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Qualitative assessment of a challenge-based learning and teamwork applied in electronics program

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A B S T R A C T

Every student of industrial technology engineering must develop and acquire specific electronic competencies and skills, such as those pertaining to the design, analysis, and assembly of basic circuits in the context of both analogue and digital electronics, including the corresponding instrumentation. Additionally, as is the case for practically all university degrees but has not always been addressed adequately in the field of engineering, generic competencies such as oral communication and teamwork must be acquired. The experience discussed in the article focuses on the design, implementation, and assessment of a hybrid (face-to-face and virtual) educational activity that facilitates the acquisition of specific engineering skills through a teamwork-based approach and enhances communication among students in the context of experimentation. The students, who are divided into teams, must develop a series of embedded systems with the aim of providing a solution to a problem derived from Sustainable Development Goal 11: Sustainable Cities and Communities. This approach entails the challenge of working with a heterogeneous sample of students studying for a dual degree in design and mechanics, whose motivations are also highly varied. The innovative objective of the educational proposal focuses on adapting the practice to the roles and profiles of the students and tailoring project phases to the competency needs of each student. The results highlight the need to design real practices that foster the motivation of engineering students; they also emphasize the fact that in the context of teamwork, roles pertaining to the specific competencies required by dual-degree students should be defined. The evaluation of such an experiment using the Bipolar Laddering Assessment has exhibited utility and reliability regarding small samples of users and has been shown to be valid regarding identifying the strengths and weaknesses of educational experiments.

1. Introduction

Universities aim to serve society. University programmes seek to respond to social needs by providing professionals who can satisfy them. It is therefore necessary to consider the functions that these professionals must perform in the sector, which determine the specific and generic competences that they must acquire when studying for the degree [1,2]. In engineering, technology is advancing more quickly than curricula, the profile of graduates is becoming increasingly cross-disciplinary, and good professionals must face the changing challenges resulting from societal demands [3–5]. Therefore, as important as working on a series of competences pertaining to a specific technology about the ability to adapt to any technology based on basic knowledge and methodologies, to work in a team requires the abilities to achieve objectives more efficiently and effectively and to communicate what has been achieved using the appropriate terminology for the field in question [6–8].

For several years, employers who are in contact with universities have reported that students are graduating without having developed these competences sufficiently [9]. Even students with excellent academic results often prefer to work alone, often because they lack interpersonal skills and/or consider teamwork to be a burden rather than an opportunity for improvement [10,11].

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On the other hand, oral communication competence is also relevant. Because we begin to speak at an early age, we believe that we know how to do so well and that others understand what we want to say. However, there is often a large gap between what we want to communicate and what is understood [12–15].

In addition, the new profile of students entering university must be considered [16–20]. It is necessary to include certain activities, which must be active [21,22] to compete with external stimuli to enhance students' motivation, maintain their attention and substantially improve their performance [21]. According to Jones [23], this improvement is even greater when in the context of direct interactions with peers and teachers. That is, even if students initially reject teamwork or exposure to their peers, the development of these competences improves not only their motivation but also their final experience and results [24]. Motivation is an important factor to consider considering the high risk of dropout in the first two years of university.

The main aim of this project is to develop a proposed methodology that combines the following:

- A hybrid activity (capable of integrating in-person and virtual classes, monitoring, and work) based on project-based learning (PBL) and differentiated challenges was designed, implemented, and evaluated.
- The activity was conducted in the field of industrial technology engineering, specifically in the context of a dual degree in design and mechanics. This context involves students with distinct motivations who must engage in shared practices, thereby developing both specific and cross-disciplinary competencies.
- Specifically, for the project, we focused on level 2 of the teamwork and oral communication competencies as described in the university's general framework. The experiment focused on second-year students who had previously completed level 1 of these competencies.
- Finally, a qualitative assessment of the method allowed us to obtain a precise overview of the main suggestions that students made regarding the enhancement and improvement of future versions of the method, thereby validating the approach chosen.
- Moreover, the methodology we employed introduced students from diverse engineering fields to the concept of sustainable development goals (SDGs), a fundamental component of the development of future engineers. This aspect is being integrated into the Spanish context as a key element in the task of redefining studies and practices in the realm of industrial engineering.

2. Case presentation

a) Context description

The case presented is related to the field of electronics, which is part of the 2 nd year of the double degree in design and mechanics. Students begin by acquiring completely novel knowledge regarding the development of electronic systems, and in approximately 14 weeks, they must develop the skills corresponding to one specific competence and two generic competences:

- Specific Competence (SC): Design, analyse, assemble, and measure basic circuits in the context of both analogue and digital electronics, including the corresponding instrumentation.
- Generic Competence 1 (GC1), Oral Communication: Expressing one's ideas, knowledge, and feelings in speech in a clear and opportune manner that is well adapted to the audience and situation to ensure good comprehension and attention.
- Generic Competence 2 (GC2), Teamwork: Actively joining groups and participating in the attainment of shared objectives with other persons, departments, and organisations.

Through their development of the SC, students acquire the ability to implement a small programmed system that can control a series of actuators based on the information captured by sensors.

Regarding GC1, its development is based on the guidelines provided by the University of Deusto [25–27]: "Proficiency in oral communication means being effective in conveying ideas, knowledge, and feelings through words, both in conversation and in group activities such as talks before audiences of different sizes … In professional life, except in cases where people work alone apart from colleagues and third persons (suppliers, clients, etc.), the consequences of lack of good communication are reflected in loss of time, effectiveness and, from the individual point of view, opportunities for promotion".

Regarding Teamwork, i.e., GC2 [25–27], the same documents state that the following: "Considered by many specialists as a core competence, teamwork involves thinking analytically and systemically, reflectively, and critically, administering time and meetings, participating in decision-making and in management of objectives and projects … In professional life, competence in teamwork is required in two-thirds of employment subjects, even including group interviews or group dynamics exercises in the selection process to observe how candidates perform in a group context. Tasks that involve working with others in teams occur not only within departments (e.g., sales teams, accounting, or production teams) but also among departments in multidisciplinary teams created specifically to undertake projects, resolve problems, draw up innovation or improvement proposals, etc."

b) Case history

During the same semester, students were enrolled in a course on the basic structures of structured programming. However, this context represents their first approach to electronics as developers, since their only previous experience was as users. Thus, during the first ten weeks of the course, students are introduced to digital electronics by being asked to explore combinational, functional, and sequential systems in a theoretical and practical way, and they become sufficiently familiar with analogue electronics to understand

how the sensors and actuators that they will use at a later point work. Students face the challenge of concentrating on the completion of a project in just 4 weeks. The results depend on what each student has learned from the course during the previous weeks, as all aspects are closely related, particularly attitudes with which students approached the course and progressed to this point. Since these students are undergoing a double programme, the entry profiles [19,28,29] and concerns of students who focus on design are not the same as those of students whose motivation for entering the programme was mechanics. It is also common for some students to perform better than others in the subject due to their participation in extracurricular activities related to one of the two relevant fields. The proposed structure responds to the changes promoted since the COVID-19 pandemic to improve the options for students' study of these subjects. In this sense, the new structure of the course features only 3 face-to-face hours per week instead of 4; only 2 of these hours are face-to-face, while the third occurs in a synchronous remote format.

The aim of the project is to enable students to develop the competences described above, considering all these factors and the new unintended context of a hybrid face-to-face-remote learning model. The specific competence is assessed based on the execution of the project itself according to the evaluation criteria that have been formulated. The generic competencies are evaluated based on the institutional rubrics of the University of Deusto, which are used for all subjects [25–27]. In addition, these competencies are subsequently evaluated using a qualitative tool. Given the context described above and the conviction that motivation is a key element that must be considered [30,31], we chose to design the project methodology to ensure that it included the factors that, according to Chapter 4 of Paricio, Fernández and Fernández [4], can be associated with a high level of engagement, which in turn facilitates deep learning.

- Relevance: perceiving that what is being done is important and has significance, as is the case in real situations. In this project, Sustainable Development Goal 11: Sustainable Cities and Communities (https://www.un.org/sustainabledevelopment/) was chosen as the central theme of the projects. Each group of students could choose a situation within this theme to which they thought they could find a solution based on an electronic system. In this case, it is important that the students perceived that what they were going to do was relevant. For that reason, a topical and socially relevant topic was chosen, and it was determined that students themselves should choose exactly what they wanted to do instead of assigning them a closed project that would be the same for all groups or chosen by the teacher.
- Autonomy: doing things for personal reasons in environments that suit one's interests, having options, and the possibility of deciding, planning, and regulating the relevant processes … All these factors generate intrinsic motivation that enables students to feel effective and capable and to develop beliefs regarding control, strategy, and ability; furthermore, these factors elicit pride and satisfaction with the results from the students. Autonomy is undoubtedly the most difficult factor to implement in an activity, as it is influenced by the personality and cognitive maturity of each student. Thus, students must be able to choose based on their own preferences, albeit from a series of closed options. A certain level of planning must be left to the group but only within certain limits, such as partial deliveries on certain dates. It is necessary to provide a good basis the objective to be achieved but without doing everything for the students, not even in terms of providing them with all the necessary information. It may even be useful to give the groups and the class a certain degree of freedom to choose the rules that will govern their performance, such as the distribution of students among the groups, the distribution of marks within the group, or rules of operation. In this case, it the agreements made by the class were applied.
- Academic challenge: to face personal challenges in problematic situations that test one's creativity and resources. Rather than viewing the double programme as a potential problem due to the differing interests involved, the groups were encouraged not only to implement the electronics and programming part of the project but also to draw on their knowledge of other subjects to develop a model to support the prototype. This task required the integration of learning from different areas, the acquisition of learning at different levels, including conceptual, procedural and transfer knowledge, as well as the implementation of theories that had not previously been applied. The role of the teacher in this context is fundamental, both as a promoter of the challenge, so that its complexity can help students reflect, and as a supporter, providing the necessary scaffolding to ensure that this complexity does not demotivate students and cause them to give up.
- Collaboration: the opportunities offered by the activity about interaction and collaborative learning, sharing and contrasting ideas, debating, arguing, adopting the perspectives of others, etc., which increase students' deep understanding, engagement with others and shared satisfaction. These goals are achieved by developing the project through teamwork, a competence that will be relevant in students' professional future, particularly if the "final product" must be presented to the rest of their peers. However, by virtue of the autonomy mentioned above and due to the limited time and organisational problems, the students were given the opportunity to organise themselves into groups according to their own preferences. The students took advantage of this possibility by forming the same groups in which they participated in other subjects, although it would have been better to organise the groups according to other criteria.
- Tension between theory and experience: the experiential dimension, the conflict between immediate concrete experience and analytical distance, which is rooted in the analysis of cases based on theories, the application of abstract principles in concrete situations, experimental designs, examples, personal experiences, stories …. This factor specifically is best facilitated by the development of a project. Students must put into practice in a global way what had hitherto been isolated practices involving either abstract or very concrete cases. They must analyse, for example, how a certain mathematical equation can be used to obtain a random number or why the system does not work the first time, such that a delay must be introduced into a programme to enable the sensor to detect the blinking of an LED (Light-Emitting Diode) diode properly, a task which seemed to be so simple in theory. This approach thus requires the provision of a series of resources, including, in this case, a learning platform, simulators, remote laboratories and electronic equipment as well as meeting spaces in both face-to-face (laboratories) and virtual (video conferencing

platform) contexts. The use of information sources is also essential at this point, a fact of which students must be made aware. This approach is particularly essential in a profession such as engineering, in which context it is not only necessary to learn current technology but also the base methodology and the competence of learning itself to enable the student to adapt to technologies that have not yet been invented.

No studies like ours have been found. However, we did find literature and literature reviews that support our strategies. Passow & Passow [32] suggested that engineering educators should focus on developing general engineering competencies rather than separating general competences from engineering competences. The aim of this study is precisely to focus on general engineering competences such as communication or teamwork. Although 2 h are conducted face-to-face and one is conducted in a synchronous online format, working in small teams, as Qadir & Al-Fugaha [33] noted, helps students achieve better grades, retain information more effectively and acquire communication and teamwork skills. Berry & Lingard [34] noted that the fact that students work in teams requires greater effort from teachers, although in this study, we addressed this problem by giving the students autonomy and providing opportunities for collaboration. Similarly, based on our experience, we tried to integrate the attributes proposed by Chowdhury & Murzi [35] for effective teamwork, such as interdependence, constructive feedback, and accountability through peer assessment. Peer assessment is also an effective tool for improving communication. Flores & Rios [36], after applying peer assessment in an electronics course, reported that students were more confident, better prepared, and interactive with the audience with whom they were communicating. In turn, students were mindful of the remaining time. In terms of motivation [37], we try to infer interest and enthusiasm and provide sufficient choices as well as to guide students through the process in case any questions or problems arise.

In conclusion, we can confirm that previous studies have made claims leading in all directions. For instance, some studies have literally stated that "the industry has no homogenous requests. Large ICT (Information and Communication Technologies) companies ask for a solid scientific background, as they have resources to further train their staff to undertake a broad range of tasks and projects. Smaller ICT companies prefer specialised ICT graduates who are ready to work, providing returns without further human resource training expenses. It is impossible to reconcile the two opposing requirements of the industry to have ICT graduates who are both flexible and immediately useable" [38]. In contrast, other studies have promoted a greater focus on generic competencies based on the information revealed by industry employer surveys [1,9].

c) Qualitative assessment

Any teaching experiment, whether it is based on technologies or methodologies, begins with the design of the experiment itself as well as the knowledge of the context that will interact with that design, the mode of experimentation, and the mode of evaluation, among other factors such as the definition of specific rubrics for each activity and competences [38–45]. Our approach, which was clearly identified as a process of active learning, can be defined as any method that "involves students in doing things and thinking about the things they are doing", a question that can be assessed in different ways in the context of an engineering course [46,47] and can be defined in terms of classroom-based activities designed to engage students in their learning by asking them to answer questions, solve problems, discuss content or teach others, whether individually or in groups [48].

Learning assessment is generally conducted using two approaches, i.e., formative, and summative [49]. The main purpose of summative assessment is to assess student learning at the end of the learning unit, project or assessment activity corresponding to a specific syllabus. Summative assessment provides teachers with information regarding the degree to which the student has mastered the learning content or competences. In contrast, the main purpose of formative assessment is to feed into the instructional model to meet the needs of learners. Formative assessment is used to identify learners' level of understanding and plan the most appropriate instructional design for learning to guide teachers through the learning process. Formative assessment helps (a) identify strengths and weaknesses, (b) report objective data, (c) implement improvement actions and (d) detect and advance actions intended to solve problematic situations in time; it also provides a database approach that can help analyse the relevant information.

According to Borrego et al. [46], the evaluation methods used in teaching or learning experimentation are typically quantitative, qualitative, or mixed depending on the type of data recollected and the sample of users to be studied [50–52]. Basically, all these evaluation methods are based on two longstanding approaches, i.e., Plato's rationalism and Aristotelian empiricism, both of which are valid and appropriate based on a detailed description [53]. In general, quantitative methods are intended to provide data summaries that facilitate the validation of generalisations concerning the phenomenon under study. To accomplish this task, such methods usually employ a small number of variables and depend on validation procedures to ensure the results' reliability, which usually requires statistical analysis. The most common examples are evaluation surveys or tests that feature closed questions for students. Quantitative results are limited because they provide numerical descriptions rather than details about the perceptions or motivations of those included in the sample.

Qualitative studies, on the other hand, begin with the broad goal of improving our understanding of the sample's human perspectives and end with a detailed description of a specific event or phenomenon associated with the experiment being assessed. Their results are more difficult to compare since they essentially exhibit singular responses. For this reason, qualitative approaches facilitate the identification of the main positive characteristics to be empowered or the main weaknesses to be mitigated. The main criticism of these approaches is based on their systematisation or their presumed lack of rigour resulting from the fact that they involve small samples, which is often the result of a misinterpretation of the study's goals and/or the responses obtained [54,55]. However, both quantitative and qualitative methods yield scientifically valid results. Their use and validity have been studied and compared in previous works. No significant differences have emerged in terms of their scientific citations, and both types of studies have been used equally as references [56].

For each qualitative method, Leydens et al. defined up to 10 types of characteristics in terms of their function and quantitative equivalent [54,57]. The collection of observations, interviews and/or focus group work and organised documentary work in ethnographic studies are essential. These methods are especially interesting, and their credibility has been demonstrated [53] not only regarding small samples that can generate deviations in quantitative approximations but also when, due to the typology of users, it is necessary to obtain more personal information [58].

Regarding studying the effectiveness of teaching and/or teaching strategies [59], investigated the evidence concerning any methodological design in education [58,60], or exploring the evidence of both generic and specific competences [61], particularly at the present time following the COVID-19 pandemic [62], qualitative studies and sample size has been shown to be relevant factors [63]. In this regard, a wide variety of studies have been conducted, and many recommendations concerning sample size have been given depending on the type of study in question. From a quantitative point of view, Wolf, Harrington, Clark, and Miller [64] proposed that for experimental research, the minimum number is 15 samples per group; for descriptive research, the minimum is 100; for correlational research, the minimum is 50; and for structural modelling research, the minimum is 10–15 participants per variable. Depending on the applications and approaches used, the minimum sample size for research using SPSS (the Statistical Package for the Social Sciences application) is 30 according to Ghasemi and Zahediasl [65]; however, for research using PLS-SEM (Partial Least Squares - Structural Equation Modelling) analysis, at least 80 responses are, and 100–150 responses are required for the use of AMOS (Analysis of a MOment Structures) software. Some tools even allow the researcher to obtain the sample size depending on the degree of confidence that he or she is seeking (http://www.raosoft.com/samplesize.html) based on the idea that a p (significance) value of 0.05 is generally considered to be the bare minimum, with 0.01 being even better. If a researcher is examining correlations with other scales, the p value must be calculated based on the number of data points and the lowest expected correlation [66,67].

However, a review of existing work on sample sizes in qualitative approaches reveals two main factors that must be considered. On the one hand, the method of data collection used (for example, in-depth interviews, focus groups and ethnographic research, which are among the most frequently used approaches) and on the other hand, the types of questions under study all consider the principle of saturation [68]. This principle tries to define the extent to which the data collection fails to provide new information in terms of the possible universe and the sample. The broad purpose of qualitative research is to improve our understanding of human perspectives and provide a detailed description of a given event or phenomenon; thus, at a certain point, the addition of more samples in each context leads to a repetition of the information, and this point has been recognized globally as indicating an adequate sample size [69]. If, however, one wants to be more precise, the literature and systematic studies of sample size in qualitative studies [70,71] have shown that single-user studies can even be valid in exceptional cases, although samples of 5–25 users from open-ended and/or semi structured interviews are naturally considered to be acceptable.

Interviews are often the main method used in qualitative research. However, interviews do not necessarily exhibit scientific formality. This approach has been widely criticised for two basic reasons: it is not applied correctly (even today, professionals still do not distinguish among facilitation, interview and even questionnaire approaches), and interview data are not treated in a systematic way, which renders them very unattractive for scientific presentation. In this sense, the Socratic Method or Socratic interview (SQ) approach is a methodology according to which the user is asked to mature and reflect on a specific topic in such a way that an answer is not given to a question; rather, the user's reflection is encouraged through dialogue between the user and the guide. The guide can formulate reflections or use other resources to enable the user to identify the strengths and weaknesses associated with an experience and resolve any doubts and conflicts that may have arisen [72,73].

However, why apply an SQ when a task test can be used instead? The first answer to this question pertains to the type of information that may be obtained. It is virtually impossible to reveal certain details of the user experience without the use of qualitative exploration techniques. The use of these techniques reflects the user's satisfaction, motivation, and interest with the elements of the study. The second notable factor is the radical shift between the facilitator role and the interviewer role (in the case of an exploratory interview). While the role of the facilitator is aseptic, distant (although cordial), and noninterventional, the role of the interviewer is much more direct and strategic, and it involves direct intervention [73].

In summary, qualitative interviews have many applications and are very useful if applied correctly (in terms of the cognitive grid, contextual design, etc.). Qualitative methods may not provide visually appealing data as do quantitative approaches, but they are very useful for users and experts, as they can reveal valuable information that cannot be obtained by other testing techniques.

d) Intervention

To develop the competencies outlined above, we decided to use an Arduino-based educational kit containing both a microcontroller board to be programmed and a variety of sensors and actuators that would allow the groups to implement their ideas in a creative way. We chose Arduino for this course because it is an open-source prototyping platform that features, in addition to the hardware, a free development environment and a community for sharing code and ideas that is very appropriate for the purposes of this programme. Its advantages also include the facts that it is multiplatform, that it features a programming language very similar to C/C++ and that its cost is not high. This last feature was even more important this year than in previous iterations of the course. Due to the pandemic situation, the students were required to do part of their work individually at home; thus, they needed an individual kit for their own use. This platform also has certain disadvantages. Its simplicity is often excessive, and the low cost limits the available resources. However, the aim of this subject is to provide a first approach to the design and programming of embedded systems. In addition, for some students, this course is their only opportunity to develop their knowledge in this area. Therefore, these limitations do not prove to be major. The kit ultimately chosen was the Crowtail Starter Kit for Arduino from Elecrow (https://www.elecrow.com) (see Fig. 1).

The board supporting the Arduino features 11 digital input/output ports, 6 analogy input ports and 5 communication ports (see

Fig. 2).

The board is founded on a Base Shield system in which the different modules to be used are connected. This situation allows us to ignore the electrical connections of the devices to focus on the design and programming of prototypes, which is the aim of the course (see Fig. 3). The modules include typical button and switch input modules or LED and buzzer output modules. More striking in terms of results and with great potential to support the projects involved in this course are the flame sensor, moisture sensor, touch sensor, light sensor, thermistor temperature sensor, linear potentiometer, tilt switch, sound sensor, relay, vibration motor and 4-digit display.

The first 10 weeks of the course were devoted to working on the baseline competencies for the project (see Fig. 4). Subsequently, before starting the project, the focus was on working with the students on the generic competences of teamwork, communication, and motivation enhancement. For this purpose, the students were divided into three groups according to their interests and the results of a test of their previous experience in and motivation regarding the subject. A dossier consisting of documentation and didactic information concerning these competences was prepared, and each group was asked to reflect on one of the three topics. They were then asked to share their conclusions with the rest of the class in terms of the corresponding difficulties, advantages, disadvantages and guidelines for teachers and students as well as the agreements they reached. The aim of this process was to reach a consensus concerning the characteristics and mode of operation associated with the project, including guidelines, recommendations, procedures, forms of action and evaluation. This first part began in a lecture hour under the guidance of the teacher and was required to be completed outside the classroom.

The students were then introduced to the key concepts of programmable electronic systems, and the teacher presented the steps to be followed in the execution of their project (see Fig. 5). A project of this type involves two distinct parts: the hardware and the software. Each of these parts must be planned at the beginning of the process, specifically in the requirements analysis phase. Thereafter, students must work on the project independently in a second phase, after which they are finally brought together again after the individual aspects have been refined. This dynamic forced the groups to work together on some occasions and in pairs or even individually on other occasions. The need to spend some days working face-to-face in the classroom and others working remotely from home further accentuated this already complex division. Accordingly, the groups were required to plan the roles of each member and the timing of the tasks very carefully.

The next step was to focus on the specific hardware to be used, namely, the Crowtail Starter Kit for Arduino, as well as its use and programming. Accordingly, the teacher presented the hardware's characteristics, the structure and flow of an Arduino program and the main variables and operators. She also emphasized the similarities with the programming language that students were learning in another field as well as the new functions and libraries involved in programming a programmable electronic system, specifically using the Arduino language.

From this point, each group was required to design and develop a prototype that responded to one of the issues raised by Sustainable Development Goals (SDG) 11: Sustainable Cities and Communities. They could accomplish this task with the help of the manufacturer's documentation and examples, a bibliography that was carefully chosen by the teacher and other sources that they themselves could consult on the internet. Four groups of 4–5 students were formed. The projects on which these students worked focused on water quality control, air quality, road safety for people with special needs and awareness of the need for housing and access to basic services for all people (see the example in Fig. 6).

The rating of the project was based not only on how well the prototype worked but also on its design with a focus on the end user and on the process followed during its development. Students were required to develop an electronic prototype executable on Arduino that the following characteristics for evaluation:

- Minimal:
  - o The project's statement must respond to one of the needs of Sustainable Development Goal #11: Sustainable Cities and Communities.
  - o It must contain at least 2 digital input peripherals.
  - o It must contain at least 2 digital output peripherals.
  - o It must contain at least 1 analogic input or complex data output peripheral.

Fig. 1. Presentation of the contents of the Crowtail Starter Kit for Arduino by Elecrow.

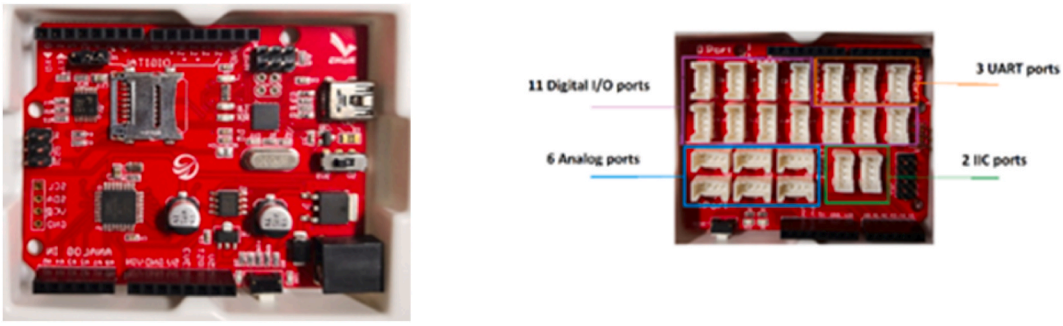

Fig. 2. View of the Arduino board and its input/output ports.

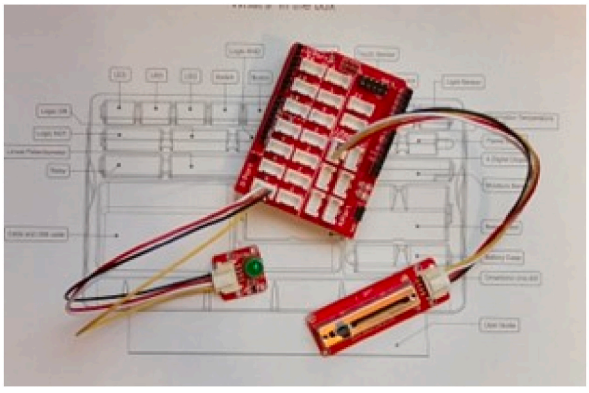

Fig. 3. The Base Shield system allows the modules to be easily connected to the microcontroller ports.

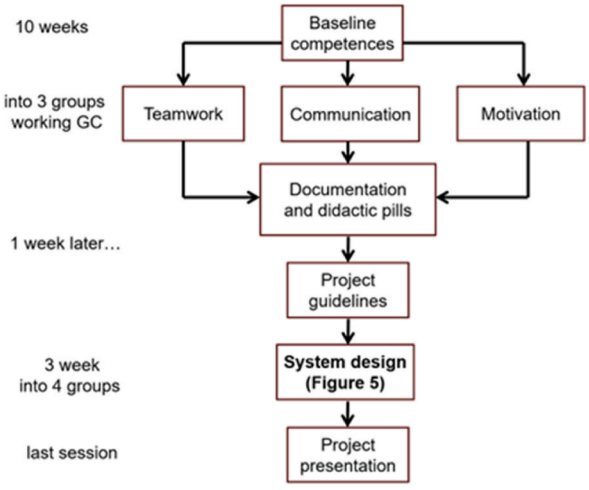

Fig. 4. Case development during the subject.

- Other features for increasing the project's qualification, which were not mandatory, were as follows:
  - o Use of other analogue input or complex data output peripherals.
  - o Use of complex programming structures for data processing.
  - o Use of interrupts.
  - o Development of a prototype model.

Once the prototype was finished, it was presented to the rest of the classmates in the final session of the course, which was held remotely (see the evaluation rubric for the generic competency of oral communication in Table 1). Once again, this modality forced the

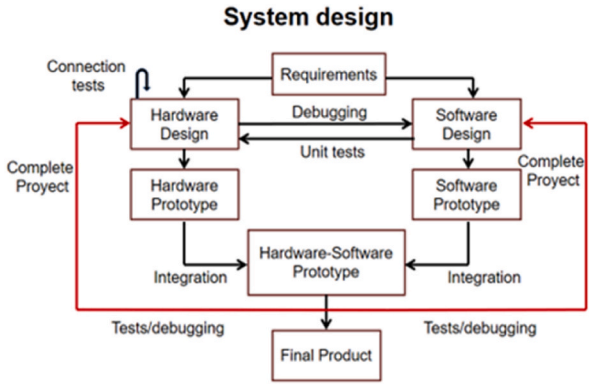

Fig. 5. Steps for the development of the system.

Fig. 6. Example of a prototype developed by one of the groups: P. Galicia, N. Martínez de las Rivas, B. Rico, J. del Río and A. Tricio.

groups to invest extra effort into their preparation, since all the members were required to participate in the presentation but only one of them had the prototype; this assessment completed the evidence on the teamwork competence developed during the course (see the evaluation rubric for generic teamwork competence in Table 2).

At the end of the semester and the exams and grading process had been completed, students were invited to participate an interview to collect their perceptions of their experience with the project as well as their ideas for possible improvements.

e) Outcomes

The initial group for the subject consisted of 18 students (10 girls and 8 boys); these participants had an average age of 19 years and were drawn from the same 2 nd year degree course. They were divided into 3 groups containing between 5 and 7 students each for the preliminary work on competences and into 4 groups containing between 4 and 5 members each for the project. In both cases, the students chose their groups, but the difference in the number of groups and members was intended to prevent a situation in which the same people were involved in both activities. This purpose was achieved.

Regarding the evaluation of the projects, after the use of the rubrics had been presented, although one group stood out from the others and some of the individuals were distinct from each other, all students managed to develop the three competencies and to exhibit outstanding performance. Their results were several percentage points above those of their peers in previous courses in which they had worked on the same competencies using a different methodology.

The ability to participate in the interview was offered to all students but given that the interviews took place at the end of the course and that the exams had already started, the sample consisted of only 6 participants. Nevertheless, the sample was sufficiently representative, as members of all groups were present, including the groups formed for the competence work and those established for

Table 1
Rubric for the assessment of the generic competency of oral communication, level 2 [26].

LEVELS OF MASTERY	INDICATORS	Descriptors				
		1	2	3	4	5
	Delivering interesting, convincing talks	Doesn't manage to capture attention.	Intermittently manages to capture attention.	Manages to capture and maintain attention.	Is convincing.	Noteworthy for power of conviction.
Second level of mastery:	**Voluntarily giving opportune talks in public**	Never volunteers to deliver talk.	Volunteers, but does so inopportunely.	Makes voluntary opportune talks in public.	His/her voluntary talks foster the participation of others.	His/her voluntary contributions inject added value in the process.
Speaking before groups with ease; conveying conviction and assurance, and adapting discourse to suit formal requirements	**Matching speech and body language**	Body language contradicts and distracts from oral discourse.	Speech and body language sometimes contradict each other.	Body language is appropriate to oral discourse.	Modulates body language to emphasize the keys to his/her discourse.	Body language is natural and appropriate for the audience.
	His/her talks are duly prepared	Talk not structured.	Talk not fluid.	The talk shows structure and rigor.	The audience clearly grasps content structure.	The structure and talk are appropriate for the type of audience.
	Helping audience to follow ideas through visual aids	Uses required or reasonably necessary visual aids.	Visual aids help the audience to follow the talk.	Keys to the talk emphasized through visual aids.	Audience grasps keys more easily thanks to visual aids.	The visual aids used help the audience to assimilate content.
	Responding to questions easily and well	Only basic answers.	His/her answers support talk.	Utilizes questions to respond and to develop the talk.	Utilizes questions to stimulate audience interest.	His/her responses generate new observations and questions.

the project.

Considering several previous works on sample size in qualitative studies, two outcomes can be observed. On the one hand, the technique was applied for data collection, and on the other hand, the saturation principle was always considered in the analysis of these data [74]. This principle is based on the extent to which the data collection provides new information in terms of the setting and the possible sample. The aim of qualitative research is to understand people's perceptions in depth and to develop a detailed description [69]. Therefore, a larger sample size may lead to a repetition of information [75].

Regarding the number of users needed, no unanimous agreement concerning this question has been reached. According to Almanasreh et al. [76], the sample selection depends on aspects such as the ease of accessing participants or the possibility of obtaining enough answers regarding the subject under investigation. On the other hand, authors such as Delgado-Rico et al. [77] have noted that the sample that should be employed in a trial depends on the levels of practice and the diversity of knowledge. The characteristics of the user to be interviewed must be defined according to the knowledge of the issue under assessment; simultaneously, the sample size must include a minimum of three users [77]. The instrument proposed, i.e., the Bipolar Laddering Assessment (BLA), fulfils this recommendation, as has been demonstrated by previous studies [78–80].

f) Follow-up

In our study, we used the BLA a SQ technique [81]. This psychological exploration technique allows us to systematise qualitative data in a simple way by categorising them with the goal of organising and ranking them in an intelligible and visual way. The BLA is only one of the many SQ models, but its usefulness for evaluating techniques, technologies, and methodologies in the field of teaching, both exclusively and in combination with quantitative approaches, has previously been demonstrated [82–85]. In this sense, BLA does not include any expert-subject hierarchy, as both participants are experts. Expert 1, the facilitator, is a specialist in user experience, while expert 2, the user, is a specialist in the use of the product, system, method, or technology under evaluation. Through a strategic conversation, the facilitator obtains explicit and relevant information regarding the details that affect the user's experience of using the proposal under evaluation.

The BLA method can be defined as an exploratory technique based on the psychological framework, and it aims to identify the critical factors associated with any user experience. The main goal of the BLA is to identify personal opinions regarding the characteristics of the element under evaluation, including users' frustration, confidence, or gratitude (alongside many others). The BLA technique works to identify positive and negative elements with the goal of identifying the system's advantages and limitations. The aim of a laddering interview is to explore how the qualities of the system, the implications of use, and personal values are connected in the mind of an individual.

One of the most important characteristics of the BLA lies, as has been previously demonstrated [80,86–88], in the fact that its results are valid based on only three samples (interviews with users). The degree of depth of the interviews allows us to obtain scientific and replicable data from very few users (from 2 to 5), identifying from 7 to 10 repetitions that usually do not provide new content or

Table 2
Rubric for the assessment of the generic competency of teamwork, level 2 [26].

LEVELS OF MASTERY	INDICATORS	Descriptors				
		1	2	3	4	5
Second level of mastery: ***Contributing to the consolidation and development of the team, fostering communication, balanced distribution of work, good team atmosphere and cohesion***	**Accepting and respecting group norms**	Doesn't accept or respect group norms.	Questions group norms to suit them to own interests.	Accepts and respects group norms.	Participates in deciding group norms.	Proposes norms to improve the group's functioning and atmosphere. Helps to enforce norms and rules.
	Helping to decide and apply the team's work processes	Doesn't know or apply the methods and procedures agreed by the team.	Has difficulty in understanding and applying established work processes.	Applies good methods and procedures for effective undertaking of the team's work.	Participates actively in designing team's work processes.	Introduces changes in processes to improve quality of team's work.
	Acting constructively to resolve team conflicts	Provokes conflicts in group without contributing solutions.	Avoids addressing conflicts.	Acts positively to resolve conflicts that arise in group.	Sees first symptoms of conflict and acts quickly.	Own actions provide constructive ways out of conflicts before they become prolonged or much worse.
	Helping to bring group together through way of communicating and interacting	Aggressively attacks or questions team's capacity to try to reach an agreement.	Is passive and interacts little with other group members.	Conveys clearly and directly own ideas and opinions to the other team members.	Interacts positively with other group members, supporting and encouraging them.	Proposes ways of getting together apart from formal meetings to improve group cohesion.
	Furthering the social importance of the activity undertaken by the group	Denies or questions utility or importance of team's task.	Is interested in getting members to participate in common activities.	Supports and defends utility and importance of team's task. Makes positive evaluations.	Insists on the importance of each team member's work to the final collective outcome.	Makes others see that what they are doing has repercussions on other groups.

identify common aspects that are important to solve (in negative cases) or to enhance (in positive cases).

In the interview, the user (the student, in our case) is allowed to decide and freely identify the issues that he or she believes to be positive and those that he or she believes to be negative and could thus be improved in the activity under analysis; the user can also provide corresponding justification and detail. At no time does the facilitator suggest specific terms to the student or ask direct questions to avoid conditioning the student. The student is the one who freely and spontaneously mentions or does not mention the topics that he or she wants to discuss. The value of this type of survey lies precisely in the fact that it is possible to know which aspects are relevant (either in a positive or improvable way) for the users, independently of what the teacher has planned with regard to the activity, or the methodology used.

Students can also assess each strength and each weakness that they have highlighted in the BLA survey by assigning a grade from 1 to 10. As noted by Pifarré and Tomico [81], extreme marks have a strong emotional component. Extremely positive marks (9 or 10) indicate that the student is grateful for that element, while extremely negative marks (1 or 2) signify that the student especially dislikes

Table 3
Global results regarding positive elements according to the BLA.

Item Id	Description	Av. Score (Av)	Mention Index (MI)
CP1	Implementation: further utility	9,25	66,67 %
CP2	Amazing method	8,75	66,67 %
CP3	Teamwork competence improvement	8,50	66,67 %
CP4	Objective (achievable and reasonable)	6,63	50,00 %
CP5	Teamwork task distribution	6,63	50,00 %
CP6	Further professional uses	5,00	50,00 %
CP7	Motivation	9,00	33,34 %
CP8	TIC uses	8,50	33,34 %
PP1	Time	10,00	16,67 %
PP2	Productivity improvement	10,00	16,67 %
PP3	Teacher's support	9,00	16,67 %
PP4	Strengthening relationships	9,00	16,67 %

that element. Finally, the student must propose an improvement for each of the issues mentioned, whether they are improvable or even positive (excluding issues that received a rating of 10), as any aspect could be improved to some degree.

The answers obtained through the BLA survey are open-ended; that is, they allow for multiple responses. To be able to systematise the information and extract some common points that can facilitate further analysis and assessment, the first task is to organise the answers according to themes. In other words, the comments are classified as "common" or "particular". This approach facilitates subsequent quantification to evaluate the weight of each issue based on the total number of responses. Thus, this information makes it possible to identify not only the strong points of the evaluation but also the extent to which possible solutions have been identified and what those possible solutions are. Thus, the elements obtained are divided into 6 groups:.

- Common positive (CP) elements: elements considered positive and mentioned by more than one user. Identified as CP# in Tables 3, 4 and 8.
- Particular positive (PP) elements: elements considered positive and mentioned by only one user. Identified as PP# in Tables 3, 4 and 8.
- Common negative (CN) elements: elements considered negative and mentioned by more than one user. Identified as CN# in Tables 5, 6 and 9.
- Particular negative (PN) elements: elements that are considered negative and referred to by only one user. Identified as PN# in Tables 5, 6 and 9.
- Common solutions (CS): proposals for improvements mentioned by more than one user. Identified as CS# in Table 8.
- Particular solutions (PS): proposals for improvements mentioned by only one of the users. Identified as PS# in Table 8.

In a first approach, if we compare the common positive elements with the negative elements, we can see that, in the case of the positive elements, 3 stand out due to a mention rate of 66.67 % and a high Av. Thus, the students rated "Implementation: further utility" (Av 9.25), "Amazing method" (Av 8.75) and "Teamwork competence improvement" (8.50) highly. However, only one item reached a consensus of 66.67 % among the students, with a medium-low Av, i.e., "Work: task distribution between group members" (Av 3.15), which was simultaneously caused by the implementation of teamwork; nevertheless, this item was viewed as positive. Furthermore, if the percentages of CPx on the one hand (333.35) and those of CNx on the other hand (250.03) could be added together, it could be said that the number of positive aspects reported was significantly higher than the number of negative aspects.

After asking about the positive and negative aspects, the third step of the BLA involved, as previously mentioned, collecting proposals for improvement and change in relation to the positive and negative aspects of the experience. Table 7 shows the global set of solutions thus identified, both common (CS#) and (PS#). The MI is based on the number of citations received for each aspect, considering the analysed sample of six students, and providing a relative value. The number of citations considers the fact that the same student may have provided the same solution to several issues, reflecting the percentages described. To understand this distribution of solutions more concretely, we must turn to Tables 6 and 7, which present the breakdown of solutions per user for each positive and negative aspect identified.

The most relevant items obtained from the BLA and the ways in which they relate to the project objective are identified below. Regarding the "common positive elements" (see Tables 3 and 4), it can be observed that all items except for CP6 (ICT uses and professional training) were mentioned by at least half of the participants (MI: 50.00 % with an average rating of almost 7, and MI: 66.67 % with an average rating of between 8 and 10). These items respond to aspects related to the characteristics sought when the project was designed: the relevance of and tension between theory and experience (CP1), autonomy (CP2), academic challenges (CP4) and collaboration (CP3 and CP5). The "particular positive elements" are also included in some of these characteristics. This grouping of citations of positive aspects is very relevant, as it indicates a strongly homogeneous experience, which features very clear indicators of positive aspects that must be reinforced in future iterations.

Regarding the "common negative elements" (see Table 5 and 46), only two (CN2 and CN1) pertain to the concerns of at least 50 % of the participants, with an average rating between 3 and 5, albeit with a wide range (2–6); these items pertain to aspects related to the internal functioning of the group. The rest of the issues, both common and, are also related to the competence of teamwork or to the

Table 4
Positive elements according to the BLA by user.

Item Id	User 1	User 2	User 3	User 4	User 5	User 6
CP1		9		10	9	9
CP2	9	9			8	9
CP3	8		8	10	8	
CP4		9	10			7
CP5		10	9			7
CP6	5				5	5
CP7	8					10
CP8	7					10
PP1		10				
PP2				10		
PP3					9	
PP4			9			

Table 5
Global results regarding negative elements according to the BLA.

Item Id	Description	Av. Score (Av)	Mention Index (MI)
CN1	Work: task distribution between group members	3,25	66,67 %
CN2	On-line interaction with the group	4,67	50,00 %
CN3	Time of work/delivery	4,00	33,34 %
CN4	Number of group members	3,00	33,34 %
CN5	Personal prior knowledge of the technology	2,78	33,34 %
CN6	Lack of answers to doubts	2,45	33,34 %
PN1	Group composition	5,00	16,67 %
PN2	Support/Initial explanation	5,00	16,67 %
PN3	Lack of knowledge	4,00	16,67 %
PN4	On-line content	2,00	16,67 %

Table 6
Negative elements according to the BLA by user.

Item Id	User 1	User 2	User 3	User 4	User 5	User 6
CN1			3	5	3	
CN2	2			6	6	2
CN3			2		6	
CN4			2			
CN5	4	5				3
CN6		3				4
PN1	5					
PN2						5
PN3				4		
PN4						2

Table 7
Common and particular solutions for both the positive and negative aspects identified by global citations.

Item Id	Improvement proposed	Cited	(MI)
CS1	Nothing	15	250.00
CS2	Improve Task distribution in the group//organization	8	133,33
CS3	More initial explanations	4	66,67
CS4	Simplify the challenge for a real case or basic example visualization	4	66,67
CS5	More Teamwork practices	3	50,00
CS6	Improve doubts and problems resolution (teachers and contents)	3	50,00
CS7	More time in face-to-face sessions	2	33,33
CS8	More implementation in the subjects	2	33,33
PS1	Anonymous Teamwork peer-assessment	1	16,67
PS2	Anonymous votes for group selection	1	16,67
PS3	Clarify temporalization	1	16,67
PS4	Learning by Challenge	1	16,67
PS5	More support contents	1	16,67
PS6	Identify possible professional uses for new practices	1	16,67
PS7	Sessions with professionals	1	16,67
PS8	Practices in companies	1	16,67

heterogeneity in terms of knowledge mentioned in the introduction. The results highlight a problem about teamwork, either due to the selection of team members and/or the internal lack of coordination. In this matter, it is necessary to reinforce the explanation, indications and support included in future iterations to ensure that teamwork, its management, and the solution of incidents do not affect the students and groups in such a global way.

Similarly, the solutions and/or improvements table (see Table 7) shows that most of the students mentioned teamwork and the need for more knowledge for the development of the project. The students asked for a better organisation regarding the distribution of tasks within the group, a simplified version of what is requested with respect to the project, as well as more support in terms of initial explanations as well as in terms of doubts and content. Moreover, the very need for peer selection or peer co-evaluation seems to have caused these students anxiety, as they requested that these actions be carried out anonymously.

If each proposal is compared with the positive (see Table 8) or negative (see Table 9) element that motivated it, for most of the positive elements, both common and (CP# and PP#), no improvement proposals are considered to be necessary. In fact, the proposals for improvement thus presented coincide with those presented in Table 9 as proposals for the improvement of negative aspects. Proposals referring to positive aspects indicate satisfaction with the dynamics of teamwork despite its drawbacks. Thus, the proposed improvements refer to working in the same way on more occasions, both in this subject and in other subjects. This finding shows once

Table 8
Elements pertaining to the improvement of positive aspects as identified by the user.

Positive Item	Possible Improvement	User 1	User 2	User 3	User 4	User 5	User 6
CP1	Simplify the challenge for a real case or basic example visualization		1				
CP1	Nothing				1		
CP1	Nothing					1	
CP1	More implementation in the subjects						1
CP2	More Teamwork practices	1					
CP2	Nothing					1	
CP2	More implementation in the subjects						1
CP3	Nothing	1					
CP3	Improve Task distribution in the group//organization			1			
CP3	Nothing				1		
CP3	Nothing					1	
CP4	More initial explanations		1				
CP4	Nothing			1			
CP4	Nothing					1	
CP4	Simplify the challenge for a real case or basic example visualization						1
CP5	Nothing		1				
CP5	Nothing			1			
CP5	Improve Task distribution in the group//organization						1
CP6	Simplify the challenge for a real case or basic example visualization	1					
CP7	Identify possible professional uses for new practices	1					
CP7	Sessions with professionals					1	
CP7	Practices in companies	1					1
CP8	Nothing						
CP8	Nothing						1
CP6	More initial explanations						1
PP1	Nothing		1				
PP2	Nothing				1		
PP3	Nothing					1	
PP4	Nothing			1			

Table 9
Elements pertaining to the improvement of negative aspects as identified by the user.

Negative Item	Possible Improvement	User 1	User 2	User 3	User 4	User 5	User 6
CN1	Improve Task distribution in the group//organization	1					
CN1	Improve Task distribution in the group//organization			1			
CN1	Anonymous Teamwork peer-assessment				1		
CN1	Improve Task distribution in the group//organization					1	
CN2	More time in face-to-face sessions				1		
CN2	Improve Task distribution in the group//organization				1		
CN2	More time in face-to-face sessions					1	
CN2	Improve doubts and problems resolution (teachers and contents)						1
CN3	Clarify temporalization			1			
CN3	More Teamwork practices					1	
CN4	Improve Task distribution in the group//organization	1					
CN4	Improve Task distribution in the group//organization			1			
CN4	Learning by Challenge			1			
CN5	More initial explanations		1				
CN5	Improve doubts and problems resolution (teachers and contents)						1
CN6	Improve doubts and problems resolution (teachers and contents)		1				
CN6	Simplify the challenge for a real case or basic example visualization						1
NP1	Anonymous votes for group selection	1					
NP2	More Teamwork practices						1
NP3	More initial explanations				1		
NP4	More support contents						1

again that the bases/standards of teamwork must be reconsidered but that this approach should undoubtedly continue to be applied to the subject and even gain greater relevance, given the good results. However, it is necessary to offer greater teaching support.

3. Discussion

The motivation for this study is the need to develop several competences, both generic and specific, through a specific subject in a double engineering program; the difficulties that the programme itself entails are also relevant in this context. To determine whether the objective has been achieved, the application of the BLA questionnaire at the end of the experience is considered, resulting in the findings discussed in the previous section. The adaptation of a software-hardware project that usually features a face-to-face approach

to the online format involves adapting the teacher's monitoring of the student groups to this new medium as well as the interactions that occurred within the student groups themselves. This adaptation represents an innovation in its own right. In addition, the project follows the guidelines of Challenge-Based Learning to maintain the motivation of the students, which is heavily weakened by distance learning.

The following aspects can be highlighted based on these results.

- The specific competences of the subject were satisfactorily developed. The four teams managed to produce projects that met the assessment criteria at a high level, albeit with different levels of depth. Although the marks are not shown in the tables, the students themselves noted in their comments that they were satisfied with the work they performed and that they observed that what they had learned in the subject became tangible in the form of a project.
- One point of clarification should be noted regarding communication skills. The competence that was intended to be addressed in the course focused on communication "in public" at performance level 2. Initially, the fact that students were required to present the results of the projects remotely, with each member of the team presenting from home, might be viewed as a disadvantage. However, in the end, this approach did not prove to be a disadvantage. Moreover, it is possible that the students may have improved this presentation by using images and videos alongside the slide-based visual support. The students made no direct mention of this presentation format in the final interviews, whether regarding positive or negative elements. However, they did mention communication within the groups as a negative aspect, mainly due to the medium used, as it was necessary to complete a large part of the project outside the classroom, i.e., remotely. Likewise, although students did not explicitly mention communication with the teacher, some of the negative aspects, such as "Lack of answers to doubts" or "Support/Initial explanation", addressed this same problem, i.e., the difficulty of resolving specific doubts about the projects when the work was completed remotely. This situation was due to the dual hardware/software aspect of the projects, in which context direct manipulation of devices is required to find errors. However, although these situations were viewed seen as problems and/or negative aspects by the students, the authors of this work believe that the lower amount of face-to-face support provided by the teacher during the work was one reason for which the groups were required to invest more effort in the tasks of understanding and solving the problems by themselves, thus increasing their autonomy and resulting in better projects and a better understanding of the subject than in previous years. Thus, for example, this competence of oral communication, which is listed at level 2 in the map of competences of the degree, was developed in many respects at level 3 due to the implicit complexity of the exposition through videoconferencing software.
- The competence of teamwork caused the most difficulties. This fact was evident both in the aspects with the lowest scores and in the proposed solutions. As already mentioned, this year, the challenges faced were greater, as it was necessary for students to complete a large portion of the project in groups that were nevertheless remote, even though hardware and software elements could not be shared. Moreover, when the work was performed in the classroom, the groups were "supported" by the teacher regarding both resolving doubts and the functioning of the group itself, an issue which was also partly delegated to the teacher. However, considering the results concerning the projects, these problems were solved; thus, students' perceptions suggest that there may have been imbalances in terms of involvement or performance on the part of some members of the group, an issue which is more difficult to address in this modality. The autonomous work associated with the remote group required a level of self-regulation to which students were not accustomed, leading us to think that, in addition to the teamwork competence, the competence of autonomy must be reinforced.
- Finally, despite the problems detailed above, it is believed that a high degree of motivation was achieved. This conclusion is based on the positive elements drawn from the interviews, which corresponded to the factors considered when designing the project methodology.

Thus, the competence that must be fundamentally improved in future editions and subjects is that of teamwork, with all the relevant aspects, including interpersonal communication within the team.

Regarding the resolution of doubts to address the heterogeneity in terms of knowledge, independent of the environment or context in which the task is developed, a whole series of videos and new support materials have been developed and are in use. Additionally, the order of some activities has been changed to offer more face-to-face teamwork sessions, thus returning to a certain degree of post pandemic normality; finally, a series of previous activities that were not directly related to the project have been adapted to ensure that teamwork focused on the objectives of the practice is promoted.

4. Conclusion

This experience focuses on the development of motivation and generic competences in students in a transversal way regarding a specific competence in the field of electronics. It takes place in the context of a specific subject and degree, in a blended environment and using an innovative methodology, i.e., Challenge-Based Learning; its background is the Sustainable Development Goals. The choice of the problem that can truly represent a challenge, the steps followed, the facilitating role of the teacher in this methodology and the way in which its application is evaluated make the experience rigorous.

This case study has implications in several areas, especially for students and future professionals, who can have a closer encounter with professional reality through a challenge. The challenge, which is focused on the sustainability of the planet, raises awareness, and allows these students to include sustainability in their decision-making criteria. Likewise, this study also has implications for the university teaching community pertaining to the aim of developing generic competences and motivation further in an environment in which face-to-face presence is naturally combined with moments of blended learning.

The qualitative approach employed in this research has offered us a precise characterisation of the positive and negative aspects of the case study. Placing the student at the centre of the user experience and teaching innovation allows him or her to participate in educational improvement and facilitates an intrinsic improvement in motivation and therefore in academic results.

The limitations of this approach are precisely due to the specific nature of the environment in which it was employed. The extrapolation to new working groups and even the possibility of including control groups and a larger number of samples can help us combine the qualitative approach used in this research with a quantitative approach. This method can lead to a mixed study that can allow us to define the aspects that must be improved and supported more specifically. In this respect, we are already working to expand the study to more groups pursuing the same degree and other entities collaborating on the project that frames the study.

Therefore, it is desirable to conduct future research into new experiences in other contexts featuring new specific competences, subjects, degrees, or other challenges pertaining to other SDGs. However, these new studies should also guarantee methodological rigour to ensure that they are comparable and complementary to the results found in this case.

Ethics statement

The research presented, as well as the design, collection, and management of its data, has been POSITIVE evaluated and APPROVED, by the Ethics Committee of the Ramon Llull University with the file number: CER URL_2020_2021_009 as well as by the Ethics Committee of the University of Deusto, with the reference number ETK-26/20–21. Informed consent was obtained from all subjects involved in the study. The authors declare no conflict of interest.

Data availability statement

The data associated with our study is not deposited into a publicly available repository due it has some personal data of students. In case of necessity or request, the information would be anonymized and provided upon demand. The data is the property of the project that has funded the research.

CRediT authorship contribution statement

Susana Romero-Yesa: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing – original draft, Writing – review & editing. **David Fonseca:** Data curation, Formal analysis, Funding acquisition, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. **Marian Aláez:** Conceptualization, Supervision, Validation, Writing – original draft. **Daniel Amo-Filva:** Conceptualization, Data curation, Formal analysis, Methodology, Resources, Supervision, Writing – original draft.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:David Fonseca reports financial support was provided by Aristos Campus Mundus. Non

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References

[1] S. Necchi, E. Peña, D. Fonseca, M. Arnal, Improving teamwork competence applied in the building and construction engineering final degree project, Int. J. Eng. Educ. 36 (2020) 328–340.
[2] E. Peña, D. Fonseca, N. Martí, Relationship between learning indicators in the development and result of the building engineering degree final project, in: Proceedings of the ACM International Conference Proceeding Series, 2016, pp. 335–340, 02-04-Nove.
[3] C. Benito Olalla, A. Merino, Competences for sustainability in undergraduate business studies: a content analysis of value-based course syllabi in Spanish universities, Int. J. Manag. Educ. 17 (2019) 239–253, https://doi.org/10.1016/j.ijme.2019.02.006.
[4] J. Paricio, A. Fernández, I. Fernández, Cartografía de la buena docencia universitaria. Un marco para el desarrollo del profesorado basado en la investigación, vol. 52, Narcea Ediciones, Madrid, Spain, 2019. ISBN: 9788427726147.
[5] S. Iqbal, Z.A. Bhatti, A qualitative exploration of teachers' perspective on smartphones usage in higher education in developing countries, Int. J. Educ. Technol. High. Educ. 17 (2020), https://doi.org/10.1186/s41239-020-00203-4.
[6] E. Rolf, O. Knutsson, R. Ramberg, An analysis of digital competence as expressed in design patterns for technology use in teaching, Br. J. Educ. Technol. 50 (2019) 3361–3375, https://doi.org/10.1111/bjet.12739.
[7] M. Domingo-Coscollola, A. Bosco, S.C. Segovia, J.A.S. Valero, Fostering teacher's digital competence at university: the perception of students and teachers, Rev. Invest. Educ. 38 (2020) 167–182, https://doi.org/10.6018/rie.340551.
[8] C. Mercader, J. Gairín, University teachers' perception of barriers to the use of digital technologies: the importance of the academic discipline, International Journal of Educational Technology in Higher Education 17 (1) (2020) 4, https://doi.org/10.1186/s41239-020-0182-x.
[9] E. Peña, D. Fonseca, N. Marti, J. Ferrándiz, Relationship between specific professional competences and learning activities of the building and construction engineering degree final project, Int. J. Eng. Educ. 34 (2018) 924–939.

[10] F.J. Rodríguez-Sedano, M. Conde, C. Fernández-Llamas, Measuring teamwork competence development in a multidisciplinary project based learning environment, in: Proceedings of the Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 10924, LNCS, 2018, pp. 466–479.

[11] M. Conde, F.J. Rodríguez-Sedano, C. Fernández, A. Gutiérrez-Fernández, L. Fernández-Robles, M. Castejón Limas, A Learning Analytics tool for the analysis of students' Telegram messages in the context of teamwork virtual activities, in: Proceedings of the ACM International Conference Proceeding Series, 2020, pp. 719–724.

[12] L. De Grez, M. Valcke, I. Roozen, The impact of an innovative instructional intervention on the acquisition of oral presentation skills in higher education, Comput. Educ. 53 (1) (2009) 112–120, https://doi.org/10.1016/j.compedu.2009.01.005.

[13] A. Greculescu, L.-L. Todorescu, M.-M. Popescu-Mitroi, A.-C. Fekete, Oral communication competence and higher technical engineering, Procedia - Soc. Behav. Sci. 128 (2014) 169–174, https://doi.org/10.1016/j.sbspro.2014.03.138.

[14] D. Verano-Tacoronte, S.M. González-Betancor, A. Bolívar-Cruz, M. Fernández-Monroy, I. Galván-Sánchez, Valoración de la competencia de comunicación oral de estudiantes universitarios a través de una rúbrica fiable y válida, Rev. Bras. Educ. 21 (2016) 39–60, https://doi.org/10.1590/S1413-24782016216403.

[15] A.C. Mikkelson, J.A. York, J. Arritola, Communication competence, leadership behaviors, and employee outcomes in supervisor-employee relationships, Bus. Commun. Q. 78 (2015) 336–354, https://doi.org/10.1177/2329490615588542.

[16] D. Fonseca, N. Martí, E. Redondo, I. Navarro, A. Sánchez, Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models, Comput. Hum. Behav. 31 (2014) 434–445, https://doi.org/10.1016/j.chb.2013.03.006.

[17] D. Fonseca, M.Á. Conde, F.J. García-Peñalvo, Improving the information society skills: is knowledge accessible for all? Univers. Access Inf. Soc. 17 (2018) 229–245, https://doi.org/10.1007/s10209-017-0548-6.

[18] M.V. Sanchez-Sepulveda, D. Fonseca, A. García-Holgado, F.J. García-Peñalvo, J. Franquesa, E. Redondo, F. Moreira, Evaluation of an interactive educational system in urban knowledge acquisition and representation based on students' profiles, Expet Syst. 37 (2020), https://doi.org/10.1111/exsy.12570.

[19] M.S. Beqiri, N.M. Chase, A. Bishka, Online course delivery: an empirical investigation of factors affecting student satisfaction, J. Educ. Bus. 85 (2009) 95–100, https://doi.org/10.1080/08832320903258527.

[20] M. Ozkan, B. Solmaz, The changing face of the employees–generation Z and their perceptions of work (a study applied to university students), Procedia Econ. Finance 26 (2015) 476–483, https://doi.org/10.1016/S2212-5671(15)00876-X.

[21] S. Freeman, S.L. Eddy, M. McDonough, M.K. Smith, N. Okoroafor, H. Jordt, M.P. Wenderoth, Active learning increases student performance in science, engineering, and mathematics, Proc. Natl. Acad. Sci. U.S.A. 111 (2014) 8410–8415, https://doi.org/10.1073/pnas.1319030111.

[22] K. Moore, R.S. Frazier, Engineering education for generation Z, Am. J. Eng. Educ. 8 (2) (2017) 111–126, https://doi.org/10.19030/ajee.v8i2.10067.

[23] B.D. Jones, Motivating students to engage in learning: the MUSIC model of academic motivation, Int. J. Teach. Learn. High. Educ. 21 (2009) 272–285.

[24] D. Fonseca, F.J. García-Peñalvo, Interactive and collaborative technological ecosystems for improving academic motivation and engagement, Univers. Access Inf. Soc. 18 (2019) 423–430, https://doi.org/10.1007/s10209-019-00669-8.

[25] A. Villa Sánchez, O. Villa Leicea, El aprendizaje basado en competencias y el desarrollo de la dimensión social en las universidades, Educar 15–48 (2007), https://doi.org/10.5565/rev/educar.149.

[26] A. Villa, M. Poblete, Mensajero, Aprendizaje basado en competencias: una propuesta para la evaluación de las competencias genéricas. *Vicerectorado de Innovación y Calidad, ICE de la Universidad de Deusto*, 2007. Bilbao (Spain), 336pp. ISBN: 978-84-271-2833-0.

[27] M.L. Cruz, G.N. Saunders-Smits, P. Groen, Evaluation of competency methods in engineering education: a systematic review, Eur. J. Eng. Educ. 45 (5) (2020) 729–757, https://doi.org/10.1080/03043797.2019.1671810.

[28] M.A. Hutchison, D.K. Follman, M. Sumpter, G.M. Bodner, Factors influencing the self-efficacy beliefs of first-year engineering students, J. Eng. Educ. 95 (2006) 39–47.

[29] S.E. Rodenbusch, P.R. Hernandez, S.L. Simmons, E.L. Dolan, Early engagement in course-based research increases graduation rates and completion of science, engineering, and mathematics degrees, CBE-Life Sci. Educ. 15 (2016), https://doi.org/10.1187/cbe.16-03-0117.

[30] F.J. García-Peñalvo, A. Corell, V. Abella-García, M. Grande, La evaluación online en la educación superior en tiempos de la COVID-19, Educ. Knowl. Soc. 21 (2020) 26, https://doi.org/10.14201/eks.23086.

[31] L. Mishra, T. Gupta, A. Shree, Online teaching-learning in higher education during lockdown period of COVID-19 pandemic, International journal of educational research open 1 (2020), 100012, https://doi.org/10.1016/j.ijedro.2020.100012.

[32] H.J. Passow, C.H. Passow, What competencies should undergraduate engineering programs emphasize? A systematic review, J. Eng. Educ. 106 (3) (2017) 475–526, https://doi.org/10.1002/jee.20171.

[33] J. Qadir, A. Al-Fuqaha, A student primer on how to thrive in engineering education during and beyond COVID-19, Educ. Sci. 10 (2020) 1–22, https://doi.org/10.3390/educsci10090236.

[34] E. Berry, R. Lingard, Teaching communication and teamwork in engineering and computer science, in: Proceedings of the ASEE Annual Conference Proceedings, 2001, pp. 9379–9389.

[35] T. Chowdhury, H. Murzi, Literature review: exploring teamwork in engineering education, in: Proceedings of the Proceedings of the 8th Research in Engineering Education Symposium, REES 2019 - Making Connections, 2019, pp. 244–252.

[36] R. Alba-Flores, F. Rios, Incorporating peer review techniques to enhance students' communication skills and team performance in engineering capstone projects, Int. J. Eng. Educ. 35 (2019) 1969–1982.

[37] Y.M. Tang, P.C. Chen, K.M.Y. Law, C.H. Wu, Y. yip Lau, J. Guan, D. He, G.T.S. Ho, Comparative analysis of Student's live online learning readiness during the coronavirus (COVID-19) pandemic in the higher education sector, Comput. Educ. 168 (2021), 104211, https://doi.org/10.1016/j.compedu.2021.104211.

[38] V. Baltac, European universities and the ICT Industry, Proceedings of the IFIP International Federation for Information Processing 280 (2008) 81–94.

[39] C.A. Mertler, Designing scoring rubrics for your classroom, Practical Assess. Res. Eval. 7 (2001).

[40] K. Montgomery, Authentic tasks and rubrics: going beyond traditional assessments in college teaching, Coll. Teach. 50 (2002) 34–40, https://doi.org/10.1080/87567550209595870.

[41] H.G. Andrade, Teaching with rubrics: the good, the Bad, and the Ugly, Coll. Teach. 53 (2005) 27–31, https://doi.org/10.3200/CTCH.53.1.27-31.

[42] A. Jonsson, G. Svingby, The use of scoring rubrics: reliability, validity and educational consequences, Educ. Res. Rev. 2 (2007) 130–144.

[43] A.A. Mitchell, Introduction to rubrics: an assessment tool to save grading time, convey effective feedback and promote student learning, J. Coll. Student Dev. 47 (2006) 352–355, https://doi.org/10.1353/csd.2006.0033.

[44] O. Kallioinen, Defining and comparing generic competences in higher education, Eur. Educ. Res. J. 9 (1) (2010) 56–68, https://doi.org/10.2304/eerj.2010.9.1.56.

[45] M.R. Rivasy, M.C. De La Serna, E. Martínez-Figueira, Electronic rubrics to assess competences in ICT subjects, Eur. Educ. Res. J. 13 (5) (2014) 584–594, https://doi.org/10.2304/eerj.2014.13.5.584.

[46] M. Borrego, E.P. Douglas, C.T. Amelink, Quantitative, qualitative, and mixed research methods in engineering education, J. Eng. Educ. 98 (1) (2009) 53–66, https://doi.org/10.1002/j.2168-9830.2009.tb01005.x.

[47] D. Fonseca, F.J. García-Peñalvo, Interactive and collaborative technological ecosystems for improving academic motivation and engagement, Univers. Access Inf. Soc. 18 (3) (2019) 423–430, https://doi.org/10.1007/s10209-019-00669-8.

[48] K.A. Nguyen, M. Borrego, C.J. Finelli, M. DeMonbrun, C. Crockett, S. Tharayil, P. Shekhar, C. Waters, R. Rosenberg, Instructor strategies to aid implementation of active learning: a systematic literature review, Int. J. STEM Educ. 8 (2021) 1–18, https://doi.org/10.1186/s40594-021-00270-7.

[49] S. Olmos Migueláñez, Evaluación Formativa y sumativa de estudiantes universitarios: Aplicación de las tecnologías a la evaluación educativa, Teoría la Educ. Educ. y Cult. en la Soc. la Inf. 10 (2009) 305–307, https://doi.org/10.14201/gredos.18453.

[50] J.-I. Löfstedt, Qualitative research methods in education, Interchange 21 (1990) 73–80.

[51] C.A. McKim, The value of mixed methods research: a mixed methods study, J. Mix. Methods Res. 11 (2017) 202–222, https://doi.org/10.1177/1558689815607096.

[52] Y.I. Bangi, Prevalence of mixed methods research in education journals, Int. J. Acad. Res. Bus. Soc. Sci. 8 (2018), https://doi.org/10.6007/ijarbss/v8-i6/4182.
[53] H. Liao, J. Hitchcock, Reported credibility techniques in higher education evaluation studies that use qualitative methods: a research synthesis, Eval. Progr. Plann. 68 (2018) 157–165, https://doi.org/10.1016/j.evalprogplan.2018.03.005.
[54] J.A. Leydens, B.M. Moskal, M.J. Pavelich, Qualitative methods used in the assessment of engineering education, J. Eng. Educ. 93 (2004) 65–72, https://doi.org/10.1002/j.2168-9830.2004.tb00789.x.
[55] S. Daly, A. McGowan, P. Papalambros, Using qualitative research methods in engineering design research, in: Proceedings of the Proceedings of the International Conference on Engineering Design, 2 DS7vols. 5–02, ICED, 2013, pp. 203–212.
[56] H.R. Jamali, Does research using qualitative methods (grounded theory, ethnography, and phenomenology) have more impact? Libr. Inf. Sci. Res. 40 (2018) 201–207, https://doi.org/10.1016/j.lisr.2018.09.002.
[57] H. Liao, J. Hitchcock, Reported credibility techniques in higher education evaluation studies that use qualitative methods: a research synthesis, Eval. Progr. Plann. 68 (2018) 157–165, https://doi.org/10.1016/j.evalprogplan.2018.03.005.
[58] E.B. Kozleski, The Uses of qualitative research: powerful methods to inform evidence-based practice in education, Res. Pract. Persons Severe Disabil. 42 (2017) 19–32, https://doi.org/10.1177/1540796916683710.
[59] L.R. Lattuca, J.M. Domagal-Goldman, Using qualitative methods to assess teaching effectiveness, N. Dir. Inst. Res. 2007 (2007) 81–93, https://doi.org/10.1002/ir.233.
[60] K. MacKinnon, L. Marcellus, J. Rivers, C. Gordon, M. Ryan, D. Butcher, Student and educator experiences of maternal-child simulation-based learning: a systematic review of qualitative evidence protocol, JBI database Syst. Rev. Implement. reports 13 (2015) 14–26.
[61] H.W. Tseng, H. Yeh, Te Team members' perceptions of online teamwork learning experiences and building teamwork trust: a qualitative study, Comput. Educ. (2013), https://doi.org/10.1016/j.compedu.2012.11.013.
[62] T. Piyatamrong, J. Derrick, A. Nyamapfene, Technology-mediated higher education provision during the COVID-19 pandemic: a qualitative assessment of engineering student experiences and sentiments, J. Eng. Educ. Transform. 34 (2021) 290–297, https://doi.org/10.16920/jeet/2021/v34i0/157158.
[63] J.E. Sale, L.H. Lohfeld, & Brazil, K.; Revisiting the quantitative-qualitative debate: implications for mixed-methods research, Qual. Quantity 36 (2002) 43–53, https://doi.org/10.1023/A:1014301607592.
[64] E.J. Wolf, K.M. Harrington, S.L. Clark, M.W. Miller, Sample size requirements for structural equation models: an evaluation of power, Bias, and solution propriety, Educ. Psychol. Meas. 73 (2013) 913–934, https://doi.org/10.1177/0013164413495237.
[65] A. Ghasemi, S. Zahediasl, Normality tests for statistical analysis: a guide for non-statisticians, Int. J. Endocrinol. Metabol. 10 (2) (2012) 486, 10.5812%2Fijem.3505.
[66] E. Guadagnoli, W.F. Velicer, Relation of sample size to the stability of component patterns, Psychol. Bull. (1988), https://doi.org/10.1037/0033-2909.103.2.265.
[67] A.B. Costello, J.W. Osborne, Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis, Practical Assess. Res. Eval. (2005), https://doi.org/10.7275/jyj1-4868.
[68] P. Samuels, Whats is ideal sample size in qualitative research?, Available online: https://www.researchgate.net/post/Whats_is_ideal_sample_size_in_qualitative_research. (Accessed 23 March 2021).
[69] K. Vasileiou, J. Barnett, S. Thorpe, T. Young, Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period, BMC Med. Res. Methodol. 18 (2018), https://doi.org/10.1186/s12874-018-0594-7.
[70] S.L. Dworkin, Sample size policy for qualitative studies using in-depth interviews, Arch. Sex. Behav. 41 (2012) 1319–1320.
[71] M. Mason, Sample size and saturation in PhD studies using qualitative interviews, Forum Qual. Sozialforsch. 11 (2010), https://doi.org/10.17169/fqs-11.3.1428.
[72] J.C. Overholser, Elements of the Socratic method: I. Systematic questioning, Psychotherapy 30 (1993) 67–74.
[73] M. Turkcapar, M. Kahraman, A. Sargin, Guided discovery with socratic questioning, J. Cogn. Psychother. Res. 4 (2015) 47, https://doi.org/10.5455/jcbpr.188198.
[74] M. Sandelowski, Sample size in qualitative research, Res. Nurs. Health 18 (2) (1995) 179–183, https://doi.org/10.1002/nur.4770180211.
[75] E. Villegas, D. Fonseca, E. Peña, P. Bonet, S. Fernández-guinea, Qualitative assessment of effective gamification design processes using motivators to identify game mechanics, Sensors (2021) 21, https://doi.org/10.3390/s21072556.
[76] E. Almanasreh, R. Moles, T.F. Chen, Evaluation of methods used for estimating content validity, Res. Soc. Adm. Pharm. 15 (2) (2019) 214–221, https://doi.org/10.1016/j.sapharm.2018.03.066.
[77] E. Delgado-Rico, H. Carretero-Dios, W. Ruch, Content validity evidences in test development: an applied perspective, Int. J. Clin. Health Psychol. 12 (2012) 449–460, https://doi.org/10.5167/uzh-64551.
[78] D. Fonseca, J. Cavalcanti, E. Peña, V. Valls, M. Sanchez-Sepúlveda, F. Moreira, I. Navarro, E. Redondo, Mixed assessment of virtual serious games applied in architectural and urban design education, Sensors (2021) 21, https://doi.org/10.3390/s21093102.
[79] D. Fonseca, I. Navarro, I. de Renteria, F. Moreira, Á. Ferrer, O. de Reina, Assessment of wearable virtual reality technology for visiting world heritage Buildings: an educational approach, J. Educ. Comput. Res. 56 (2018) 940–973, https://doi.org/10.1177/0735633117733995.
[80] C. Campanyà, D. Fonseca, D. Amo, N. Martí, E. Peña, Mixed analysis of the flipped classroom in the concrete and steel structures subject in the context of covid-19 crisis outbreak. A pilot study, Sustain. Times (2021) 13, https://doi.org/10.3390/su13115826.
[81] M. Pifarré, O. Tomico, Bipolar laddering (BLA): a participatory subjective exploration method on user experience, in: Proceedings of the Proc. DUX, conference on Designing for User eXperiences, 2007, pp. 1–13, 2007.
[82] M. Sanchez-Sepulveda, D. Fonseca, J. Franquesa, E. Redondo, Virtual interactive innovations applied for digital urban transformations. Mixed approach, Future Generat. Comput. Syst. (2019), https://doi.org/10.1016/j.future.2018.08.016.
[83] D. Fonseca, F. Valls, E. Redondo, S. Villagrasa, Informal interactions in 3D education: citizenship participation and assessment of virtual urban proposals, Comput. Hum. Behav. (2016), https://doi.org/10.1016/j.chb.2015.05.032.
[84] D. Fonseca, E. Redondo, S. Villagrasa, Mixed-methods research: a new approach to evaluating the motivation and satisfaction of university students using advanced visual technologies, Univers. Access Inf. Soc. (2015), https://doi.org/10.1007/s10209-014-0361-4.
[85] D. Fonseca, E. Redondo, F. Valls, S. Villagrasa, Technological adaptation of the student to the educational density of the course. A case study: 3D architectural visualization, Comput. Hum. Behav. (2017), https://doi.org/10.1016/j.chb.2016.05.048.
[86] J. Petchamé, I. Iriondo, E. Villegas, D. Riu, D. Fonseca, Comparing face-to-face, emergency remote teaching and smart classroom: a qualitative exploratory research based on students' experience during the covid-19 pandemic, Sustain. Times (2021) 13, https://doi.org/10.3390/su13126625.
[87] J. Petchamé, I. Iriondo, E. Villegas, D. Fonseca, S.R. Yesa, M. Aláez, A qualitative approach to help adjust the design of management subjects in ict engineering undergraduate programs through user experience in a smart classroom context, Sensors (2021) 21, https://doi.org/10.3390/s21144762.
[88] J. Cavalcanti, V. Valls, M. Contero, D. Fonseca, Gamification and hazard communication in virtual reality: a qualitative study, Sensors (2021) 21, https://doi.org/10.3390/s21144663.