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Design Sprint: Enhancing STEAM and engineering education through agile prototyping and testing ideas

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ABSTRACT

Creating project-based learning experiences in the classroom where students learn in a team to solve complex problems and to develop creative and critical thinking is a challenge. Design Sprint (DS) is an agile methodology (implemented in 5 days) with the goal of creating innovative design based on user needs (User Experience). The objective of this work was to develop an Engineering Drawing classroom experience linked to the context of the current COVID-19 pandemic with the Design Sprint methodology. The experience had to involve the integration of theory and practice, the application of knowledge, the development of both hard and soft skills, and the empowerment of students to conduct research. 56 first-year students following three STEAM degrees at the University of A Coruña participated in this experience. The activities were designed for both face-to-face and remote learning. Microsoft Teams and Moodle were used for tutoring and for monitoring student progress. The Moodle Workshop tool was used for the evaluation of the prototypes that were developed and the projects were evaluated by video. The students defended their projects through a presentation in lightning talk format (Ignite). Evaluation rubrics were used following a triple approach: co-evaluation, hetero-evaluation and self-evaluation. The 3D design of the projects was developed with Autodesk software. A total of 18 projects were developed. Once the projects were completed, a survey was administered to evaluate the levels of student satisfaction. The survey results were very positive. The Design Sprint projects also showed positive effects on grades. The Design Sprint method has promoted an interactive learning environment. In addition to its simplicity, a further advantage of DS method is that all student dedication is planned. Students were therefore less likely to feel overloaded, all of which helps with better time management. The DS methodology is multipurpose, so it can be applied to various fields and subjects.

1. Introduction

On 11 March 2020, the World Health Organization (WHO) upgraded the public health emergency generated by the spread of the COVID-19 coronavirus to international pandemic status (Cucinotta & Vanelli, 2020). The COVID-19 pandemic forced universities to adapt teaching methodologies to health and safety protocols (Heras et al., 2021; Luburic, Slivka, Sladic & Milosavljevic, 2021). This

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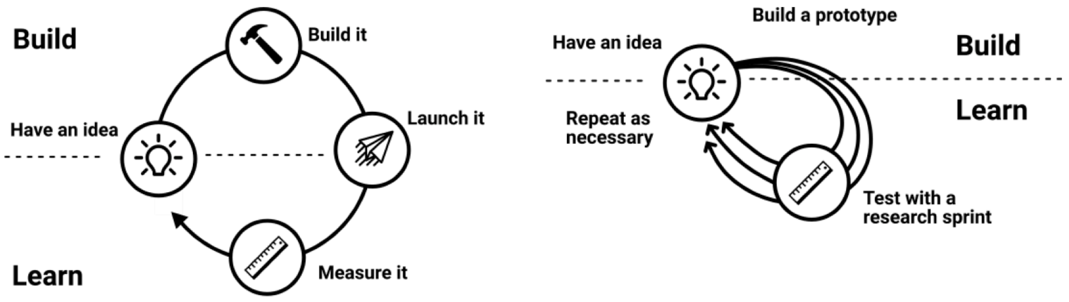

a) Launch and iterate model. b) Google Venture Design Sprint model.

Fig. 1. User research models (Google Ventures, 2021).

situation reopened the debate that began more than a decade ago in universities around the world on the need to maintain face-to-face classes. In the academic year 2020–2021, the Polytechnic University College (PUC) of the University of A Coruña opted for the face-to-face teaching modality following social distancing criteria and reduced student numbers in the classroom. In circumstances where a student was unable to attend the classes in person, they were given the option to follow the lessons remotely via Microsoft Teams. The scenario should be seen as an opportunity to find new ways of responding to the learning crisis and to provide practical solutions. It was therefore decided to combine lectures with other teaching methodologies, trying to seek the integral development of the student, without any need to share a common space. It has been demonstrated that students need to develop a combination of abilities, acquiring core skills (hard) and transferable skills (soft) (Clarke, 2018). The development of soft skills is considered highly relevant within the OECD and the European Union, due to the relevance of soft skills both at school and in the labor market, (Hurrell, Scholarios & Thompson, 2013; Llamas et al., 2019). Additionally, education should also promote the development of competencies and skills that are not specifically included in the curriculum, but which are in demand in the labor market (soft skills). Thus, soft skills should be included in government training policies as priorities (da Silva Fernandes, Jardim & de Sousa Lopes, 2021). However, the methodologies, contents and assessment systems of conventional syllabus design are developed according to the core skills (Yildiz, Topcu & Kaymakci, 2021). Lecturers should promote the development of skills, so the making of materials and experiences should primarily be focused on it rather than content (Rizzi, Pigeon, Rony & Fort-Talabard, 2020). One valuable tool for teaching the soft skills is the evidence based model called Creative Problem Solving (CPS). CPS is the mental process of searching for an original and previously unknown solution to a problem. The CPS was originally developed by Alex Osborn in the 1940s, and further developed by Osborn and Sidney Parnes (Miller, Vehar & Firestien, 2001; Osborn, 1953; Puccio, Mance & Murdock, 2011), nurturing the Buffalo State College and the Creative Education Foundation since then. It involves breaking down a problem to understand it, generating ideas to solve it and evaluating the ideas to find the most effective solutions. The approach uses techniques to make the problem-solving process engaging and collaborative. The basic structure is comprised of four stages: clarify, ideate, develop, implement. Each one of the stages uses divergent and convergent thinking. As it will be seen, it has much in common with the methodology presented in this text. Hence, it could be considered the ancestor of the Design Thinking method.

Design is a core activity in the field of engineering (Simon, 2019). As far as Engineering Drawing is concerned, it is one of the learning outcomes: designing effective solutions to meet societal needs (Camacho, 2016). In the current context of constant change, learners need to know and work with flexible methods that respond to these fluctuating needs, generate innovation and allow rapid adaptation to the context. One methodology stands out in the field of innovation generation: Design Thinking. The Design Thinking (DT) methodology, popularized by the Hasso Plattner Institute at Stanford University, is well suited to promote these problem-solving skills, as it emphasizes iterative and user-centered design (Google, 2018; Plattner, Meinel & Leifer, 2011). That is, DT can be defined as a cyclical process of inspiration, ideation and implementation. Design Thinking represents an evolution of the CPS methodology. DT incorporates additional elements of "human-centered design": that is, empathizing (or incorporating an element of ethnographic research at the beginning of the design process), learning from those for whom you are designing, prototyping to get feedback from users, and iterative evaluation with the target audience (Dell'Era, Magistretti, Cautela, Verganti & Zurlo, 2020). All this to ensure that human needs and capabilities are addressed. As the DT process requires a relatively large timeframe, Google Ventures combined DT with agile methodologies (e.g., Scrum, Kanban) to create the Design Sprint (DS) method, which is a 5-day process (Knapp, Zeratsky & Kowitz, 2016). This delimited and short timeframe helps to adapt it to the classroom time schedule. Unlike popular Silicon Valley user research project models (Fig. 1) such as "launch and iterate", ideas (prototypes) can be tested with the DS model without the time and expense of a risky product launch (Google Ventures, 2019). In other words, in "launch and iterate" models, if starting out with a bad idea (obviously, with no initial awareness that it is bad), fixing the bugs and "uninstalling" it once customers are using it can be highly expensive. Hence, DS rather than DT was selected in the PUC Engineering Drawing experience developed at the University of A Coruña. Although the DS methodology has generally been applied to the field of software design, it is suitable for product design (Tsai, 2021). In the educational context, students can develop subject-specific and transversal competences with the DS method (e.g., creativity, decision-making, teamwork, communication, appreciation of one's own and others' work). in other words, both soft and hard skills.

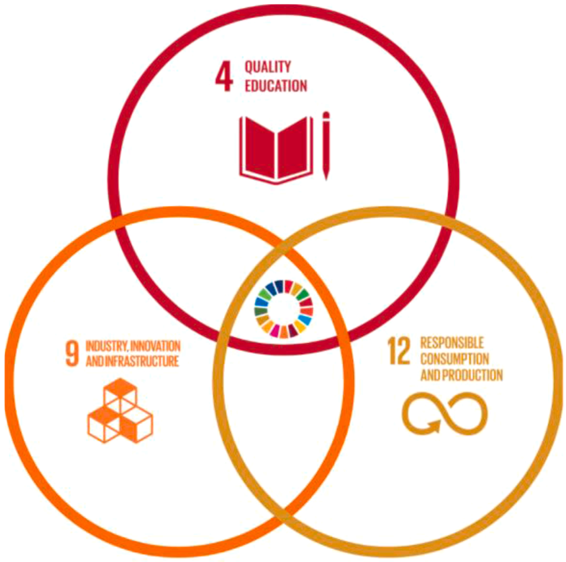

Fig. 2. The three Sustainable development goals applied in this experience.

Design Sprint is intended to be used within the framework of Challenge-based learning (CBL) where students can develop soft skills. The CBL approach seeks to have students develop a project providing real solutions to real problems in technology rich environments incorporating 21st century skills (Conde et al., 2021). Soft skills can be defined as a dynamic combination of cognitive and meta-cognitive skills, and social, and practical skills (Succi & Canovi, 2020). The development of soft skills will help students to adapt to the challenges of their everyday and professional future life. The European Union classified the soft skills of the SkillsMatch project into four different categories (SkillsMatch project, 2019): self-image and vision of the world; context and performance related; social interaction and methodological, intuitive and lateral thinking. In addition, the DS method made it possible to create a that encompassed all the design phases and techniques worked on in the subject: sketching, 2D plans according to standards and 3D modeling.

Design Sprint can have an effective approach in meeting sustainability goals. University educators have a key role in social transformation towards education for Sustainable Development as highlighted by UNESCO (Mulà & Tilbury, 2009). Thus, education is a requirement for achieving sustainable development as stays the UNECE. In this context, methodologies applied to teaching-learning processes are key to achieve sustainable development (Miguez-Alvarez, Crespo, Arce, Cuevas & Regueiro, 2020). Sustainability skills as well as soft skills should be integrated into the syllabus in all areas of knowledge, mainly engineering courses. The Design Sprint experience aims were assessed in terms of the 17 Sustainable Development Goals of the 2030 Agenda of the United Nations for sustainable development approved by world leaders in September 2015. The development of this experience was focused on three of the 17 Sustainable Development Goals (Fig. 2). Each goal is divided into a series of targets (United Nations. Department of Economic and Social Affairs. Sustainable development., n.d.). This activity contributes to the development of four targets: 4.4, 9.5, 9.b and 12.1. Target 4.4, under Sustainable Development Goal 4 (Quality education), states that by 2030, the number of youth and adults who have relevant skills will have substantially increased, including technical and vocational skills, for employment, decent jobs and entrepreneurship. Targets 9.5 and 9.b come under Sustainable Development Goal 9 (Industry, Innovation and Infrastructure). Specifically, target 9.5 seeks to enhance scientific research, to upgrade the technological capabilities of industrial sectors in all countries and particularly in developing countries. Target 12.1, under Sustainable Development Goal 12 (Responsible Consumption and Production), refers to the implementation of the 10-year framework of programs on sustainable consumption and production, in which all countries take action and developed countries take the lead, considering the developmental capabilities of developing countries.

Design Sprint projects could be considered as sustainability-oriented innovations (Buhl et al., 2019). The aim of those sorts of projects is to create tailored solutions and the key question. What is the best way to fulfill user needs? In other words, consumption can be rationalized by developing products tailored to consumer needs, whence the development of sustainable consumption and production (Target 12.1). In the instructions for the DS activity, the following statement was included: "The product to be developed must meet the specific needs of the selected target audience, so that they do not need to buy more products that fulfill the same function. This allows rationalizing consumption and generating sustainability-oriented behaviors". In addition, students can develop hard skills related to scientific research with Design Sprint methodology (Stages: 1. Understand, 2. Sketch, 3. Decide, and 5. Validate), innovation and added value generation (Stages: 2. Sketch and 4. Prototype). These core skills are associated with Target 9.5 and Target 9.b. The development of hard skills is insufficient in itself, so the Design Sprint work philosophy encourages students to develop soft skills or vocational skills that are demanded both in the labor market and in society as a whole (Target 4.4).

Having in mind the state of the literature, a field research with the aim of evaluate the implementation of a new teaching-learning method to engineering drawing courses was designed. The following hypothesis were formulated: 1) DS will improve the student performance in comparison with practical exercises in lectures; 2) DS will improve the student performance in comparison with

Table 1
Subject competences.

Type	Code	Competence
Specific	S1	To master graphic representation techniques (traditional methods of metric geometry and descriptive geometry and computer-aided design applications).
Basic	B1	To be able to solve problems with initiative, decision-making, creativity and critical reasoning.
Basic	B2	To be able to work and to learn autonomously and with initiative.
Basic	B3	To be able to employ engineering techniques, skills and tools necessary for practical application.
Basic	B4	To be able to make appropriate use of information resources and apply Information and Communication Technologies (ICT) to engineering.
Basic	B5	To be able to gather relevant data (normally within their area of study) and to interpret it, in order to make judgements that include a reflection on relevant social, scientific, and ethical issues.
Transversal	T1	To master the use of basic ICT tools that are necessary for the exercise of their profession and for lifelong learning.

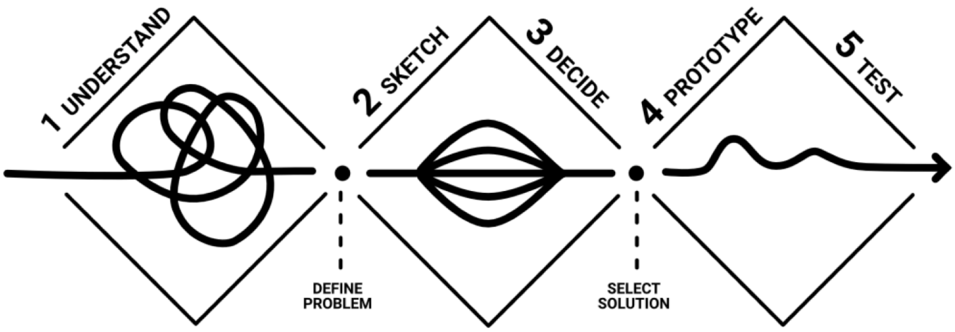

Fig. 3. Design Sprint stages.

AutoCAD practical exercises; 3) DS will improve the student performance in comparison with final exam; 4) Assessment of the same task under different approaches (self-assessment, hetero-assessment and co-assessment) produces different results. Additionally, as satisfaction is related with performance, the students' satisfaction with this new method was assessed. That is, this qualitative study presents an experience for Engineering Drawing course using DS methodology with the main objective of addressing some deficiencies in the application of conventional learning methodologies and achieve 21st century skills. Moreover, this experience was designed to align the competencies of the Engineering Drawing course, the user experience based methodologies implemented (DS) and the evaluation system with a social approach.

2. Methodology

2.1. Engineering drawing course

Engineering Drawing is a subject linked to the academic disciplines of Science, Technology, Engineering, Arts, and Mathematics (STEAM) (Perignat & Katz-Buonincontro, 2019). Engineering Drawing, a basic training subject taught in the first year, is mandatory in all engineering degrees taught at PUC Its Degree Report (approved by the Spanish Ministry of Education and published by the University of A Coruña) specifies that Engineering Drawing "will contribute to the student acquiring abilities to solve engineering graphic problems, expressing graphic solutions in a clear and objective way and acquiring the capacity of abstraction to visualize objects in space". Lecturers should therefore promote activities in which students develop skills related to the knowledge of graphic representation techniques and the use of ICT tools.

Engineering Drawing (6 ECTS) is a 1st year and core type (compulsory) subject. This subject is taught in all the degrees offered at the PUC. Students following the Industrial Engineering degree and the Automation and Industrial Electronics Engineering degree simultaneously take Engineering Drawing (first semester). Thus, the approach towards the selection of both resources and materials must be adapted to both degree courses. The main competences to be acquired are summarized in Table 1. The two main types differ according to their applicability in the labor market: Technical-scientific competences (i.e., specific, and basic) and transversal competences (Sa & Serpa, 2018).

The training activities for this subject were divided into 100% face-to-face lectures and computer aided practices. The evaluation systems consisted of: a written exam, which accounted for 40% of the final grade; exercises and questions during lecturing, which were weighted at 20% of the final grade; and practices through ICT that amounted to 40% of the final grade.

2.2. Participants

The student sample consisted of 56 students in the first year of their degree course, among whom 16 students were from the Industrial Engineering degree, 36 from the Automation and Industrial Electronics Engineering degree and 4 from the Electrical

Table 2
Soft skills developed at each stage.

	STAGES				
	1. Understand	**2**. Sketch	**3**. Decide	**4**. Prototype	**5**. Validate
Communication	■		■	■	■
Critical thinking and problem solving	■	■	■	■	■
Lifelong learning and information management	■	■	■	■	■
Teamwork	■		■	■	■
Entrepreneurial skill	■		■		
Moral and professional ethics	■	■	■	■	■
Leadership	■		■	■	■

Engineering degree. Of the participants, 80.36% were male (45 students) and 20.45% were female (11 students). The age of the participants aged from 18 to 47 years ($M = 20.11$, SD = 4.85). The projects were carried out in groups of 2–4 students. A total of 18 projects were developed.

2.3. Design Sprint method

The five stages of DS (Fig. 3) were based on Google Ventures (GV). Design sprint and project-based learning (PBL) (Wilkerson & Trellevik, 2021) provide an effective method to design quality products using User Experience (UX) techniques and creativity. The checklists for each stage and the portfolio file were downloaded from the GV webpage (Google Ventures, 2019).

The work was carried forward in groups of 2–4 students. The stages and sub-stages of the process, adapted to this work, are described below. In order to avoid confounding variables, a single professor gave the instructions to students. The professor involved in the study was part of the research team.

The purpose of Stage 1 (Understand) is to understand the problem and to define the objective. The problem was set. They were asked to design a tool to fit a surgical mask that could be printed on a 3D printer. The choice of target audiences was as follows: Children (age 6–8 years), elderly people, people who wear glasses and people with disabilities. A brief was given to all students, so that they were informed of the challenge, the goals and the deliverable at the end of the Design Sprint project. Each group, which had all or some members in attendance, was given a workspace. One of the group members took on the role of team leader with the lecturer as the facilitator. The team had to gather all existing information on the customer profile and the problem. Group members adopted user roles, to identify needs. Direct interaction with potential users was not requested, due to the current health situation arising from COVID-19. Throughout this stage the team should be working on defining who will be using the product and how the product will adapt and solve a problem that users have. The team members must constantly ask "How might we…?". All students had to share what they knew about the problem in their groups.

The goal of Stage 2 (Sketch) is to seek solutions. Students have to explore different options individually, to solve the problem defined in Stage 1. This stage, unlike the others, promotes individual work. Each team member has the task of designing the prototype in the form of a quick sketch.

In Stage 3 (Decide), students have to choose one idea. The goal of this phase is to hone in on a single option/idea for the prototype. The team had to vote on and to select one of the proposals (sketches) from Stage 2. The team had to create a storyboard for the design of the prototype. The selected sketch had to have sufficient views for the complete definition of the design and it had to be dimensioned according to the UNE 1–039–94 standard.

In Stage 4 (Prototype) students have to prototype the design that is under development. The chosen sketch (stage 3) will be drawn in Autodesk AutoCAD 3D or Autodesk Inventor for the additional improvement. Files generated in AutoCAD or Inventor may be exported to *.stl for online community sharing.

In the last stage (Stage 5. Validate), students evaluated the projects. The health situation resulting from COVID-19 meant that the prototypes could not be validated in the presence of users, so project validation was through video. The video was a presentation in Ignite format, similar to PechaKucha (Warmuth & Caple, 2021). The Ignite format consists of a five-minute presentation of a project

Table 3
Rubrics.

	DIMENSIONS	Level 1 (0%)	Level 2 (50%)	Level 3 (100%)
CO-EVALUATION (PEERS)				
#1	DS development	Stages of the Design Sprint process were not developed. (0 points)	Stages of the Design Sprint process were partially developed. (0<score≤1.25 points)	Stages of the Design Sprint process were developed. (1.25<score≤2.5 points)
#2	Product	Failure to develop a viable product adapted to the target audience. (0 points)	A feasible product was developed, but it was not suitable for the target audience. (0<score≤1.25 points)	A feasible product was developed that was suitable for the target audience. (1.25<score≤2.5 points)
#3	DS description	The design process was neither explained nor justified. (0 points)	The design process was explained and justified. (0<score≤1.25 points)	The design process was explained and justified. (1.25<score≤2.5 points)
#4	3D Model	Unable to generate a 3D model or an *.stl file. (0 points)	The .stl file was not generated or the 3D model was only partially developed. (0<score≤1.25 points)	A 3D model was developed and an *.stl file was generated. (1.25<score≤2.5 points)
HETERO-EVALUATION (LECTURER)				
#5	Sketch	The sketches were not completed, nor was the product defined. (0 points)	The sketches were partially dimensioned and the product was partially defined. (0<score≤1 point)	The sketches were dimensioned and the product was defined. (1.25<score≤2 points)
#6	Dimensions	The dimensions were not correct. (0 points)	The dimensions were partially correct. (0<score≤1 point)	The dimensions were correct. (1.25<score≤2 points)
#7	Standard	The standard was not applied in the dimensioning. (0 points)	The standard was partially applied in the dimensioning. (0<score≤1 point)	The drawing dimensioning followed the standard. (1.25<score≤2 points)
#8	Part views	No product (part) views were created in the drawings. (0 points)	Product views were shown in the drawings, but they were not adequate. (0<score≤1 point)	A sufficient number of product views were provided in the drawings. (1.25<score≤2 points)
#9	3D model	Multiple errors were found in the 3D solid (and the *.stl file) that was generated. (0 points)	Some errors were found in the 3D solid (and the *.stl file) that was generated. (0<score≤1 point)	An error-free 3D solid (and the *.stl file) was generated. (1.25<score≤2 points)
SELF-EVALUATION				
#10	DS development	Stages of the Design Sprint process were not developed. (0 points)	Stages of the Design Sprint process were partially developed. (0<score≤1.25 points)	Stages of the Design Sprint process were developed. (1.25<score≤2.5 points)
#11	Product	Failure to develop a viable product adapted to the target audience. (0 points)	A feasible product was developed, but it was not suitable for the target audience. (0<score≤1.25 points)	A feasible product suitable for the target audience was developed. (1.25<score≤2.5 points)
#12	3D Model	Unable to generate either a 3D model or an *.stl file. (0 points)	The *.stl file was not generated or the 3D model was only partially developed. (0<score≤1.25 points)	A 3D model and an *.stl file were generated. (1.25<score≤2.5 points)
#13	Involvement	I have only been involved in 1 phase of the project. (0 points)	I have been involved in some phases of the project. (0<score≤1.25 points)	I have been involved in all phases of the project. (1.25<score≤2.5 points)

(Quick & Blue, 2019). The presentation consisted of 20 slides and each slide was shown for 15 s, so clear communication was essential. The presentation required the participation of all group members.

The professor acted as a facilitator of the process. Classroom work time was set for each stage: Stage 1 (80 min), Stage 2 (50 min), Stage 3 (35 min), Stage 4 (80 min), Stage 5 (25 min). Three practical sessions (1.5 h each) were used for the development of the project. In the first practical session, Stage 1 was developed and Stage 2 was introduced. Stages 2 and 3 were completed in the second practical session. Stage 4 was partially developed in the second practical session. Stages 4 and 5 were completed in the third and last session. The videos of the presentations were recorded outside the classroom time. This experience was performed in the last weeks of the semester. Thus, the students had previous experience with traditional teaching methodologies for both CAD software and freehand sketching. It allowed them to form an opinion about the effectiveness of this new method.

2.3.1. Development of competencies

As indicated above, the design intent of this experience sought to align competences, methodology and assessment. Moreover, the activity sought to combine individual and team work. The Design Sprint method fostered the development of all the subject competences (basic, specific and transversal) listed in Table 1.

This qualitative study used the Malaysian Soft Skills Scale (called My3S) areas, which summarizes the 36 key soft skills identified by the SkillsMatch project. The soft skills cover seven areas deemed crucial for employability purposes: Communications, Critical Thinking and Problem Solving, Teamwork, Moral and Professional Ethics, Leadership, Life Long Learning and Entrepreneurial aspects (Karim et al., 2012; Succi & Canovi, 2020). Table 2 shows the soft skills developed by the authors in this study at each stage. As can be seen in Table 2, there are skills that are not developed at all stages. Each stage has a series of characteristics that make them more individual, such as Stage 2 Sketch. In this stage 2, each student individually makes his or her own sketch, so communication between students is not necessary. Leadership is something that is developed when students have to agree and make decisions, so here, this competence is not developed either. Stage 1 (Understand) and stage 3 (Decide) allow more skills to be put into practice, as they are developed in teams and involve key decisions for the project. Thus, for example, stage 4 (Prototype) depends on the sketch selected in stage 3 (Decide), so Entrepreneurial skill is not developed. The same applies to stage 2 (Sketch) which is dependent on stage 1 (Understand). Stage 5 (Validate), although developed in teams, consists of the presentation of the project and its evaluation, so

Entrepreneurial skill is not developed either.

2.4. Procedure

2.4.1. Project monitoring

The students were able to follow the project in both face-to-face classes and remotely, due to the health situation resulting from COVID-19. In other words, we had synchronous teaching (students at home and students in the classroom). In addition, for reasons of space, at certain times we had mirror classrooms: the professor was in a classroom with some students and other students were in another classroom. The students who chose to study remotely or who were located in a mirror classroom connected with their classmates and professor through the Microsoft Teams platform. The project work schedules were common to all students, both face-to-face and distance learners. Immediate feedback was given to the students studying remotely through the Microsoft Teams platform. The work sessions were recorded within the Microsoft Teams team, so that the students could review concepts and instructions. Different Moodle tasks were created, in order to facilitate the follow-up and development of the work. In this way, students could receive feedback on their progress.

2.4.2. Evaluation system

The guidelines of Biggs and Tang were followed (Biggs & Tang, 2011) to design the evaluation methods. In other words, a constructive alignment approach was applied between learning outcomes, the assessment system and the formative activities (in this case Design Sprint). It is an approach that clarifies the relationships between learning outcomes, learning activities, formative feedback and assessment tasks.

A three-pronged evaluation approach was used: co-evaluation, hetero-evaluation and self-evaluation. Three analytic scoring rubrics for the assessment of student performance in DS projects were designed (Table 3). Thus, the professor/student scored separately, individual parts of the performance first, and then the individual scores were summed to obtain a total score. The main benefit of analytic scoring rubrics is that they provide a description of what is expected at each scoring level (Alberta Assessment Consortium, 2008; Petkov & Petkova, 2006). A user-friendly rubric with three quality levels was developed using a technical approach to design the scale and Bloom's taxonomy to identify criteria on the scale (Krathwohl, 2002). The three scoring criteria were: Level 1 (Unacceptable standard), Level 2 (Acceptable standard), Level 3 (Excellent standard). A student-friendly language for the descriptors was used.

The grade for the assignments was obtained by weighting peer assessment (40%), self-assessment (20%) and professor assessment (40%). The work had a weight of 7% in the final grade for the subject. A rubric was used for Co-evaluation (Table 3) and the evaluations made, as received, were taken into account to compute the Co-evaluation grade, as detailed below. The items of the Co-evaluation and Self-evaluation rubrics had a maximum score of 2.5 points, while the items of the hetero-evaluation rubric had a maximum score of 2 points (Table 3). The Moodle workshop tool was set up for Co-evaluation (peers).

The peer review (co-evaluation) was carried out using the Moodle Workshop module (Moodle, 2021). The progress of the groups can be monitored in the evaluation phases (i.e., submission phase, evaluation phase) with this Moodle tool. As expected, the Workshop grading strategy was presented in the form of a rubric. The grading evaluation settings for assessment comparisons were strictly defined. The grade calculation method was set so as to compare it with the best assessment. The grade for submission was set at 80 and the grade for assessment was set at 20. The final grade was a weighted mean of the grades for both submission and assessment. Two types of feedback were included: overall feedback mode (reviewers are required to give an overall comment about the submission) and conclusion (professor comments shown at the end of the workshop). Each group was randomly assigned 5 projects (videos) to evaluate.

In the self-assessment, students had to rate their level of achievement in the development of the project and to assess their level of contribution. Finally, the professor scored the presentation, the 3D model and the drawings obtained from AutoCAD or Inventor. The self-assessment focused on the development of the project and the individual contribution (Table 3). Several items were common to all 3 assessment approaches, which was useful for the comparison of the results

2.4.3. Student feedback

At the end of the Design Sprint experience, the students were administered an opinion survey. The questionnaire was administered via Moodle, so students could fill it in autonomously. The survey was divided in two sections:

The first part of the survey consisted of a Net Promoted Score (NPS) survey. NPS is a metric designed by Reichheld (2003) to measure and manage customer loyalty. It has two parts: (1) a Likert question with a scale from 0 to 10 asking how likely you would recommend a product or service to friend or colleague (Palmer & Devers, 2018), and (2) an optional open question asking the reason for the scoring "What was the reason for your response?". It is one of the most widely used surveys for collecting and scoring user experiences. Both the responses to the Likert question and the statements were analyzed. In this case, the users were the students and the service was the DS methodology. The users are classified into three categories: promoters, passive users and detractors (Juntumaa, Laitinen & Kirichenko, 2020). Promoters are the students who gave an answer of 9 or 10. They are the ones who will spread positive word-of-mouth in relation to the DS method. The passive users were the students who gave scores of 7 or 8. They were not excited by the DS method. The detractors were the students who scored between 0 and 6. They were considered as dissatisfied customers. The NPS final score is a percentage that is achieved by subtracting the percentage of detractors from the percentage of promoters, so that the indices of the metric go from −100 to +100. There were other options considered like the Customer Satisfaction Score (CSAT) and Customer Effort Score (CES). Both of them have only one Likert questions asking for the satisfaction and the easiness for handling issues. The NPS was chosen because it gathers more information than the other ones. In this case, the open-ended question helps to identify the reasons why students tend to recommend or not recommend the methodology. This makes it possible to identify

Table 4
Opinion survey on the Design Sprint project.

ID	Statement
Q1	I find the subject of Graphic Expression interesting.
Q2	The Design Sprint project helped me to gain a better understanding of the concepts of design, sketching, modeling, drafting and dimensioning.
Q3	Doing traditional 3D modeling and plotting practices would have been a worse way to work on these concepts.
Q4	The Design Sprint methodology was easy to understand and apply.
Q5	This experience helped to increase my interest in Engineering Drawing.
Q6	I found it difficult to understand and to follow the Design Sprint project instructions.
Q7	Another chance to practice with this methodology would increase my understanding of UNE standards applied to technical drawing.
Q8	I enjoy modeling using CAD software.

Table 5
Design Sprint projects.

Problem related to COVID-19 masks	Target audience	Product	No of projects
Ear pain	Children	Ear saver	10
Ear pain	Elderly	Ear saver	1
Ear pain	People who wear glasses	Eyeglasses ring	2
Fogged glasses lenses	People who wear glasses	Nose clip	3
Touching surfaces	Elderly	Door opener	1
Touching surfaces	Children	Door opener	1

opportunities and errors in the activity developed.

As for measuring students' opinion in relation to this experience, an adaptation to our context of the Teaching Opinion Questionnaire (Suarez-Garcia, Arce, Alvarez-Hernandez & Fernandez-Gavilanes, 2021) was administered to participants. The questionnaire (Table 4) consists in eight items that participants endorsed in a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Participants check the place on the scale that best reflects their feelings about the item (Spooren, Mortelmans & Denekens, 2007). The internal consistency of the measure with the participant in the study was good, $\alpha = 0.72$ with item test correlations in all items $>$ 0.30. There were questions related to the Engineering Drawing subject (Q1, Q7), the Design Sprint method (Q2, Q4, Q5, Q6), and the programming skills of the students (Q3, Q8).

3. Results and discussion

3.1. Design Sprint project

A total of 18 projects were followed to design mask ear-savers (10 projects), nose clips (3 projects), eyeglasses rings (2 projects), and door openers (2 projects). Most of the projects were focused on children. Table 5 summarizes the Design Sprint projects that were developed. The results at each stage are described below.

In Stage 1 (Understand) the students freely decided on the formation of the working groups. A total of 18 working groups were formed: 5 groups of 4 members, 8 groups of 3 members and 6 groups of 2 members. Most of the projects had children as their target audience and mask-related ear pain as the issue on which they focused (Table 5). In addition, at this stage the students had to put themselves in the shoes of the user. To this end, students completed questionnaires with batteries of questions in three formats: open-ended questions, yes/no questions, and Likert-type scale questions. These questionnaires helped to gain users' perspective and evaluate user's experience. In view of the current pandemic, 3 types of strategies were used to gather the opinions of potential users: using social networks (i.e., Instagram, TikTok, Facebook), contacting family members, and assuming user roles (the different members of the group).

The information collected in Stage 1 (Understand) was summarized according to the characteristics of the target audience. It was evident from the potential users' responses that design was the most relevant variable for child-centered products, followed by comfort and a means of identification (i.e., a sticker with the user's name). People wearing glasses and elderly people requested comfortable, simple and lightweight products. A female public reporting discomfort with their hair due to the use of masks or current designs of ear savers was also identified. In the case of door openers, users requested that they should have several functions and be easy to store/transport. All the information gathered made it possible to understand that each target audience has specific demands, so the product they expect is also different.

At the end of the Stage 1, students should ask "How might we…?" That is, each of the team members had to pose a "How might we" question related to the needs identified by the different target audiences. A vote was carried out within each group to choose the "How might we" question that would guide the next steps of the project. The most voted question was "How might we create a product that prevents a mask from hurting the ears with an attractive design for children?", selected by four groups, followed by "How could we design a product that prevents a mask from hurting the ears so that wearing the mask is comfortable?", selected by three groups.

In Stage 2 (Sketch) the students analyzed real solutions that worked (why they were successful). The products or ideas were treated as an inspiration, so in the final design (stage 4) modifications for improvement were added. At this stage, several websites were

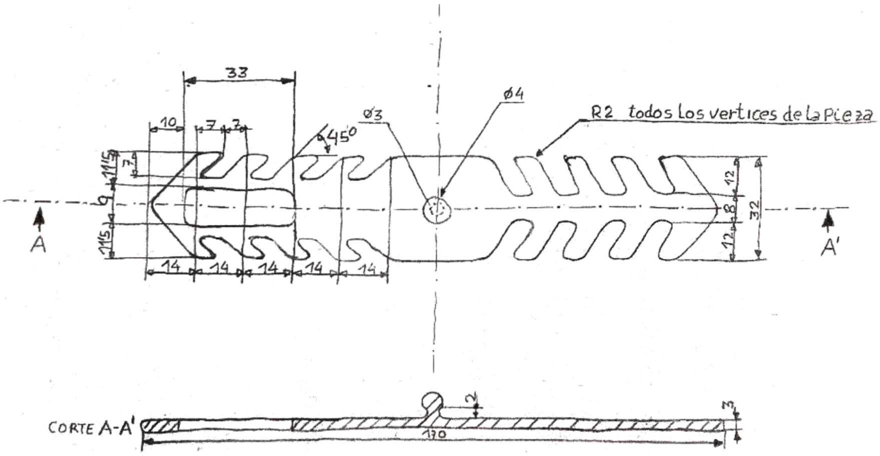

Fig. 4. Sketch of an ear saver for children with multiple functions.

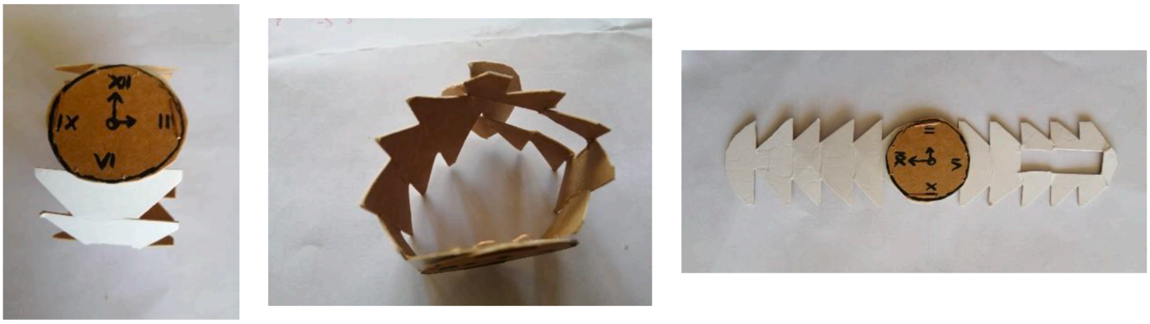

Fig. 5. Prototype of an ear saver with multiple functions for children.

consulted, among which the following: https://www.thingiverse.com/, https://cults3d.com/, and https://free3d.com/es/. The students were expected to apply in practice the lessons that they had learn from the subject matter of Graphic Expression. The tutoring functions of the professor became more intensive at this point. The sketches were handed in at the end of the practical session and the errors found in the drawings were individually discussed in a tutorial (feedback for improvement) (Fig. 4).

In Stage 3 (Decide), the students analyzed each proposal from the previous stage (Fig. 3). Pros and cons were specified for each of the alternatives. The selection criteria were aesthetics, simplicity, novelty, functionality, among others. They voted between the available alternatives. The design that received the most votes was selected for stage 4 (Prototyping).

Stage 4 (Prototype) also required intensive professor interventions, due to the multiple doubts that arose when starting to design the 3D model. Very similar questions were raised and were solved in a Moodle forum, making the information available to all students on the course. Before proceeding to the 3D printing of the model, some groups of students tested the feasibility of the product by making prototypes of their designs (Fig. 5). The students preferentially chose Chitubox (https://www.chitubox.com/en) as the software for preparing the *.stl files for 3D printing. This choice was mainly due to its simplicity of use. Some groups used Lychee slicer (https://mango3d.io/downloads/) for *.stl file preparation. A Creality LD-002R 3D printer was used to print the final prototype. In the project instructions, the students were told the model and brand of the 3D printer, as it limited the dimensions of the generated products and the layout in the slicer (maximum print size: 119 × 65 × 160 mm).

In Stage 5 (Validate), the validation of the projects was done through the evaluation of a presentation in Ignite format (similar to PechaKucha). Because of the health situation, the validation phase was carried out on the basis of a triple assessment approach (peer, teacher and self-assessment). In terms of learning objectives, this form of assessment allows different skills to be worked on (e.g. review of subject content, critical thinking, communication). The students themselves participated in the evaluations of each project in a process known as co-evaluation. The projects that were evaluated obtained a mean score of 67.21[66.22, 68.20] (SD 9.37) out of a possible 80 points for the submission grade, and, a mean score of 18.17[18.04, 18.30] (SD 1.22) out of a possible 20 for the assessment grade. As indicated, the submission grade was set at 80% and the assessment grade at 20% in the Moodle Workshop tool settings. The grade for submission is calculated as weighted mean of peers' assessment grades given to a particular submission. The grade for assessment estimates the quality of assessments that the group gave to the peers. This grade is calculated by the artificial intelligence algorithms hidden within the Moodle Workshop module. The method is named Comparison with the best assessment. The Moodle workshop module picks the closest to the mean of all assessments as the best assessment and gives it a grade of 100%. Then, the

Table 6
Rubric results.

		Dimensions	Measurement scale(points)	M[95% CI]	Median	Standard Deviation	Range Min	Max
Co-evaluation (peers)	#1	DS development	0 to 2.50	2.08[1.93, 2.23]	2.50	0.63	0.00	2.50
	#2	Product	0 to 2.50	1.95[1.79, 2.11]	2.50	0.66	0.00	2.50
	#3	DS description	0 to 2.50	2.11[1.94, 2.29]	2.50	0.72	0.00	2.50
	#4	3D Model	0 to 2.50	2.28[2.15, 2.40]	2.50	0.53	0.00	2.50
Hetero-evaluation (lecturer)	#5	Sketch	0 to 2.00	1.06[0.64, 1.48]	1.00	0.85	0.00	2.00
	#6	Dimensions	0 to 2.00	1.63[1.38, 1.87]	2.00	0.50	1.00	2.00
	#7	Standard	0 to 2.00	1.06[0.64, 1.48]	1.00	0.85	0.00	2.00
	#8	Part views	0 to 2.00	1.63[1.38, 1.87]	2.00	0.50	1.00	2.00
	#9	3D model	0 to 2.00	1.94[1.82, 2.06]	2.00	0.25	1.00	2.00
Self-evaluation	#10	DS development	0 to 2.50	2.31[2.18, 2.44]	2.50	0.45	1.25	2.50
	#11	Product	0 to 2.50	2.15[1.97, 2.33]	2.50	0.63	0.00	2.50
	#12	3D Model	0 to 2.50	2.31[2.16, 2.46]	2.50	0.52	0.00	2.50
	#13	Involvement	0 to 2.50	2.14[1.98, 2.31]	2.50	0.57	1.25	2.50

Table 7
Overall results for co-evaluation, hetero-evaluation, and self-evaluation.

	M[95% CI]	Median	Standard Deviation	Range Min	Max
Co-evaluation (peers)	8.34[8.09, 8.84]	8.85	1.73	5.00	10.00
Hetero-evaluation (lecturer)	7.20[6.89, 7.81]	7.00	2.11	0.00	10.00
Self-evaluation	8.93[8.74, 9.29]	8.75	1.20	5.00	10.00

algorithm measures the 'distance' of all other assessments from the best one and gives them lower grades based on the distance to the best one. The final result of the (peer) co-evaluation was obtained from the sum of the grades for both submission and assessment. The mean final score was 85.39 points. The grade for assessment was a measure of how well a student (or in this case a group of students) assessed the work of other students. In other words, it measured the distance between the assessment given by a group and the average grade that same work received on the basis of the assessments of the other groups. All the projects received 5 evaluations. The projects to be evaluated by each group were randomly assigned. From the results, the assessments on average there was a broad consensus in the ratings (results of assessment grades). This consensus in the results validates the different approaches applied. In the overall feedback phase, peers mainly commented on improvements in presentation, security issues with the product and problems with downloading and viewing the dumped file on the Thingiverse webpage. The comments (conclusions) from the professor focused on the dimensioning and the views of each design. Feedback was given for improvement and was not simply retrospective feedback on the project, meaning that the students had to modify the points that were raised.

3.2. Evaluation system

Table 6 shows the results of the scores given for each of the rubric items. Each group had to evaluate 5 projects. The professor evaluated each of the projects ($n = 18$). The students individually performed a self-evaluation. The ratings of self-assessment ($n = 56$) were factored individually as well as peers-assessments ($n = 90$). Several dimensions of the rubrics used for the assessment (Table 3) were the same. This provides an analysis of the existence of differences in the criteria used in peer and self-assessment. Specifically, items #1 and #10 (DS development dimension), items #2 and #11 (Product dimension) and items #4 and #12 (3D model) were equal (Table 3). Thus, the results of these six items were compared. The results showed neither significant differences between the ratings of items #2 and #11 (t(142) = 1.60, ns), nor between items #4 and #12 (t(142) = 0.30, ns). That is, the results of the peer ratings for dimensions Product and 3D model were homologous with the results of the self-assessment. However, the results showed significant differences between the ratings of items #1 and #10 (t(142) = 2,42, $p < 0.05$). That is, the results of peer ratings for dimension DS development are significantly lower than the self-assessment ratings for this dimension. In other words, when students self-assess themselves, they have a higher perception of accomplishment and performance than when the assessment is carried out by their peers. This result confirms the fourth hypothesis i.e., the assessment of the same task under different approaches (self-assessment, hetero-assessment and co-assessment) produces different results. It is noteworthy that the self-assessment rubric item #13 (Involvement) received the lowest score. A finding that indicated that not all group members had actively participated in all phases of the project.

Table 7 shows the overall results of the ratings under the three evaluative approaches: co-evaluation, hetero-evaluation, and self-evaluation. The overall results were obtained by summing all the items of each of the three evaluation approaches. That is, co-evaluation, hetero-evaluation and self-evaluation scored a maximum of 10 points (base 10). Because several approaches have been used to evaluate the same task, it is necessary to analyze whether there are significant differences between them. For this purpose, the ANOVA test was used. The results of an ANOVA on the DS project evaluations ($n = 56$) for each evaluator factor (Co-evaluation, hetero-evaluation and self-evaluation) showed significant differences, F(2, 165) = 10.97, $p < 0.001$, explaining 14.8% of the variance,

Table 8
Summary of grades in the assessment tasks.

	M[95% *CI*]	Median	Standard Deviation	Range	
				Min	Max
Practical exercises in lectures	6.66[6.32, 7.00]	6.74	1.16	3.66	8.76
AutoCAD practical exercises	6.92[6.36, 7.49]	7.43	1.95	2.37	9.40
DS project	7.88[7.47, 8.29]	8.12	1.42	3.75	10.00
Final exam	3.67[3.19, 4.13]	3.33	1.62	0.60	7.85

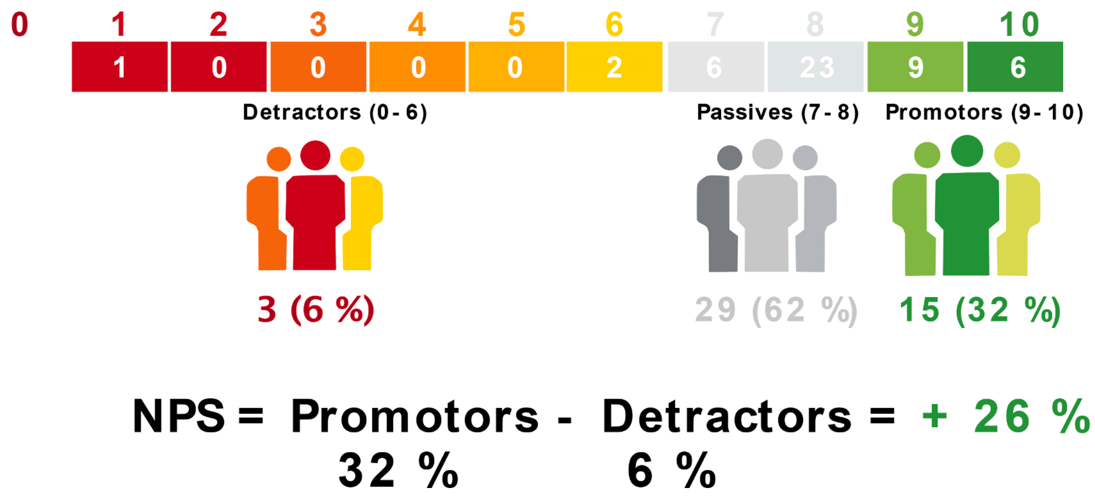

Fig. 6. NPS survey results.

η_p^2=148. Post hoc analysis (Bonferroni; $p < 0.017$) showed that the hetero-evaluation (professor evaluation) was significantly lower (7.20) than both co-evaluation (8.34), and self-evaluation (8.93), with a medium, d = -0.59, effect size and large, d = -1.01, effect size magnitude, respectively. These results confirm the fourth hypothesis "Assessment of the same task under different approaches (self-assessment, hetero-assessment and co-assessment) produces different results".

3.3. Grades

The DS project grades were analyzed and compared with the grades for other course-related assignments (Table 8). The results of an ANOVA analysis of the students' grades in the different activities ($n = 56$) including other assignments (practical exercises in lectures, AutoCAD practical exercises, DS project and final exam) showed significant differences, $F(3, 219) = 59.32$, $p < 0.001$, explaining 51.0% of the variance, η_p^2= 0.510. *Post hoc* analysis (Bonferroni; $p < 0.013$) showed that the final exam was significantly lower (3.67) than the DS project (7.88), practical exercises in lectures (6.66) and AutoCAD practical exercises (6.92), with a more than large, $d = -2.76$, $d = -2.12$ and $d = -1.81$, effect size magnitude, respectively. This result confirms the third hypothesis "DS will improve the student performance in comparison with final exam". Additionally, significantly higher grades were also found between the rating of the DS project with practical exercises in lectures and AutoCAD practical exercises with a large, $d = 0.94$, and medium, $d = 0.56$, effect size magnitude, respectively. In particular, the grade for the DS project was significantly higher (7.88) than the other grades. These results confirm the first hypothesis "DS will improve the student performance in comparison with practical exercises in lectures)" and the second hypothesis "DS will improve the student performance in comparison with AutoCAD practical exercises". No significant differences were found between the grades for the practical exercises in the lectures and the grades for the AutoCAD practical exercises. These results showed both the positive effect of the DS Project on the evaluation, and the need for continuous and non-final evaluation. One possible explanation for the low grades in the final exam was that it was not decisive for passing the subject and that no minimum grade was required to pass the final test. The DS project and the other assignments were conducted before the final exam. Students were aware of all grades before taking the final exam. None of the Engineering Drawing assignments had a minimum grade.

3.4. Surveys

The results of the NPS survey showed an excellent acceptance of the Design Sprint experience. The total number of opinions registered were 47. Net Promoter Score is calculated by subtracting the percentage of detractors from the percentage of promoters. The results showed an NPS figure of 26. A total of 15 students were promoters, 29 were passive users and 3 were detractors (Fig. 6). The result was very positive, because scores higher than 0 were typically considered to be good and scores above 50 were considered to be

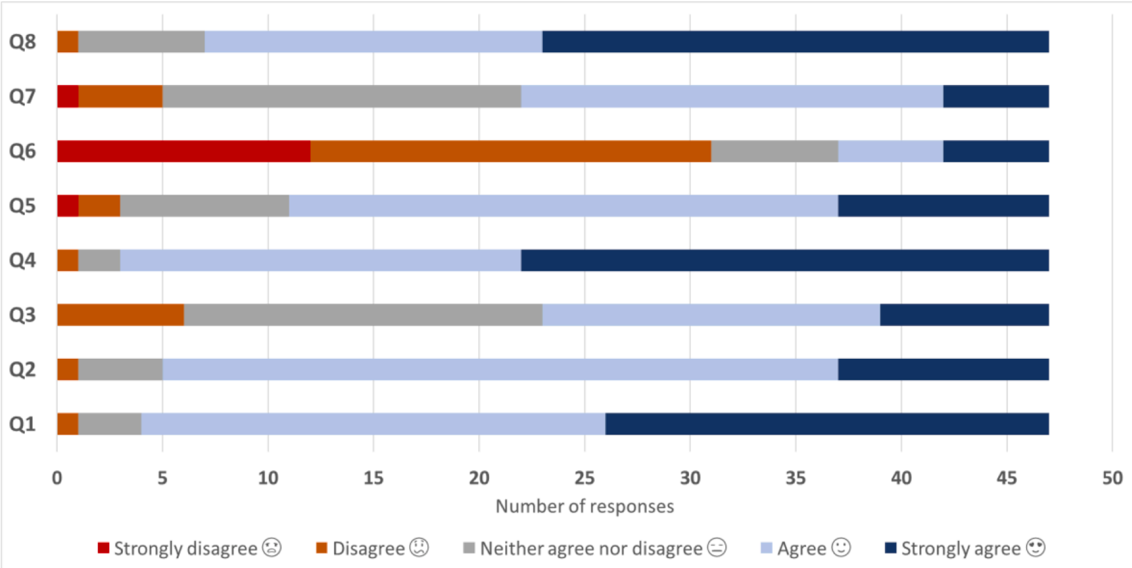

Fig. 7. Results of the Opinion survey.

Table 9
Summary of survey results.

ID	M	SD	*t*	CI 95%
Q1	4.34	0.70	13.12**	[1.13; 1.55]
Q2	4.09	0.62	12.01**	[0.90; 1.27]
Q3	3.55	0.93	4.09**	[0.28; 0.83]
Q4	4.45	0.69	14.47**	[1.25; 1.65]
Q5	3.89	0.87	7.08**	[0.64; 1.15]
Q6	2.40	1.28	-3.19**	[-0.097; -0.22]
Q7	3.51	0.88	3.97**	[0.25; 0.77]
Q8	4.34	0.79	11.66**	[1.11; 1.57]

CI, Confidence Interval; M, Mean; SD, Standard Deviation.
$^{**}p < .01$ df(46).

excellent (Buell, Raman & Muthuram, 2015). We compared our results with those from different companies, in order to establish that a high NPS value had been achieved. For example, Google has a NPS score of 11, Amazon has 25, McDonald's has −8, Facebook has −21 and KFC has 11.

Despite the fact that the open-ended statement for the NPS survey "What was the reason for your response?" was not mandatory, 100% participants answered it. Based on the responses of the students, four main benefits of the DS method were identified:

1 Simple methodology. 45% of participants.
2 Useful methodology. 28% of participants.
3 Entertaining methodology. 11% of participants.
4 Methodology applicable to multiple disciplines. 6% of participants.

Three students pointed out drawbacks of the DS method: Very limiting (rigid) method; The obligatory nature of developing the stages in several practical sessions; Very basic process with a number of unknown outcomes.

The ad-hoc questionnaire results also provided evidence of the good acceptance of this new teaching methodology (Fig. 7 and Table 9). The data analysis was performed using the Student *t*-test for a statistical comparison of the mean opinion and the central value (neutral) of the five-point Likert scale (Chomeya, 2010). The *t*-test null hypothesis was rejected in all cases and the *t*-test results indicated a higher mean value than the central one. The DS method experience was hyphenate. Question 6 was formulated in reverse, in such a way as to check that students had read the questionnaire and had not been giving random responses. The mean for question 6 was less than 3 (2.40), unlike the other questions.

4. Conclusions

In this paper, a practical project experience is proposed for engineering students using the Design Sprint method (combination of

Design Thinking and agile methodologies). The projects focused on solving problems related to the use of masks due to the COVID-19 pandemic. They connected subject matter with current realities (COVID-19) and applied knowledge to the solution of real problems. In basic first-year subjects (i.e., Engineering Drawing), it is very important for students to check the usefulness and real applicability of the theoretical contents. The DS projects made it possible to put into practice all the phases and techniques of representation studied in Graphic Expression (i.e., sketching, 2D drawings according to standards and 3D modeling). In addition to using CAD, the DS projects introduced the students to the use of Computer Aided Manufacturing (CAM) tools.

Student feedback has been recorded. The qualitative results of an NPS survey on the DS experience, showed high student loyalty (approximately 32% of promoters). In other words, students noted their satisfaction with the use of this tool in Engineering Drawing. In the open-ended question, the students stated that this tool is simple, multipurpose, useful and funny. The results of the ad hoc opinion survey with a 5-point Likert scale on the Engineering Drawing subject and the DS method showed very good student acceptance. In this paper, it has been used to address a real problem in a STEAM subject area; however, it has not been directly linked to the community Thus, as a future line of work, we propose the development of DS projects within a service-learning approach.

The Design Sprint method has promoted an interactive learning environment in which students must face different challenges proposed by the professor both individually and in groups. Throughout the 5 stages of the DS method, students develop the seven areas deemed crucial for employability purposes (based on Malaysian Soft Skills Scale (My3S)). The DS methodology also facilitates links between the content and the 17 Sustainable Development Goals of the 2030 Agenda. This encourages the use of this methodology in future editions of this subject. The presence of active learning has been evident, both during its development and the evaluation carried out by the students themselves. However, any teaching that involves learning by doing should always be prioritized over other more passive approaches. This is key for the engineering field where the association between the concepts taught and their application in the real world is of vital importance.

In the future, the authors want to continue using the methodology presented here. This methodology may be difficult to apply in theoretical subjects belonging to the Industrial Engineering Degree like Fundamentals of Thermodynamics or Strength of Materials. It should be noted that there is a strong affinity between DS and Engineering Drawing. The resolution of a real problem and the production tangible product are differential features that cannot be overlooked. It is also intended to make variations to the Design Sprint process. It should not be forgotten that this process arose within the world of web programming. There may be steps that could be adapted or simplified. Although, the three main steps Think-Make-Check always have to be present.

Author statement

Elena Arce: Conceptualization, Methodology, Writing- Original draft preparation. Andrés Suárez-García: Conceptualization, Writing- Reviewing and Editing. José Antonio López-Vázquez: Data analysis, Methodology, Writing- Original draft preparation. María Isabel Fernández-Ibáñez: Methodology, Writing- Reviewing and Editing.

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