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Improving Design Project Management in Remote Learning

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Abstract: Design Thinking has the potential to train the soft skills of preservice teachers who will need to continuously design their future towards sustainable education. However, Design Thinking is intrinsically complex, and managing its learning and projects with large groups is not straightforward, especially in remote situations such as COVID-19. From collaborative work among disciplines, this study introduces a Design Thinking-based board to improve the implementation and management of remote design projects. This board was applied with university-level preservice teachers who worked in teams to design instructional materials for preschool. We assessed the perception of the usefulness of the board by the preservice teachers and the teachers responsible for their training, using mixed methods in two consecutive courses. The board was perceived as helpful in developing design projects and improving collaborative learning. It was beneficial for the management, monitoring, and communication, enriching the project process and outcomes. From the achieved learning, we provide guidelines for designing and using these boards to aid educators and researchers in integrating Design Thinking and developing practical and sustainable solutions. This study contributes to the natural integration of Design Thinking and technology in preservice teachers' education with a replicable and flexible process, improving the quality of education for future generations.

Keywords: improving teaching soft skills; design thinking for education; preservice teachers training; Trello; collaborative learning; COVID-19

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1. Introduction

In a world that is constantly changing, students need to be engaged and empowered toward sustainability [1]. Education for sustainable development involves educational, and learning activities aimed at developing knowledge, skills, and attitudes to face and solve problems in our society, ensuring the welfare of future generations [2,3]. The educational field is essential to promote sustainable solutions to make students capable of adapting throughout their lives to a changing world, and therefore, nowadays, skills development has received considerable attention [4,5]. Indeed, there is an increasing demand for graduates with creative soft skills [6,7] that will allow them to contribute effectively and positively to the resolution of sustainability problems in their lives, occupations, and communities [8].

Under this sustainable education objective, education is immersed in the process of necessary change, from a focus on teaching to a focus on learning [9], in which innovation has a fundamental role [10]. Innovating in education implies thinking, designing, planning,

and assessing projects that solve problems, which are both internal demands and responses to external demands [10].

These innovation processes with new training dynamics and strategies have modified the traditional methodology [11–13] mainly based on teacher instruction and learning through copying, memory, or reproduction [14–16]. Among these new learning methodologies, for example, Guillén-Gámez et al. [17] apply 'cooperative learning' in the development of skills in preservice teachers. Duran and Dökme [18] indicate the significant effects of introducing 'inquiry-based learning' activities to promote critical-thinking skills. Caniglia et al. [19] present and demonstrate how 'experience-based learning' in university-level introductory courses fosters the development of skills in sustainability. Seitamaa-Hakkarainen and Hakkarainen [20] highlight the growing interest in 'learning by making' experiences, and cultivating new manners of thinking and acting. Dag and Durdu [21] implement 'project-based learning' with preservice teachers, who report improved problem-solving and collaboration skills. In these active methodologies, the students become the center of the educational process [22], allowing them to be the protagonist of their own learning and to develop their skill-learning [23]. Nevertheless, conveying this skill-based learning to students in practice is a complex challenge [11,24]. As soft skills are considered transversal matters, courses specifically focused on their development are not often found [25,26].

One of the knowledge areas that positively influence the development of these skills and on which this article focuses is the design field and Design Thinking (DT) in its broadest sense [27–31]. DT consists of the formulation and resolution of complex problems through a creative human-centered process [27,28], being suitable for challenges characterized by a high level of uncertainty, such as most sustainability-related problems [32]. Thus, DT provides a framework (i.e., an innovation approach) for sustainability-oriented innovation (i.e., an innovation outcome) [33]. This sustainable innovation implies the creation of new (or improved) products, services, processes, or practices that aim at environmental or social benefits [33]. Different methodologies are collected under DT [34–36], which habitually consist of three main stages: inspiration, ideation, and implementation [34]. There are many design methods or tools to support the development of the DT stages [37]. The efficiency, affordability, and adaptability of these tools, as well as the highly visual and universal language used, have allowed the DT to be actively applied in different fields outside design [28,38], such as education [39,40].

1.1. Design Thinking (DT) in Education to Develop Soft Skills

The application of DT in the educational environment is becoming increasingly popular. This process provides open-mindedness in students [28,41], a balance between convergent and divergent thinking [42,43], and the development of soft skills [29–31] such as collaboration, problem-solving, or innovation [40,44], which according to Brundiers et al. [8] are key skills in sustainable education. These benefits have made the application of DT in education more and more popular at all levels, from the early years to the university [45–52].

In this sense, research advocates for the concept of training educators as designers [53–55]. Indeed, Mishra and Koehler [56] developed their recognized approach to technological pedagogical content knowledge supported by the concept of educators as designers [57]. The importance of DT is justified because, in their teaching work, the teachers not only transmit knowledge to students but also adopt roles as coaches, resource providers, and designers of their classes, instructional materials, learning experiences, or teaching methodologies [58,59]. Thus, the teacher is responsible for innovating and building 'ways' [10], working with content, tools, and ideas to design experiences for students [56]. Moreover, their teaching work is essential for training students on how to create and live in a sustainable world [60–62]. Teachers should be encouraged to develop skills to understand and internalize the relationship between their teaching work and society's problems [17].

Therefore, the preservice teachers need to be prepared and trained with 'critical thinking, problem-solving, collaboration, and networking skills' [63]; and precisely, DT implies a team learning process, which facilitates constructivist learning, offers a high-level vision, and fosters the 21-st century skills [45,64,65]. Thus, there is interest in training preservice teachers in DT because it may aid in future teaching work to address complex and varied challenges at a local level, such as lesson and curriculum development, student motivation, school climate, relationships, and countless others [57], and at a global level to promote the sustainable development of future students in these soft skills [17].

Nevertheless, despite the global interest in training preservice teachers in DT, at a practical level, the programs and curriculums do generally not include this type of training [66–68]. This is due to barriers of widely varied natures that do training in DT and managing DT projects with large groups of students challenging [52,57]. The DT itself is a multifaceted, messy, and complex process [69,70] that promotes the divergent and the indefinite in a converged and defined environment, placing the educator in an uncertain position [71]. As shifting this thinking or approach is not straightforward, sustainable solutions are needed to facilitate the integration naturally of DT in preservice teacher training.

1.2. Design Project Management Challenge in Remote Learning

A critical challenge for applying DT for sustainable education is related to the difficulty of managing design projects with large groups of students, as well as the long-term (subject duration) planning of such projects. First, for teachers, in this case, those responsible for the training preservice teachers, who must manage large groups of students with a high level of organization, planning, monitoring, and feedback. Second, for the preservice teachers, who act as students who apply the team learning process, acquiring the teamwork skill necessary for learning and personal growth and essential in their future professional work [72,73].

There are many interaction requirements between teachers and students to consider. First, the teacher-teacher interaction must be collaborative [74]. Teachers should desirably come from different work environments or disciplines; they must 'cross their own islands of knowledge' to establish common ground and shared understanding [25]. Likewise, the teacher-student interaction must ensure a shared understanding. The teacher should actively involve the students and establish an atmosphere that avoids division between teacher and students, making that 'the students relax and get involved in the activities in an uninhibited manner' [52]. Therefore, the teacher must foster interest and participation, allowing mistakes, and welcoming opinions, curiosities, questions, and answers [75,76]. Finally, the student-student interaction must be appropriate to achieve teamwork, considering that they can come, like teachers, from different disciplines. Students must learn to work as a cohesive team through smooth communication, structured collaboration [77], and adequate management of different situations that may arise among team members, such as the 'hitchhikers and couch potatoes on teams' (brief definition) [78].

Additionally, these interactions are influenced by remote situations, such as the unforeseen COVID-19 pandemic. In just a few days, abruptly, teachers from different disciplines had to work together towards the new scenario of remote learning [79]. The remote learning concept is understood as the opportunity to provide sustainable education to students without being physically in the same place as the teacher through technology [80]. Remote learning implies that students and teachers remain connected but changing the teacher-student interaction from physical to virtual and making students work as a team through remote meetings. This increased the workload for teachers, who were under great pressure to redesign subjects and infrastructures [79]; however, remote learning is a necessity in times of lockdowns [81], preventing students from experiencing setbacks during school closures [82]. In this regard, COVID-19 has implied the opportunity to adopt remote learning, making the education system immersed in a substantial change toward new teaching and learning models [81,83,84] more student-centered [32]. In addition, according to

Foo et al. [85], new teaching and learning models should not be limited to crisis situations; it is necessary to learn about them to ensure sustainable education and face future and uncertain challenges.

1.3. Project Management Opportunities

To mitigate the difficulty of managing this type of project, the adaptation and incorporation in the education of workflow management methods such as Kanban are of special interest [86,87] and commonly used in software development [88]. The Japanese word 'kanban' means 'visual board'; specifically, the Kanban board is a tool to map and visualize the project workflow. The board is divided into columns to represent a different stage of the workflow, usually: 'Requested,' 'In progress,' and 'Done' [89]. The tasks of the project are visually represented in cards, which progress through these columns according to the progression of the work [90]. Thus, the Kanban board is a project management tool that allows all participants to see the process in a highly visual manner and follow the progress of the project from start to finish, supporting teamwork. Kanban implementation can be either physical (e.g., blackboard, wall, paper, sticky notes, etc.) or virtual via software support [90], essential in scenarios such as COVID-19.

Precisely, the Information and Communication Technologies (ICT) aimed to create and share ideas and content [91] are an opportunity and have a fundamental role in sustainable society [92]. If ICT had already changed our lives [93], the COVID-19 pandemic has boosted them in education [94], making the ed-tech startup sector grow exponentially [95]. ICT favor the development of 21st-century skills [96], is considered key to innovation [97] and must work closely together with DT [98].

As Stolaki and Economides [99] claim, 'to have a sustainable, innovative society, new technologies, education, and creativity training have to be linked and integrated into effective educational and training systems'. Thus, ICT serves as a lever for sustainable education, empowering students to promote their digital skills as future citizens [100].

According to Gómez [101], ICT is considered cognitive tools, i.e., unintelligent instruments that rely on the learner to generate knowledge, placing the responsibility on the learner and not on the computer. Thus, according to Jonassen [102], cognitive tools must support the collaborative construction of knowledge. This implies learning with technology, using technology as a learning tool rather than as an instructional resource [103].

In this context of shifting educational trajectories, in order to efficiently use ICT in remote learning, according to the Mishra and Koehler approach [56], the teacher should consider the knowledge of the: specific contents of the subject, pedagogical strategies for its teaching, and use of ICT [97]. Thus, it is essential for preservice teachers to acquire technological literacy. Technological literacy involves acquiring transformative and expansive skills for a sustainable society from cultural, economic, environmental, and social perspectives. Thus, digital teaching skills serve to build digital citizenship, being closely linked to sustainability [104]. Nevertheless, sometimes the preservice teachers do not develop multiple technology skills, despite the relevance and interest of using them effectively in their classrooms [105–107].

1.4. Software to Manage Projects in Education

Most educational institutions have at their disposal learning management systems platforms such as Moodle, Blackboard, or Canvas [108,109]. In addition, there has been an increase in the educational use of more specific software for managing the work of groups of students during the implementation of projects. For example, Havazík and Pavlíčková [110] applied the Jira software (8.13 version, Atlassian, Sidney, Australia) to students of Computer Science to develop a project to create a computer game. Collaguazo et al. [111] used the Asana software (9.24.0 version, Asana Inc., San Francisco, CA, USA) with students of Telematics Engineering to develop IoT and Cloud Mobile Applications. Gatwood et al. [112] assessed student pharmacists' acceptance and used a cloud-based (Evernote Business) productivity platform. Rysavy and Michalak [113] used Notion software (2.16 version, Notion

Labs Inc., San Francisco, CA, USA) to manage the academic library members during the COVID-19 pandemic. Zhu and Ryzhkov [114] applied the KanbanFlow software (2.0 version, Codekick, Gothenburg, Sweden) to manage a project of a specialized program for bachelors. Likewise, Phillips et al. [115] implemented Slack software (4.25.0 version, Slack Technologies, San Francisco, CA, USA) to create an online community in undergraduate dermatology medical education.

In this line, the implementation of social media sites in education, such as Twitter, blogs, Facebook, or YouTube, has the potential to enhance the teaching and learning of design projects. As Withell et al. [116] or Caruso [117] demonstrate, social media sites can offer the opportunity to investigate users' experiences, reflect and write freely, record and review the process, as well as share or collaborate. All of these opportunities are essential for design projects, which involve investigating, empathizing with the user, collecting information 'on the fly' [116], and especially collaborating and actively participating during the process [117]. About these examples for project management and social media tools, it is observed how, in general, these software solutions are not initially developed for the educational environment. Thus, this type of software needs to consider educational premises to adapt to pedagogical needs [118]. The remote teaching-learning process should not consist of uploading the existing material or digitizing the processes by doing the same as before [119], whereas a digital transformation is required, redesigning processes and involving people [120]. Indeed, in their study, Tejedor et al. [97] show how the students reported the lack of adaptation of the materials in the COVID-19 crisis, assuring that they were exactly the same as in the face-to-face stage. Therefore, a sustainable society requires adopting this digital transformation which implies deep changes and adaptations in emerging educational technologies, innovations, and research [97,121].

Considering all the previous subsections, it can be deduced that there is a global interest in training preservice teachers in DT since it improves the quality of education for future generations toward a sustainable society; assuming that sustainability is not anticipated as a definite result but rather as a global direction that considers long time periods [33]. However, managing DT projects in remote situations such as COVID-19 is a challenge. ICT, understood as useful cognitive tools, can favor the management of this type of project, fostering the use of technology as a learning tool.

Thus, in this study, a multidisciplinary team of specialists (design, technology, and education) worked together to consider educational premises and pedagogical needs to develop a new use of an online board called DT-based board. This board aims to support preservice teachers and the teachers responsible for their training in the implementation and management of remote design projects, empowering preservice teachers to face and solve problems in their future teaching work in a changing world towards a sustainable education. The board is based on the DT process and is embodied in guidance documents and templates, structured on cards according to the Kanban method. The research question is: what is the perception of the usefulness of the DT-based board for sustainable education during its application with preservice teachers?

To answer this research question, this DT-based board was applied with university-level preservice teachers to accomplish team projects to design instructional materials for preschool classrooms. During the application, the perception of the usefulness of the board as supporting the project was assessed through mixed methods. As a result of the learning, generalizable knowledge was established in the form of guidelines for designing and using these types of boards. Therefore, this article provides (1) the foundations of a new DT-based board, (2) replicable experimentation about the perceived usefulness of the board, and (3) guidelines to aid educators and researchers in integrating DT training for sustainable education.

2. Materials and Methods

2.1. Research Context and Sample

Two iterations were conducted for the DT-based board assessment, where a total of 125 preservice teachers aged 19–21 years participated: 56 during the first iteration (course 1); and 69 in the second (course 2). According to the statement terminology of Tong et al. [122], the sampling method was purposive, which involves selecting participants who are expected to provide relevant data pertinent to the research question. Participants were enrolled in the 'Instructional Materials and Resources' subject of the Education degree of the Faculty of Education of the University of (details removed for peer review). This subject is taught in the 2nd year and is compulsory for all preservice teachers. The subject aims to study instructional materials and how to create them; the project of the subject consists of the creation of instructional materials according to real needs from a classroom of local schools (preschool stage) assigned to the preservice teachers. The preservice teachers knew educational practices, as well as the types and classifications of instructional resources, but were novices in designing and creating instructional materials. They were recruited via an explanation during the first class session; all preservice teachers enrolled in the subject voluntarily accepted to take part in the experiment. Then, the preservice teachers were divided into groups of 3 to 4 members to develop the project, which according to Oakley et al. [78], is the optimal number of members. Thus, 15 teams were formed during the first iteration and 18 teams during the second.

2.2. Research Model and Procedure

Applying the DT approach to students without design knowledge and educational technology literacy involves a challenging and critical context; it demands adaptation, management abilities, and a high level of x-disciplinarity. To further define the x-disciplinarity term, note that it is assigned to the set of possibilities of collaborative work: multi-, cross-, inter-, trans- [123]. Thus, an x-disciplinary workgroup was formed by three lecturers specialists in the design, technology, and projects management disciplines; and two lecturers specialists in the didactic field, particularly in the pedagogical bases and the preservice teachers' training curriculum. They worked together, moving away from their own islands of knowledge to create a shared and optimal solution [25]. Of the team members, the two specialist lecturers in didactics and one of the specialist lecturers in design were the teachers of the subject.

The x-disciplinary team worked together to develop the solution based on guidance documents and templates that make the preservice teachers follow the DT process to design their instructional material. Then, the team decided to use a Kanban board with the aim of making it easier for preservice teachers to visualize and follow the workflow of the DT process. The board was digitally supported because of the need for remote learning and the importance of training them in ICT as useful cognitive tools. Likewise, the use of digital platforms also means reducing the use of paper and developing durable materials and resources, promoting sustainability in education.

For this purpose, the team looked for a tool that allows the creation of boards according to the Kanban method, online team collaboration, private use, uploading files, and copying boards. Thus, the Trello software (2.1.3 version, Atlassian, Sidney, Australia) was chosen for meeting the mentioned features, not requiring payments, download, subscription, and the visual and intuitive interface that makes it straightforward to learn. In fact, according to Dean [124], Trello is the 'best project management software tool for getting started,' which is essential considering that preservice teachers are not familiar with technology and project management. Specifically, a Trello board allows the creation of movable columns to add editable cards that incorporate features or attributes such as description, identification tag, date setting, member assignment, chat, checklists, or attachments.

Thus, Trello was used as a shared workspace for preservice teachers to accomplish their projects cooperatively and remotely. Then, the structure and plan were defined, and the first prototype of the DT-based board was implemented. For this, the x-disciplinary

team agreed on two main objectives: to aid preservice teachers in managing and structuring the teamwork to design instructional materials guided by the DT process. On the other hand, to aid teachers in managing and monitoring large groups of students in remote design projects. Finally, the prototype was evaluated in two iterations, as mentioned. By improving the prototypes used in the assessments, the final version of the DT-based board, presented in Section 3.1, was developed.

The DT-based board application and assessment lasted one semester (16 weeks) in each of the two iterations. The aim of the subject project for the preservice teachers was to design innovative instructional materials for use and implementation in a real classroom. For this, each team (15 in the first iteration and 18 in the second) was assigned to a local classroom (preschool stage) and their own DT-based board. During each iteration, the teams carried out the following phases based on the DT model 'Double Diamond' [24], shown in Figure 1. The 'Double Diamond' is a synthesized model of DT: the first diamond implies exploring an issue deeply (divergent thinking) and then focusing on a challenge (convergent thinking), and the second diamond involves providing different answers to the challenge (divergent thinking) and then defining the solution (convergent thinking). Thus, this model achieves a balance between convergent and divergent thinking, both of which are essential to developing creative soft skills [29,41,42] in preservice teachers.

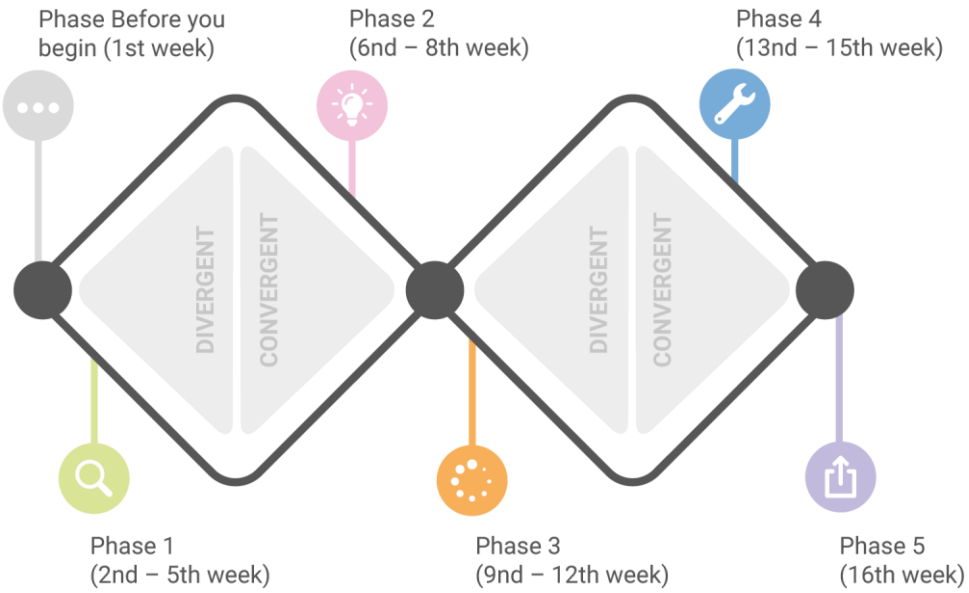


Figure 1. Phases representation based on the double diamond model.

- Phase Before you begin: At the beginning of the project, two workshops with introductory presentations about DT and Trello software were conducted.
- Phase 1: The preservice teachers analyzed the assigned center to detect needs (field research). Thus, using the DT-based board material provided, the preservice teachers accomplished a semi-structured interview with the assigned teacher and conducted context observation in the classroom of the preschool stage assigned. Additionally, they conducted theoretical research related to the main identified need.
- Phase 2: The preservice teachers synthesized the more relevant verbatim quotations of the interview on sticky notes and defined fictitious students' archetypes using the 'Personas' method to empathize with their students and consider their attributes. Likewise, they conducted a group ideation session to address the main identified need, using the 'Brainstorming' method.
- Phase 3: The preservice teachers converted the initial ideas into concepts of instructional materials. For this purpose, they used the '5 whys' technique. They reflected on the following topics (1) what is the main function, (2) what is the most related curricular area, (3) what is the content, (4) what is the didactic objectives, and (5) what

skills it works on. Additionally, they defined formal details of the materials, such as dimensions, materials, shapes, or useful features. They were encouraged to use reused materials (e.g., pallets, packaging, carton, etc.). Finally, through a 'Storyboard' method, the preservice teachers sketched the planned activity to apply their instructional materials in the classroom.

- Phase 4: The preservice teachers built their instructional materials prototypes for the class implementation with reused and low-cost materials. Then, they reflected on the results and proposed solutions or improvements for the activity with their instructional materials. Note that the COVID-19 pandemic implied that, in the first iteration, the preservice teachers did not conduct the assessment; however, the instructional material developed was sent to the preschool stage teacher, who provided feedback.
- Phase 5: At the end of the project, through the presentation phase, the preservice teachers created structured presentations that included the instructional materials created, their application in the class, and the results or feedback obtained.

2.3. Instruments and Data Analysis

The Xassess general framework was used to evaluate the application of the DT-based board in the described environment in both iterations [125]. Xassess is an evaluation methodology that merges qualitative and quantitative approaches, centered on multidisciplinary teams. In this manner, the x-disciplinary team conducted a multi-instrumental assessment with different techniques to obtain information about the perceptions (Table 1). The assessment was conducted in accordance with relevant ethical guidelines [126], providing a verbal and written explanation of the study. Before starting with the survey, students had to agree to a declaration, which informed them about the purpose of the study and assured them of the confidentiality and privacy of the information they provided.

Table 1. Instruments and data analysis to assess the Design Thinking (DT)-based board.

Instruments	Data Analysis
Survey (Quantitative and qualitative)	
Individual surveys were conducted with the preservice teachers using questionnaires with closed and open questions in the Google Forms platform. The purpose was to collect scores and feedback about the usefulness perception of the board as supporting the project by the preservice teachers. The survey included questions about certain relevant concepts, such as the material used (phases, guide documents, etc.), design of instructional materials (project aim), interaction with other students (teamwork), organization of work during the COVID-19 situation, or their future teaching work.	The resulting data were exported to MS Excel. The closed questions were examined using descriptive statistics and visual graphics. These graphics were made with the Python (3.8 version, Python Software Foundation, Wilmington, DE, USA) language. The opened questions were manually coded and grouped according to the thematic analysis approach [127]. Then, the groups of answers were read several times separately by each of the evaluators. In a joint session, they discussed their reflections and justified their suggestions with verbatim quotations to avoid inserting their judgments or beliefs without data from the research.
Observation, field notes, and periodic internal discussion (Qualitative)	
An observation process was also conducted to analyse the behaviour of the preservice teachers'. During the observation, the teachers of the subject collected field notes and accomplished six focus groups in each iteration, distributed during the assessment, 12 in total. In these focus groups, the entire x-disciplinary group attended. The focus groups were online and lasted one hour each.	The field notes were discussed and analysed, and one of the group members created records of the meetings to collect the key concepts shared. Firstly, these annotations complemented the assessment of the usefulness perception of the DT-based board conducted with the survey (see Xassess terminology about complementation). Secondly, to discover the key features and contributions of the DT-based board for teachers collected in the discussion section. Thirdly, to collect deep knowledge and insights on how to design and use this type of board exposed in the guidelines of the discussion section.

Table 1. *Cont.*

Instruments	Data Analysis
Project platform: Trello (Quantitative and qualitative)	
Finally, Trello was used as a source of information for the assessment. On this platform, the preservice teachers scored their usefulness perception of each card at the end of the task. Additionally, the preservice teachers progressively uploaded their work and interacted with the teachers in a loop of doubts and feedback that was recorded for its consultation.	These scores were transcribed to MS Excel, analysed using descriptive statistics, and plotted in Section 3.2. In addition, all data collected on the project platform (Trello) supported the assessment resulting from the other techniques, complementing the results of Section 3 and the guidelines included in the discussion section.

3. Results

3.1. DT-Based Board Features

The following describes the board provided to each preservice teacher team after the two iterations described above. On this board, the students could make modifications to the development of their project.

As shown in Figure 2, each DT-based board has an identifying title and the team members at the top. The board is configured, according to the Kanban board, in 3 columns or lists: 'To do', 'Doing,' and 'Done'. The subject teachers included in the first column 'To do' all the material divided into cards corresponding to the tasks to follow the DT process. In this manner, while the preservice teachers' team was working on one of the tasks, they moved the card to the 'Doing' column. At the end of the task, the team attached the requested files and moved the card to the 'Done' column. Thus, both teachers and preservice teachers had visible the progress and workflows.

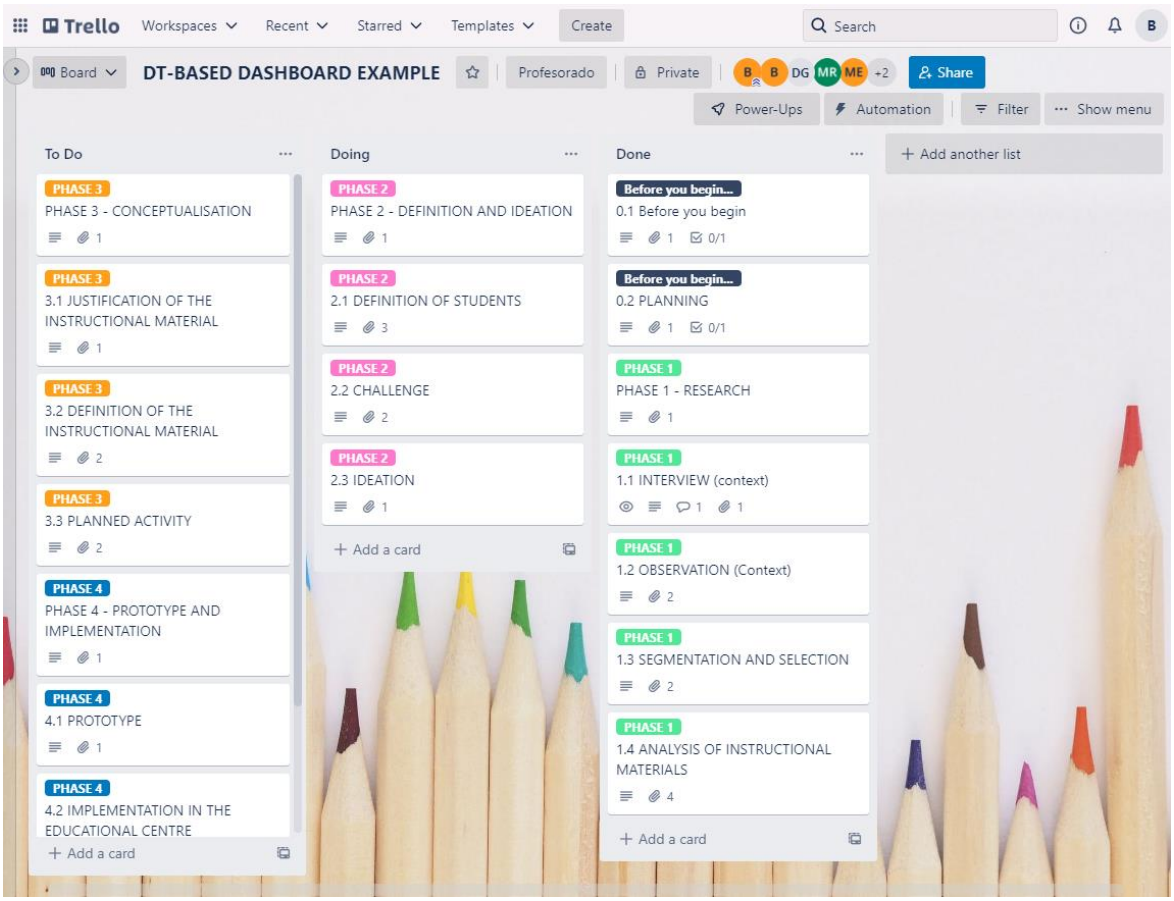
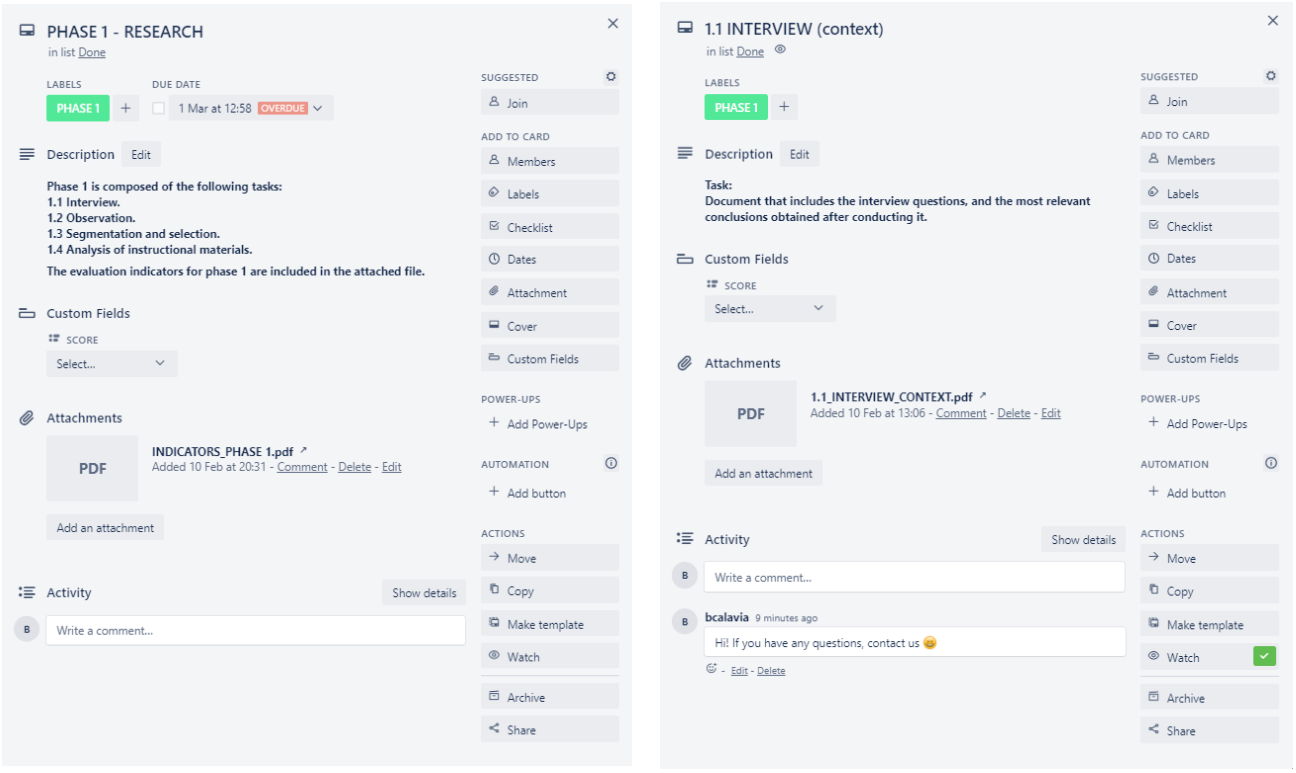


Figure 2. DT-based board example.

All the cards included in the panel have an identification code composed of three attributes. First, a tag to identify the phase: grey for the 'Before you begin' phase, which includes the introductory cards, green for 'Phase 1', which contains the research cards, pink for 'Phase 2', which incorporates the definition and ideation cards, orange for 'Phase 3', which includes the conceptualization cards, blue for 'Phase 4', which incorporates the prototype and evaluation cards, and purple for 'Phase 5', which contains the presentation cards. Second, a concise title to briefly describe the card. Finally, before the title, a number according to their chronological order. There are two types of cards:

- Six general cards (Figure 3a) aimed to present and explain the objective of each phase and contextualize (before you begin, research, definition and ideation, conceptualization, prototype and implementation, and presentation). These cards include the three attributes mentioned (tag, title, and number), (1) a checklist of the tasks to be completed during the phase, and (2) an advisable date to finish the phase.
- Sixteen specific cards (Figure 3b) aimed to guide the preservice teachers in the DT process, providing techniques, tips, and tasks adapted to the field in question. These cards include—in addition to the three attributes mentioned (tag, title, and number)—(1) a description of the task to be performed; (2) a chat called activity for board members (preservice teachers and teachers of the subject) to talk, ask questions, or leave notes, automatically notifying all board members; (3) an attached guide document to aid the preservice teachers during the specific task execution (Figure 4). Likewise, the preservice teachers can add certain information to each card to facilitate the management and planning of teamwork, such as their start and deadline dates, calendar notes, or member assignments.



(**a**) (**b**)

Figure 3. (**a**) General card example (**b**) Specific card example.

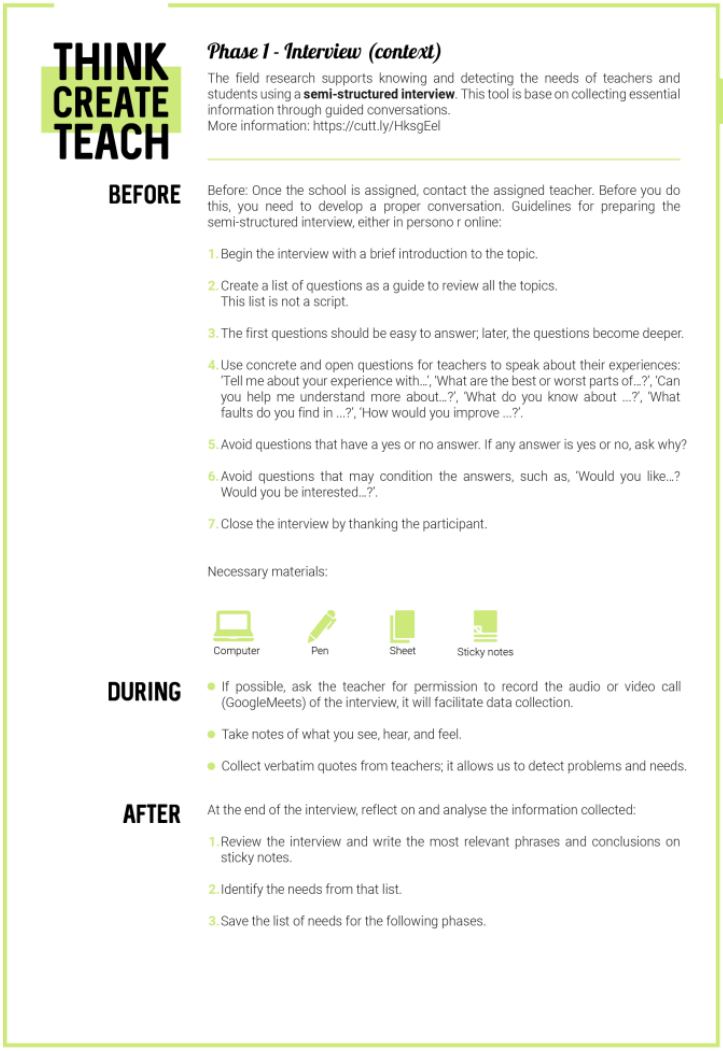


Figure 4. Guide document example.

3.2. Usefulness Perception of the DT-Based Board for Preservice Teachers

The following sections include the quantitative and qualitative results of the assessment of the first and second iterations regarding the perception of preservice teachers about the usefulness of the DT-based board.

3.2.1. Usefulness Perception of Each Card for Design the Instructional Materials

Figure 5 shows the mean scores and standard deviations of each card reported by the preservice teachers in Trello after its implementation. In general, the scores are high, and the average score of all cards is 5.8 $\pm$ 1.2 in the first iteration and 6.6 $\pm$ 0.8 (Likert scale from 0–7) in the second iteration.

The cards with the highest scores in both iterations are the 0.3 card, on which preservice teachers asserted 'how important it is to know plan since good learning is based on good planning'; 1.1 'the interview (...) was very enriching and is key to know the context and to start the project'; 2.3 'we used very dynamic and innovative methods that allowed us to think about the appropriate material for the students'; 4.1 'it is to turn all our work into reality'; 5.2 'new design and communication strategies and tools for structured presentations'. In general, the high scores for both iterations are related to the fact that students perceive that 'the guidance documents have allowed us to learn different tools and new methods to create materials in practice' from a 'dynamic, innovative, and novel' point of view.

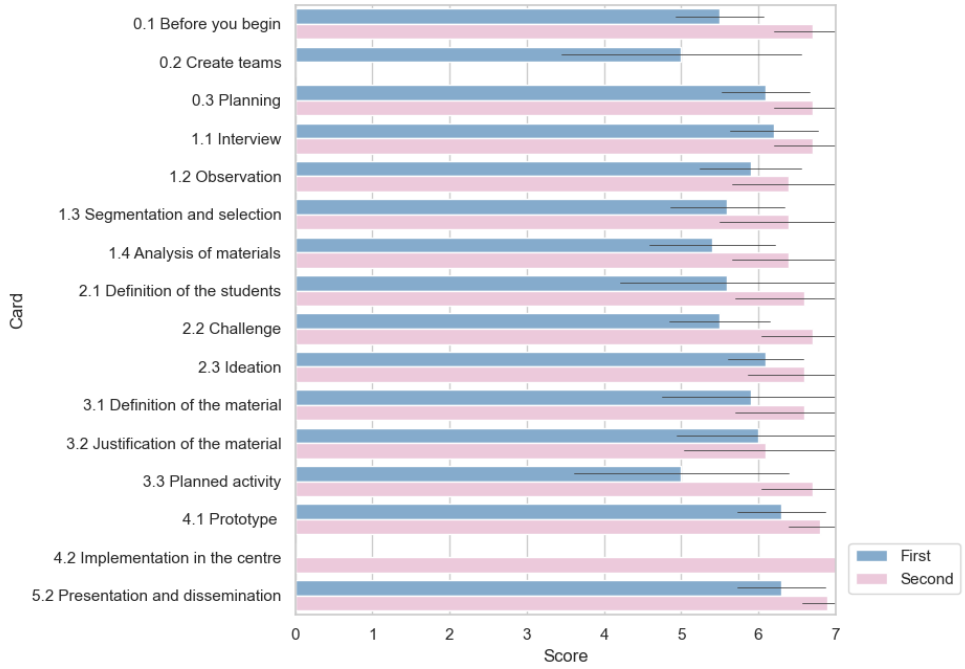


Figure 5. Card scores reported by preservice teachers (mean and standard deviation) in the first and second iterations. Scores range from 0 (minimum valuation) to 7 (maximum valuation).

During the first iteration, the 0.2 card was the worst scored, and as preservice teachers assured, 'it was less useful because I already knew my colleagues'; therefore, in the second iteration, this task was removed. Additionally, other guide documents obtained low scores in the first iteration (0.1; 2.2; 3.3), while they are among the most valued in the second iteration, which evidences the improvements implemented by the x-disciplinary team.

In the second iteration, the 4.2 card was scored with the maximum score by all teams, which coincides with the qualitative perspective '(...) carrying our material and being in the classroom has been incredible'. Note that this card was not scored in the first iteration because the lockdown (COVID-19) prevented preservice teachers from applying their instructional material in the classroom.

3.2.2. Usefulness Perception of the DT-Based Board for the Design of the Instructional Materials

Figure 6 shows the distribution of the perceptions of preservice teachers regarding three main items. In this subsection, we delve into the first item (Figure 6a) related to the question of 'How useful has the DT-based board been to design the instructional material?' whose mean evaluation is 5.2 $\pm$ 1.1 in the first iteration and 5.9 $\pm$ 1.1 (Likert Scale from 0–7) in the second. As explained in the discussion section, the scores are generally high, and an improvement can be appreciated in the second iteration.

The variety of answers on the contributions of the DT-based board to the design of instructional material (Figure 6a) can be classified into five ideas. (1) The board is useful for planning and organization, 'a structure of the complete process to plan and have everything under control'. (2) It is essential to consider the process, 'learn a process for designing materials, from research to application, reflecting on many aspects which I would not initially have considered'. (3) The board aids with the mental structure, 'It helps to organize ideas that often you do not know how to put together'. (4) The board highlights the ability to act as a designer, 'to learn to design my materials actively and not theoretically'. (5) It provides an enriching experience, 'Thank you for this wonderful experience, it has been one of the projects that I have enjoyed the most, I would do it again'.

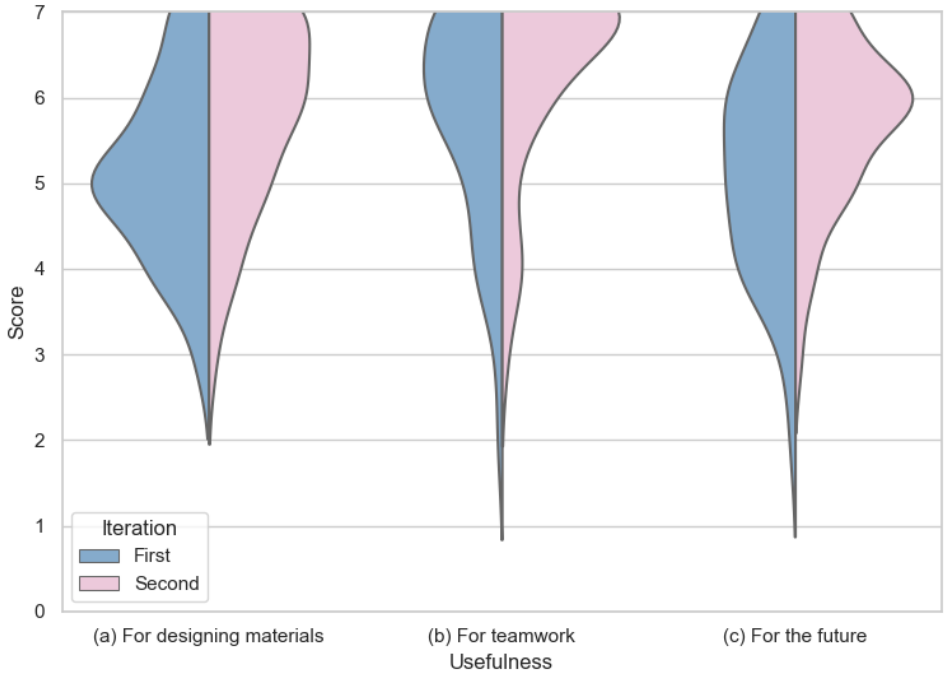


Figure 6. Usefulness perception of the DT-based board for (**a**) designing materials; (**b**) teamwork; (**c**) the future. Scores range from 0 (minimum valuation) to 7 (maximum valuation).

3.2.3. Usefulness Perception of the DT-Based Board for Teamwork

Regarding the question 'Do you consider that the DT-based board has aided teamwork?', as shown in Figure 6b, the mean of the preservice teachers' answers is 5.8 ± 1.2 in the first iteration and 6.3 ± 1.1 in the second (Likert Scale from 0–7). As shown in the violin distribution, the second iteration values are more concentrated than the first iteration, which are more dispersed. In this sense, several students mentioned this improvement during the survey with phrases such as 'it allows me to learn to work cooperatively with a real educational center and with my mates', 'this board has helped us to organize and facilitate teamwork'; 'it provides you new manners of working as a team'.

3.2.4. Usefulness Perception of the DT-Based Board for the Future

Regarding whether 'Would you like to use this DT-based board or any of its phases again in your future teaching work?' the mean of the preservice teachers' responses is 5.2 ± 1.2 in the first iteration and 5.8 ± 1.0 in the second (Likert Scale from 0–7) (Figure 6c). When justifying their answers, the lowest scores refer to 'too many phases to complete'. In contrast, the highest scores report that 'it is essential for our future to have a base with this type of training'.

3.2.5. Usefulness Perception of the DT-Based Board, Although It Is a Laborious Work

Figure 7a refers to the fact that 97.8% of preservice teachers in the first iteration and 100% in the second said that although this method is laborious, it is worth it. It aligns with the reported ideas of the preservice teachers: 'the results and experience achieved worth the effort'; 'understanding the process for my team was not easy; however, I consider it a beneficial manner to get a good result'.

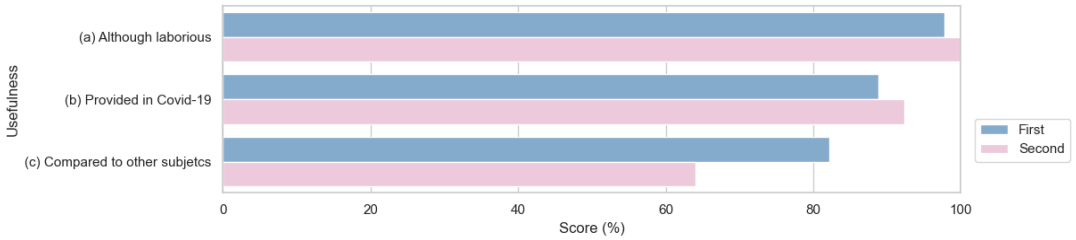


Figure 7. Usefulness perception of DT-based board (**a**) although laborious; (**b**) provided in COVID-19; (**c**) compared to other subjects.

3.2.6. Usefulness Perception of the DT-Based Board in COVID-19 Situation

Concerning the COVID-19 situation, Figure 7b shows the aid provided by the DT-based board to develop the project. In the first iteration, 88.8% affirmed that TCT helped them develop the work in the COVID-19 situation, and 92.3% in the second iteration.

Figure 7c concerns the difference with other subject projects developed in the same COVID-19 situation, where 82.2% reported that they had experienced a notable improvement in this subject thanks to the methodology. In the second iteration, 64.1% claimed to have noticed an improvement.

Many preservice teachers related this improvement in the COVID-19 situation for four reasons. (1) The continuous work, 'to be in permanent activity, working little by little'. (2) The structure of the DT-based board, 'in other projects, a single document contains everything, while the board is all explained in related sections'. (3) Remote teamwork, 'it was designed for remote use (...) we could do the work through meetings, and we all knew where we were'. (4) The feedback provided, 'the teachers have monitored everything through Trello, and we could contact them directly'.

4. Discussion

This study describes the development of the DT-based board to improve the implementation and management of remote design projects, empowering preservice teachers to face and solve problems in their future teaching work towards a sustainable education. The board was assessed in two consecutive iterations regarding the perceptions of the preservice teachers (students) and the teachers responsible for their training. From this experimentation, generalizable knowledge was established in the form of guidelines to aid researchers and educators in designing and using these types of boards.

The assessment demonstrated the board's usefulness to support and conduct DT projects remotely, specifically for the design of instructional materials. This achievement is materialized for several reasons. First, specialists from different disciplines designed and developed the DT-based board considering educational premises from the beginning: the specific preservice teachers' needs and knowledge, the curriculum features, the time available, and the project's scope. Second, and probably as a result of the first, preservice teachers showed positive attitudes toward the DT-based board materials; the average score on all cards was high (5.8 ± 1.2 in the first and 6.6 ± 0.8 in the second iteration on a scale from 0–7, see Figure 5).

Likewise, the board, structured according to the Kanban method, allowed the preservice teachers 'to have an overview of the project at a glance' (teachers of the subject) with an agile learning curve. Some learning management solutions can be challenging to use (for both teachers and students) because they are overwhelming, have much functionality that is not always known or applied, and require training and excessive time. However, the DT-based board embedded on Trello is user-friendly, flexible, and allows organizing projects visually; it is like a board full of post-its. It is beneficial for remote learning because it simulates the tangible murals or boards they are familiar with, allowing the student to participate actively through ICT [128], considering ICT as useful cognitive tools [101]. Furthermore, the use of ICT contributes to the development of digital teaching skills, which according to Colás-Bravo et al. [104], are essential for sustainable digital citizenship.

Thus, the use of the DT-based board was especially useful in the COVID-19 situation, as indicated by the preservice teachers (88.8% in the first and 92.3% in the second iteration). Solutions provided in crisis situations, such as COVID-19, make education sustainable at present and facilitate facing future and uncertain challenges in the long term [81]. In this line, the preservice teachers perceived an improvement in comparison to other subject projects developed in the same COVID-19 situation. It should be noted that in the second iteration, preservice teachers indicated less difference from other subjects; this is understandable because many teachers evolve towards ed-tech [95].

Following the perception of the usefulness of the DT-based board for the design and development of instructional materials, the preservice teachers indicated high scores (5.2 ± 1.1 in the first and 5.9 ± 1.1 in the second iteration on a scale from 0–7, see Figure 6a). The board allowed preservice teachers to not only visualize, but also follow 'a structured, cohesive, reflective, flexible, and justified design process' (teachers of the subject); in line with Kleon [129], it provided them with the opportunity to understand the importance of thinking about the process, not only about the result. To help the preservice teachers to assimilate this concept, we focused on evaluation and continuous feedback during the process, rewarding the willingness to explore, discover and innovate [130]. This DT process allowed the preservice teachers to develop human-centered and well-founded instructional materials 'they do not make a material because they have seen it on Pinterest, but there is a reasoning and a justification behind' (teachers of the subject). It is related to Carroll [131], Howard, et al. [27], and Mosely et al. [28] that ensure that design is focused on human-centered problem formulation and problem-solving. Likewise, this boosts competence learning, fosters research, facilitates 'learning-by-doing,' and provides new valuable tools and methods for their future and sustainable teaching work. Thus, numerous preservice teachers considered this training useful for their future teaching work (5.2 ± 1.2 in the first and 5.8 ± 1.0 in the second iteration on a scale from 0–7, see Figure 6c); the preservice teachers who reported the lowest scores justified it with the numerous phases to complete. However, as indicated by 97.8% in the first iteration and 100% in the second: the method is laborious, but it is worth it.

Regarding the project management, we highlight teamwork since, according to the results, the DT-based board facilitated participation and interaction in the preservice teacher teams during the project (student-student): 'it allowed a better climate among the members (...) everyone was involved' (teachers of the subject). Also, the board was used as a communication tool between teacher-students 'Boards allowed us to be connected and monitor each team's progress, avoiding behind-scheduled groups' (teachers of the subject). Thus, this board improved and facilitated the labor of the teachers responsible for the preservice teacher's training and management of remote design projects, adapting communication to each group according to their project stage [132,133].

As a general comment, the results during the second iteration were more favorable than in the first iteration. This effect is understandable for two reasons. First, because in the second iteration, the preservice teachers had the opportunity to apply their instructional materials in the classroom, whereas in the first iteration, they were not due to the lockdown (COVID-19). This may influence the improvement of the preservice teachers' perceptions (second iteration) about the board's usefulness to support their work because, according to their comments, testing their materials in the classroom enriched the experience. This reflection aligns with the results of González-Calvo et al. [134] research on the feelings of teachers in initial training during COVID-19. Second, because the DT-based board was designed through an iterative process, which implies that after each evaluation, improvements were applied. Figure 5 shows how some of the guidance documents that obtained low scores in the first iteration were among the most highly scored in the second iteration. This result demonstrates how the x-disciplinary team improved the DT-based board, focusing on those perceived as less useful. Thus, this board is not closed but is in continuous change.

This iterative design process conducted cooperatively between different disciplines (x-disciplinary team), together with the assessment process conducted from the beginning

of the project, permitted extracting deep and structured conclusions, giving rise to key contributions at a methodological level. These findings are presented as guidelines for designing and using this type of board, which are shown below, organized in three blocks. These guidelines may be useful for educators and researchers to develop practical and sustainable solutions to promote DT training. According to Guillén-Gámez et al. [17], it is necessary to implement strategies to foster education for sustainable development.

4.1. Project Organisation and Connection

The entire workspace must be carefully organized to manage student projects with software like Trello. At the teacher level, it is interesting to start creating a workspace with the subject's name (course name), which collects all the boards corresponding to the student teams of the same subject. In this manner, if the teacher uses the Trello software (2.1.3 version, Atlassian, Sidney, Australia) in several subjects, they have a workspace for each of them (Figure 8a). For example, for the detailed assessment, in each iteration, we created a workspace called 'Instructional Materials and Resources' (name of the subject), in which there were a total of 15 boards in the first iteration and 18 boards in the second iteration (corresponding to the preservice teacher teams). According to Oakley et al. [78] and Blanco et al. [11], the number of students per team should not exceed five to avoid division in the same group, and between three and four is an ideal number.

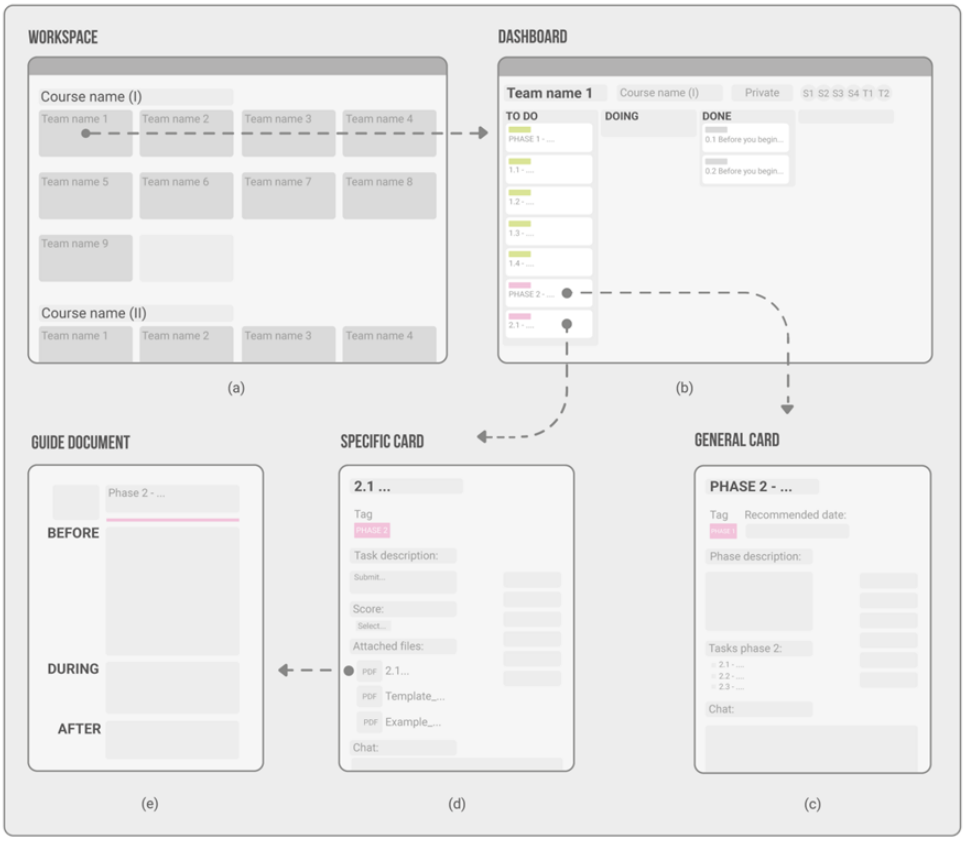


Figure 8. Trello organisation and content (**a**) workspace; (**b**) board; (**c**) general card; (**d**) specific card; guide document (**e**).

Each of these boards should have a name that identifies the group of students; this helps the teachers identify the groups and the students consolidate as a team. To organize the board, Trello allows creating columns to add cards; in our case, we have tried several combinations. In the beginning, we created a first column named 'material', and according to the agile Kanban method [135], a second column called 'to do,' a third column called 'doing,' and a fourth column called 'done'. The aim was that the teacher would move

the cards from the 'material' column to 'to do' as the project progressed; however, this created extra work for the teachers because they had to add new cards in the 'to do' column. Therefore, we decided to place the material directly in 'to do,' with the aim that students develop their autonomy and can manage the tasks in progress, those they are working on, and those they have completed, without the teacher intervening in this process (Figure 8b).

To transform the subject material into software like Trello is not about uploading a document for students to read. Still, it is necessary to create a process in which the material and Trello are connected and complement each other. Likewise, it should be noted that, in line with Dorst and Cross [136], DT is an iterative and non-linear process, posing flexibility as a fundamental consideration. The material must be connected and divided into manageable, flexible, and easily movable cards. Thus, the flexibility of the material developed should make it adaptable to the characteristics of each project; because each work is different, and not all student teams do the same thing during a project. For example, in our case, there were groups of students that analyzed the needs detected, while in other cases, the need was clear; or there were teams that analyzed existing instructional materials during the research and others after the ideation when the idea was more defined.

It is useful to have two types of cards. On the one hand, general cards (Figure 8c) aimed to introduce the phase, the tasks to be carried out, and an advisable date to finish the phase. On the other hand, specific cards (Figure 8d) aimed to guide the students in the DT process, providing methods, tips, and tasks that led them to create instructional materials. Recommended attributes to include in these cards:

- To start creating these cards, it is helpful to establish tags to help students visualize the stages of the project; as in our case, we created a tag with a name and color assigned to each phase. In addition, we recommend adding a 'before you begin' tag for the introduction cards, which are designed to explain the project, the material, and the use of Trello (because not all students attend the explanation class).
- A concise title preceded by a number according to the numerical chronology. Although, as mentioned above, the process must be flexible because not all groups follow the same one, we consider that this enumeration helps students to situate themselves and follow the process less chaotically.
- A task description to include the task to be accomplished. In the first iteration, we added only one statement. Still, we found (during the second iteration) that it was more effective and more straightforward for the students to include what they should submit, for example, 'Task: Document that includes the interview questions, and the most relevant conclusions obtained after conducting it'.
- A chat in which students can comment on doubts, and teachers can give feedback adapted to the team's specific situation. It is recommended that teachers add an initial comment on the card to create a climate of trust, e.g., 'Hi! If you have any questions, contact us'.
- Attached documents that guide the student during the project. These documents should be connected and complemented with the cards to form a single material, i.e., the students have to understand the board and the materials as one. For this purpose, at a visual level, these guide documents should use the same name, number, color, and similar aesthetic. For example, in Figure 8e, pink is used, corresponding to the phase 2 tag used on the board, and the same name and title as on the board card. In addition, at a structural level, it is important that these guide documents keep their organization simple, clear, and connected to the board. Thus, after the two iterations were conducted, we concluded that a 'before', 'during', and 'after' structure is optimal for developing such projects, and the best manner to provide information is through tips. When the students start reading, the 'before' section introduces them to where they are and provides tips for preparing for the task. The 'during' section gives them recommendations and indications on how to conduct it. Finally, the 'after' section explains how to process and analyze the information collected. This last step (after) must be directly connected to the task described in the card to facilitate the process.

4.2. Project Development

At the beginning of the project, it is important to place in context those students who are not trained in DT, project management, or software of this type, considering them as novices in these fields. During this introduction, it is advisable to show visual examples of design (e.g., the origin of things and some design cases), the process of DT, the sustainable education concept, as well as the connection of this to their training, their subject project, and their future teaching work. Likewise, for the software explanation, the boards for each team must be previously created, and each team member should be previously invited to join. In this manner, all students will follow the training session step by step. During the session, it is advisable to start from the general visualization to the more concrete specifications: panel structure, columns, cards, card contents, and card movements.

It is essential to highlight that the provided board is a flexible tool on which each team can, for example: create new columns and cards, go back between phases, change the order of the cards, set specific dates on the cards for planning, as well as establish which members are going to carry out each task. In short, to transmit that the board is not closed but can be adapted to their team's project.

While students develop the project, they follow the DT process and internalize it. However, it should be noted that the DT is a multifaceted, messy, and complex process [34,69,70]. Therefore, students must understand that at the beginning, it is normal for them to feel uncertainty and to perceive the process as chaotic. Still, then, during the project, they come to understand the process, see the meaning, and achieve more reflective outcomes [34]. For the development of the project, we adapted the following DT methods: 'semi-structured interview' and 'observation notes' to detect and understand the needs and characteristics of the teacher, students, and classroom; 'Personas' to define students; 'Brainstorming' to ideate; '5 whys' to justify the instructional material; 'Storyboard' to define the implementation of the instructional material in the classroom; as well as 'Prototype' to apply and assess the instructional material in the class.

However, these methodologies are suitable for teamwork, and although the panel is collaborative, it does not allow creating online group sessions. Thus, the teacher should establish programmed sessions using applications such as Google Meet. Even more enriching is the possibility for each team to have its own 'virtual canvas' to work on through virtual templates and sticky notes. Figure 9 details an example created from a Google Drive presentation. In this example, the created template is placed as a fixed background, and a stack of rectangles is added, simulating sticky notes. In this manner, team members discuss through Meets and collaboratively share the information; changes occur in real-time and are visible to all members. This working method is beneficial for conducting remote workshops guided by the teacher, such as the Phase 2 'Personas' (Figure 9).

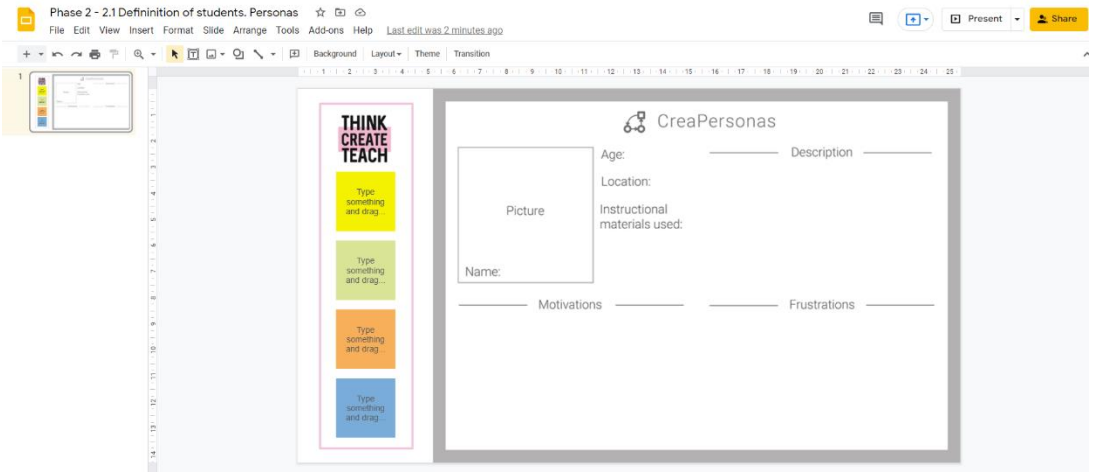


Figure 9. Example of a virtual canvas for teamwork.

In addition, it is essential to highlight some remarks that, in our case, smoothed the interactions between teacher-student during the development of the project:

- To establish a comfortable climate for students to ask questions and participate in the project in an uninhibited manner [52], allowing for mistakes and avoiding fear of failure [75,76].
- To monitor boards and provide feedback by answering questions and making general follow-up comments. To facilitate this task is recommended to have sets of comments and add a 'waiting' column on the board for students to add the cards with questions.
- According to Han et al. [137], it is essential to make students understand that the board is not to spy on them but to support them, as well as not provide too much feedback because it makes them constantly seek approval, and they must control their dependency on support.

4.3. Project Evaluation

Project management with such a board provides data to evaluate both the students (assessment of the process and the final result) and the teacher's work. Firstly, the teacher actively monitors the students during the project's development. The teacher can visualize the work of each group, check the submission dates, know which groups are working daily and which at the end, detect the changes of each board in real-time, visualize the doubts of the groups at the moment, and give feedback adapted to each group, know the tasks done correctly, incorrectly, or not done, as well as the outcomes of the project. In addition, this information is collected on the board to aid teachers to review it again for the project assessment. It is recommended to assess each project individually to evaluate the entire process (the issues raised, the decisions taken, or the context of each team). It implies that both teachers and students value the importance of process, continuous assessment, and constructivist learning, rather than just the result, in line with Kleon [129].

Secondly, these data allow the teacher to visualize and self-evaluate their own subject material by different indicators. For example, teachers can see which tasks have been the most challenging and whether their feedback had a positive effect. Likewise, it is advisable to add a 'score' tab on each card (Figure 8d), allowing the team to score the card at the end of the task (in our case, a scale of 0–7); so that the teacher can then analyze which cards have been most and least useful. Finally, it is interesting to add an 'evaluation' card at the end of the project; in our case, we use this card to add a Google Form.

4.4. Sustainability Position

Finally, in order to weave slightly further the sustainable position, it is interesting to reverse the arguments provided in the theoretical framework of this article. Doing this mental process, the bind between this study to the sustainability concept can be visualized as a big chain. The first element of the chain is the DT-based board and their associated guidelines; they contribute to applying DT effectively in remote situations such as COVID-19, facing relevant challenges such as managing large groups of preservice teachers. Achieving this effective application of DT leads to the second element of the chain: enabling preservice teachers to foster DT skills such as problem-solving [29–31,44]. This training based on problem-solving will lead preservice teachers to the third and most general element in our chain: contributing to sustainable education for future generations, which is essential in a changing world and levers a sustainable society [8].

4.5. Limitations of Study

This study has some limitations and further work to address. First, the scope of this study is limited to preservice teachers from a particular university, so it would be interesting to extend the applications to other environments to have a more extensive study. Second, the proposed guidelines aim to describe the experience and findings of a practical example of DT application to consider its potential in practice. However, generalization is not the focus of this paper, and such guidelines are neither unique nor strict. Third,

understanding and internalizing DT is not a simple task because the design is multifaceted, messy, and complex. It requires continuous training over time; thus, using the DT-based board is not a unique solution but a step towards introducing these concepts in preservice teacher training.

5. Conclusions

This paper contributes with a DT-based board to improve the implementation and management of remote design projects for large groups of students of preservice teachers, empowering them towards a sustainable education. The board results from the collaborative work of specialists from different disciplines (design, technology, and education), who considered educational premises to adapt it to pedagogical needs and address the digital transformation. Thus, this board is built on a replicable and flexible process in which the developed material is connected and complemented with existing software (Trello), being understood as a single entity. This approach provides a visual and flexible organization, allowing the development and management of design projects to be accessible, even without great knowledge of design, project management, and technology. This board was assessed and improved through two iterations with preservice teachers who used the DT-based board to conduct design projects to develop instructional materials for preschool stage classrooms.

In conclusion, the DT-based board is considered useful according to the preservice teachers' perceptions because it allows them to overview the project from the beginning, follow the DT process remotely, understand the importance of the process, design human-centered instructional materials, and develop soft skills for sustainability. Specifically, the board enhances teamwork skills during the project because it smooths interactions and serves as a communication tool between student-student and teacher-student. Likewise, the board facilitates the project management of preservice teachers, guided, supervised, and adaptively led by the teachers responsible for their training. It is especially useful for remote learning in situations such as the COVID-19 pandemic. In addition, this study provides useful guidelines for designing and using these boards to aid educators and researchers in integrating DT training and developing practical and sustainable solutions. These guidelines allow the DT-based board to be easily replicated and incorporated into an existing course without significant changes to the curriculum.

As a general conclusion, internalizing the DT process through a board to manage projects and using technology with an agile learning curve aids preservice teachers in facing complex and varied challenges in their future teaching work. This approach contributes to the natural integration of DT and ICT in preservice teachers' education, improving the quality of education for future generations toward a sustainable society.

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