N., & Assimakopoulos, V. (2018). F-LaurelXP: A gameful learning experience in forecasting. *CEUR Workshop Proceedings, 2186*, 1-10.

Li, J., Rothrock, L., & Pang, G. (2017). Peer-based gamification of challenging concepts in engineering education: Lesson learned. *67th Annual Conference and Expo of the Institute of Industrial Engineers 2017, May 20, 2017 - May 23, 2017*, 920-925.

Lobo-Rueda, M., Paba-Medina, M., & Torres-Barreto, M. (2020). Análisis descriptivo de experiencias gamificadas para enseñanza y aprendizaje en educación superior en ingeniería. *Revista ESPACIOS, 41*(16), 21.

McGonigal, J. (2011). *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*. Penguin Books.

Mekler, E., Brühlmann, F., Tuch, A., & Opwis, K. (2017). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior, 71*, 525-534.

Morales, P. (2018). *Análisis del fortalecimiento de competencias de los Ingenieros a través de experiencias de intercambio.*Industriales ETSII, Universidad Politécnica de Madrid

Nacke, L., & Deterding, S. (2017). Editorial: The Maturing of Gamification Research. *Computers in Human Behaviour, 62*(0747-5632), 450–454.

Noran, O. (2016). On gamification in action learning. *ACM International Conference Proceeding Series, 01.05.Febr*. https://doi.org/10.1145/2843043.2843344

Observatorio de Innovación Educativa. (2016). *Edu Trends - Gamificación*. Tecnológico de Monterrey

Pedroza, B., Gonzáles, J., Guerrero, J., Collazos, C., & Ramírez, J. (2017). Attach me and detach me: An interactive device to help to teach algebra. *ACM International Conference Proceeding Series, Part F1311*.

Piñeiro-Otero, T., & Costa-Sánchez, C. (2015). ARG (Alternate Reality Games). Contributions, Limitations, and Potentialities to the Service of the Teaching at the University Level. *Comunicar, 22*(44), 141-148.

Safta, C. (2015). Cross-Curricular Competencies-Access Path to Professional Development. *Procedia-Social and Behavioral Sciences, 203*, 348-354.

Sailer, M., Ulrich, J., Mayr, S., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371-380.

Sanmugam, M., Zaid, N., Mohamed, H., Abdullah, Z., Aris, B., & Suhadi, S. (2015). Gamification as an educational technology tool in engaging and motivating students; An analyses review. *Advanced Science Letters, 21*(10), 3337–3341. https://doi.org/https://doi.org/10.1166/asl.2015.6489

Schunk, D., & Mullen, C. (2012). Self-efficacy as an engaged learner. En *Handbook of research on student engagement* (pp. 219-235).

Seaborn, K., & Fels, D. (2015). Gamification in theory and action: A survey. *International Journal of human-computer studies, 74*, 14-31.

Shamshina, I. (2014). Professional competences necessary for the bachelor-degree-holding engineer specialising in engineering industries. *Pacific Science Review, 16*(2), 85-88. https://doi.org/https://doi.org/10.1016/j.pscr.2014.08.018

Soboleva, E., Galimova, E., Maydangalieva, Z., & Batchayeva, K. (2018). Didactic Value of Gamification Tools for Teaching Modeling as a Method of Learning and Cognitive Activity at School. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(6), 2427-2444

Sousa, M., & Rocha, Á. (2019). Leadership styles and skills developed through game-based learning. *Journal of Business Research, 94*, 360-366.

Stott, A., & Neustaedter, C. (2013). Analysis of gamification in education. En *Surrey, BC, Canada* (Vol. 8).

Torres-Barreto, M., Álvarez-Melgarejo, M., & Pinto, T. (2018). *Laboratorio galea: un espacio en transformación e innovación para la enseñanza-aprendizaje* (hal-01894004). https://hal.archives-ouvertes.fr/hal-01894004/

Villagrasa, S., Fonseca, D., Redondo, E., & Durán, J. (2014). Teaching case of gamification and visual technologies for education. *Journal of Cases on Information Technology, 16*(4), 38-57. https://doi.org/10.4018/jcit.2014100104

Weinert, F. (2001). *Concept of competence: A conceptual clarification*.

Zhurakovsky, V. (1997). Higher technical education in Russia: history, status and problems of development. En *Moscow: Closed Joint-Stock Company" RIK Rusanova.*