education sciences

MDPI

Article

Fostering Teamwork through Design Thinking: Evidence from a Multi-Actor Perspective

Sharon Guaman-Quintanilla [1,2,3,*], Patricia Everaert [2], Katherine Chiluiza [4] and Martin Valcke [3]

[1] i3lab Entrepreneurship and Innovation Center, Escuela Superior Politecnica del Litoral, Guayaquil EC090112, Ecuador
[2] Department of Accounting, Corporate Finance and Taxation, Faculty of Economics and Business Administration, Ghent University, 9000 Ghent, Belgium; patricia.everaert@ugent.be
[3] Department of Educational Sciences, Faculty of Psychology and Educational Sciences, Ghent University, 9000 Ghent, Belgium; martin.valcke@ugent.be
[4] Center of Information Technologies, Escuela Superior Politecnica del Litoral, Guayaquil EC090112, Ecuador; kchilui@espol.edu.ec
* Correspondence: seguaman@espol.edu.ec

Abstract: This study examines the effects of a design thinking intervention on first-year students' teamwork skills from a multi-actor perspective. A design thinking course was evaluated throughout a semester. Six-hundred-and-forty university students participated, guided by twenty-six facilitators. The students received in-class training and worked in multi-disciplinary teams to develop a solution for a real-life problem. In this quasi-experimental study, data were collected twice: in the middle (t1), and at the end (t2) of the course. Each time, students were rated by their teammates, themselves, and the course facilitator, using a rubric to map teamwork skills. The results show a significant improvement in teamwork skills, as consistently observed in the three ratings. The results also show a significant effect of sex on the improvement over time. Female students showed more considerable progress than male students. This study addresses researchers' demands regarding the lack of robust evidence to assess the impact of design thinking in higher education settings. Furthermore, building on the data from a large sample size and an intervention designed in a replicable way, this study contributes to the available empirical evidence that helps one to adopt and implement design thinking in universities to develop essential skills, such as teamwork.

Keywords: design thinking; teamwork; constructivism; cooperative learning; higher education

Citation: Guaman-Quintanilla, S.; Everaert, P.; Chiluiza, K.; Valcke, M. Fostering Teamwork through Design Thinking: Evidence from a Multi-Actor Perspective. *Educ. Sci.* **2022**, *12*, 279. https://doi.org/10.3390/educsci12040279

Academic Editor: James Albright

Received: 26 February 2022
Accepted: 11 April 2022
Published: 13 April 2022

1. Introduction

Universities are expected to deliver future professionals that can tackle cross-disciplinary problems in an increasingly complex world. Adams et al. [1] highlight the key attributes of such future professionals: being an effective collaborator, taking personal responsibility; being aware of what others and oneself can contribute; acknowledging differences in what people know and how they communicate; being comfortable asking questions, challenging assumptions, and listening for understanding; and daring to ask for information, despite the fear of feeling judged by experts in the field. In a study [2], 4225 engineering graduates rated teamwork, communication, data analysis, and problem-solving as the most critical competencies needed to succeed in their professional setting. This reiterates the key notion from the Future of Jobs Report [3] that stresses how working with people is a top skill that defines the workplace in the lead-up to 2025. Therefore, it is not surprising that teamwork is considered an essential skill, and demanded by labor markets [4]. To answer this call, universities have started emphasizing teamwork in their courses [5]. Accrediting organizations, such as ABET, emphasize that teamwork can be taught and assessed as functioning in multi-disciplinary teams [5]. Recently, design thinking (DT) has been identified as a promising educational approach to develop in-demand skills in the

workforce [6,7], providing tools and a zone in which teamwork might lead to innovation [8]. DT has been applied at various stages in business, medicine, and science education, [9]. Furthermore, teamwork is key to DT [10–12].

While the popularity of DT in higher education is increasing [13], the research remains critical regarding its potential due to the lack of robust empirical studies that uphold assumptions about its effectiveness [14,15]. Research also stresses the lack of comprehensive DT assessment approaches that fit DT's complex nature in multi-disciplinary settings [15,16]. Furthermore, research points toward student characteristics, such as sex, that might interact with expected outcomes. For instance, male students choose less voluntary teamwork than female students [17]. This gap in the literature inspired us to investigate the development of teamwork skills during a DT course offered to first-year university students while considering the sex of the students. The DT intervention met the cooperative learning conditions posed by Johnson and Johnson [18]. Students worked in the same teams over the whole semester, solving a real-life problem. Data were collected twice during the semester: in the middle of the semester and at the end. At each timepoint, students evaluated themselves, their teammates (peers) and were also evaluated by the facilitator, all at an individual level. Raters used a rubric, namely VALUE rubric [19], similar to other studies (e.g., [20]).

The present study contributes to the literature in four ways: (1) The DT intervention is presented in full detail, addressing the growing interest in DT from universities [14,21]; (2) It provides a robust empirical analysis of DT's impact, involving a large sample of university students; (3) Three type of actors were involved in the assessment of teamwork development: students, peers, and facilitators; (4) It responds to the need for research about the interaction between sex and the development of teamwork skills [22].

Below, the conceptual and theoretical framework are put forward, followed by the research methodology. Next, the results are presented. Then, those results are discussed along with the limitations and future research. Finally, this article closes with a conclusion.

2. Conceptual and Theoretical Framework

2.1. Design Thinking and Teamwork

DT is a way of working and thinking beyond the design context [23]. It is a way of solving ill-defined problems using methods and mindsets typically associated with designers [10], adapting them to real-life contexts, and applying a human-centered and prototype-driven approach [24–26]. This is expected to foster creativity and promote teamwork [12,27].

Teamwork is essential in the DT context [26]. One of the institutes that popularized DT, the Hasso Plattner Institute of Design at Stanford University (d.school) [28], poses "radical collaboration" as a mindset that brings together innovators with varied backgrounds and viewpoints, enabling breakthrough insights and solutions to emerge from diversity. Brown [10] highlights the importance of collaboration with people from other disciplines when addressing complex problems through DT. Furthermore, many researchers emphasize the importance of involving cross/multi-disciplinary teams in a DT setting to learn from deep exchanges with peers and break silo mentality [8,29–31]. In a study in which thirty-five DT faculty members participated, Lake et al. [15] found that two of the most frequent DT practices involved teamwork. Furthermore, in a literature review carried out by Panke [13], she discovered that one of the advantages of DT in education is fostering teamwork. However, the scholar also pointed out that teamwork conflicts are a potential challenge. The author suggests evaluating teamwork as one of the outcomes of DT.

2.2. Teamwork and Its Challenges

Salas et al. [32] define teamwork as "a set of interrelated thoughts, actions, and feelings of each team member that are needed to function as a team and that combine to facilitate coordinated, adaptive performance and task objectives resulting in value-added outcomes" [32] (p. 562). Based on the scope and nature of the present study, the teamwork

definition of Rhodes [19] helps to define this study's approach to the skill in the most adequate way: "Teamwork is behaviors under the control of individual team members (effort they put into team tasks, their manner of interacting with others on team, and the quantity and quality of contributions they make to team discussions.)" (p. 39). However, groups and teams are not the same, since the latter demand both individual and mutual accountability [33]. Lewrick et al. [30] and Nilson [34] propose a team size of 3–5 people to promote participation and prevent freeloading. The optimal size will depend on the type of challenge and the availability of the resources.

Despite attempts to incorporate teamwork in university courses, the research recognizes that there is insufficient guidance for students to promote group development, soliciting member input, consensus building, resolving conflict, and developing team leadership [5]. Nilson [34] affirms that facilitators are often challenged in the running of group processing sessions. Consequently, they turn away from guiding teams. Furthermore, Goldman et al. [31] explain this challenge in the specific context of DT: "Instructors hope students have a productive team learning experience and rely on student teams to be proficient enough to carry the students through the process and projects that are assigned. The team process and practice are sticky problems of design thinking education because courses are situated in educational systems that have emphasized and rewarded individual learning and achievement" [31] (p. 12).

Assessment by educators is an additional challenge. Shuman et al. [5] claim a lack of consensus on the scope of the outcome assessment. Of course, the nature of the outcome—teamwork—impedes the approaches to assess teamwork. Nevertheless, these authors suggest tackling this problem by adopting multisource assessment approaches. In addition to collecting information from students, other sources of information can be involved, such as peers and instructors. This assessment approach holds two benefits: it helps collect accurate data and impacts the learning process, since students are actively engaged in their assessment [5]. Moreover, most of the definitions of teamwork involve the interaction between two or more individuals [35,36] and in cooperative learning environments (as explained in the following section), the facilitator also plays a critical role [18]. The above implies that the nature of teamwork in a classroom setting involves at least three actors: students as individuals, peers (teammates) and the facilitator. Hence, the three of them can provide information about the members working in a team. This triangulation of raters has been highlighted in skill assessment models [37] due the unique perspectives on performance each actor may provide. In fact, there are authors that acknowledge some concerns in taking only one-actor perspective. For instance, distortion in self-assessment [36,38] or the halo effect in other-report ratings [36]. Therefore, a multi-actor perspective is important for assessing a key skill such as teamwork.

In addition, Ohland et al. [39] stress how self and peer evaluations push teams to be more explicit about the expected behaviors from the start, to monitor team performance, to make students accountable for their team contributions, and, consequently, to make teamwork less frustrating and more rewarding for all actors involved. However, Ohland et al. also indicate that, at present, there is no consensus as to what evaluation instruments are the most adequate in this context.

Based on the above, this study aims to answer the following research question:

RQ 1: Is there any improvement over time in teamwork skills as a result of a DT intervention when considering students' self-assessment, peers, and facilitators, as well as when considering a combined score among those raters?

2.3. Theoretical Connections between Design Thinking and Teamwork

Teamwork is the operationalization of cooperative learning in the present DT intervention. DT has been linked to constructivist learning theories [7,9,11,40]. Constructivism serves as an umbrella term for a diversity of views about the teaching–learning process, which share two main ideas [41]: (1) learning is not a mere transmission of knowledge, but an active process of constructing knowledge; (2) instruction is a process of supporting that

construction. Constructivist environments should engage students in their construction of knowledge through collaboration that inserts learning in a meaningful context and through reflection on what has been learned [42]. Scheer et al. [11] affirm that DT offers teacher support to bridge the gap between the theoretical advantages of constructivist learning and its practical implementation to fostering in-demand skills in the workforce. In the constructivist context and DT, teachers are seen as facilitators rather than instructors [7,9,11,43].

Johnson and Johnson [18] put forward five conditions that help cooperative learning to work in the classroom. First, cooperative learning should invoke positive interdependence where learners realize how their work and the success of their work depends on others and vice versa. Facilitators can foster positive interdependence by establishing mutual goals, joint rewards, divided resources, and complementary roles. Bene and McNeilly [44] add that, in DT, team members should tackle a relevant problem or challenge, i.e., a shared vision of the work. The second condition is individual and group accountability, which happens when participants assume personal and group responsibility for the work. Each individual's input is evaluated by the facilitator and the team product and process. In DT settings, team members are encouraged to diverge in their thinking and generate as many different solutions to their problems as they can imagine. This promotes a culture where everyone is equally responsible for successfully resolving the issue [44]. Third, develop the underlying social skills. This refers to explicit strategies to teach students leadership, decision-making, trust-building, communication, and conflict-management skills and motivate students to use these skills. Bene and McNeilly [44] suggest that teams develop trust and reliability during the DT process as members deal with the problem and possible solutions while maintaining a human-centered approach. Moreover, Bene and McNeilly [44] affirm that DT promotes radical collaboration, as teams are exhorted to reach out to external people to collect new ideas, diverse viewpoints, and innovative solutions to their problem. The fourth condition stresses that facilitators promote explicit interactions between students as part of their instructional design. DT supports this by applying a series of instructional strategies, such as brainstorming, user research, prototyping, etc. [8]. The final condition is to evaluate group processing, which emphasizes that actors should explicitly look at the progress in their interaction and whether they work effectively together. In this regard, in this DT intervention, each student anonymously evaluates their teammates, and facilitators monitor the teams and offer feedback on how well the groups are working together. The five conditions are met by the DT course, as explained in the "DT intervention" subsection.

In the literature, various researchers have identified drivers, also known as levers, that influence team effectiveness processes. Kozlowski and Ilgen [35] developed a literature review on cognitive, motivational/affective, and behavioral team processes, as well as interventions that enhance team processes. Building on their review, connections between DT characteristics and some of the levers that enhance the effectiveness of teams can be used to justify why practicing DT would develop teamwork skills, as follows. For instance, one lever for shaping collective climates is social interaction. In this regard, and as explained above, DT promotes collaboration and interdependence among team members when solving complex problems [10] since many activities in DT are designed to be performed in teams, with explicit interaction among team members [30,45]. Another lever in team cognitive processes is maintaining a shared strategic imperative. In this sense, DT interventions intend to find a solution for a real-life problem, viewed from a human-centered perspective [9,21]. This constitutes a common salient strategic imperative for the team. Shared experience is also a lever that consistently emerges in team processes. DT addresses this lever since students share a vision of the problem, which is even stronger when students empathize with the people involved in the problem [44], and work as a team to find a shared meaning [15]. As was mentioned earlier, DT is characterized by dealing with ill-defined real-life problems. The latter creates a more challenging team goal, which is another lever of team effectiveness. Challenging goals yield higher performance than simpler goals [46]. Next to goal-setting, feedback is also identified as a lever for

teamwork. In DT, iterative feedback is present as teams receive feedback by actors involved in the problem (e.g., users) [44,47]. On the other hand, in educational settings, the teachers who, as stated above, are seen as facilitators rather than instructors, also provide crucial feedback to guide and encourage student teams to navigate the whole process of dealing with ill-defined problems [48]. Finally, another lever of team effectiveness addressed by DT is collaborative tools to aid team members in collaborating and combining resources. Many DT techniques and tools play that role (see Appendix A, Table A1). For instance, while using the technique called 'Saturate and Group for insights generation' [28], each team member writes down different pieces of information collected in the research and empathy stages using post-its. Next, the post-its are put on the whiteboard to saturate. Then, each team groups these findings to explore what themes and patterns emerge, and form clusters to identify insights. The purpose of this technique is to assist team members in translating their thoughts and experiences into tangible and visual data.

Building on the insights from the literature mentioned in the previous paragraphs, the following hypothesis is put forward:

Hypothesis 1 (H1). *Students who participated in a Design Thinking intervention improved their teamwork skills during the semester.*

2.4. Sex Variable and Teamwork

The role of sex is a recurrent theme in research about cooperative learning [22,49,50]. Sex is linked to differences in self-concept. While men's self-concept is more autonomous and separated, women's sense is based on being attentive to self, others, and relationships [51,52]. There are studies that suggest some personality traits are more prominent in women than in men, such as agreeableness, extraversion, tender-mindedness, openness to feelings, among others [53–55]. These differences should be considered with caution, since these seem to be consistent with gender stereotypes [55]. Nevertheless, studies have suggested that people who possess some of these traits (e.g., extraversion, feeling-type) show more alignment with cooperative learning experiences [56,57]. Rodger et al. [22] found that female students scored significantly higher in a cooperative condition compared to a competitive one, while male students performed roughly equally in both conditions. Other study found that female university students performed better in cooperative than individualistic learning conditions [49], which confirmed a previous study, where female middle-grade students showed a higher preference for cooperative learning than male students [50]. The findings of Takeda and Homberg [58] suggest that male students tend to be less cooperative, especially in all-male groups and male gender exception groups, compared to other group compositions.

Moreover, a recent study published in 2022 [59] that tried to determine the level of teamwork skills among university students found that female students scored higher than their male counterparts in adaptability, coordination, interpersonal development and communication, except leadership. In another study, in which first-year university students participated, Peinado et al. [60] found that women seem to have better perceived self-efficacy in teamwork than men. Baker [61] conducted a study using management courses that applied team learning. She tested three types of peer evaluation instruments on teamwork behaviors. In that study, sex differences were observed, with women receiving higher ratings than men on all three instruments.

Furthermore, research about the role of sex in DT is scarce. A rare study focused on the effect of using DT on male and female students' achievements in secondary school physics [62]. No significant differences were found between male and female students. A related study [63] evaluated team assignments in IT, business, and DT Massive Open Online Courses (MOOCs). The results show no interaction effect of gender on final scores. However, women completed the team-based assignments more successfully than their male fellow students and received higher scores from their team members than men. There is a gap in the literature when looking for DT studies carried out in university face-to-face

settings. As far as the literature shows, no studies are available on the role of sex in the development of teamwork skills, as a result of a DT intervention. Since DT meets the cooperative learning conditions (as explained above), and based on the literature presented in this subsection, the following research question is posed:

RQ 2: Will female students benefit more from a Design Thinking intervention than male students in terms of teamwork skills?

3. Materials and Methods

3.1. Background

The study was conducted at a public university located in Ecuador from May to August 2019. A DT design was adopted in a mandatory course about analysis and problem-solving. This DT course is compulsory for all university freshmen, regardless of their major. The DT course comprises 14 weeks of classes. Given the large number of students, they were divided into sections. For each section of 25–35 students, a facilitator was responsible for them during the whole semester.

3.2. Field Experiment with Quasi-Experimental Design

This study includes both a within- and between-subjects design. To address Hypothesis 1, this study builds on a within-subjects design, including all students enrolled for the DT course, with multi-disciplinary teams solving a real-life problem. Teamwork skills were assessed twice, in the middle of the semester (t1) and at the end (t2), as depicted in Figure 1. Each time, teamwork skills were rated by the facilitator, teammates, and students themselves. In addition, students' background data were collected at the start of the course. Next, to address research question 2 (RQ2), the sex effect was tested using a between-subjects design, comparing male and female students.

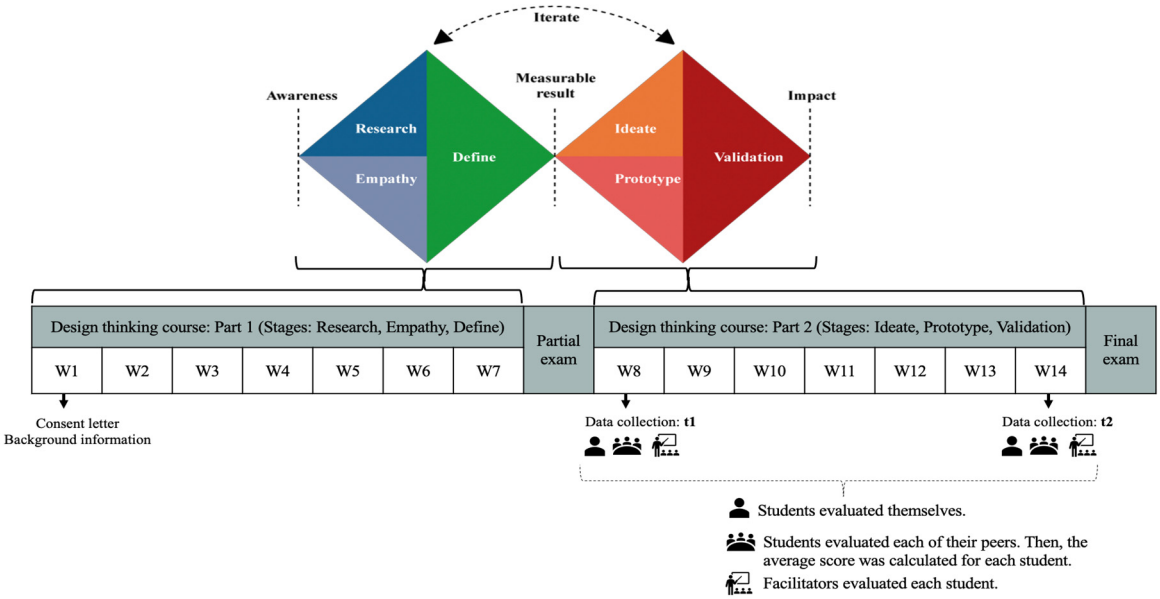

Figure 1. Data collection procedure, including the design thinking model used during the intervention. Adapted from Santos Ordóñez et al. (2017).

3.3. Procedure

Facilitators were responsible for establishing teams, considering (a) the student preferences for a given problem, (b) the students' major to guarantee multi-disciplinarity, and (c) sex balance. Team members, typically, five or six students per team, worked together on the problem during the 14-week academic term.

The students attended 28 90-min sessions (3 h per week). During each session, students worked together at rounded-shaped tables. Each team tackled a different problem proposed

by NGOs or a small business (called 'sponsors'). At the end of the course, the aim was to present a solution proposal, as reflected in a prototype. This prototype was discussed during a final presentation in the presence of all group students and the sponsors.

3.4. DT Intervention

The same course structure, guidelines, contents, activities, and other materials were implemented in each section of the DT course. The course design was based on the six-stage DT approach reported by Santos Ordóñez et al. [64], which reflects both the model of the school [28] and the "Double Diamond" model [65]. The first one is a 5-stage model (Empathize, Define, Ideate, Prototype, Test), which is probably one of the most popular models used in educational and corporate settings; that model (as others that are similar to it, e.g., [30]) poses 'radical collaboration' as one of the mindsets that needs to be adopted in order to apply DT [28]. On the other hand, the Design Council's 'double diamond' model is formed from four phases: Discover, Define, Develop and Deliver. The latter model was originally used at the corporate level, while it also emphasizes team collaboration as a key aspect [65]. Santos Ordóñez et al. [64] identified that both models had the potential to merge as follows: the Empathize stage shares characteristics with the Discover phase, since the problem is explored in both. The Define stage was the same as the Define phase, in terms of (re)framing the problem. The Ideate and Prototype stages fitted the Develop phase, as solutions are expected to be posed and built. Finally, the Test stage seemed to be more aligned with the Deliver phase, where the solution is about to be delivered after being tested. As a result, the DT model presented in Figure 1 was developed and applied in the present study. The first diamond of the DT approach comprises three stages, Research, Empathy and Define, while the second diamond includes other three stages: Ideate, Prototype, and Validation. Each diamond represents the divergent, left-side, and convergent, right-side, thinking the students go through. Following the representation of Lindberg et al. [47], in the first diamond, students navigate the 'problem space', while the Research and Empathize stages involve a divergent thinking, because students are expected to explore the problem (context, actors) and understand it from the users' perspective as much as possible before the Define stage, where students should apply convergent thinking to reflect and synthesize all the collected information to (re)frame the problem. Next, there is the second diamond, which represents the 'solution space'. In the Ideate and Prototype stages, students again apply a divergent thinking because they are encouraged to come up with as many solution ideas as possible and to use their imagination and limited resources to build prototypes, which should be tested with real users (Validation stage). This last stage involves the use of convergent thinking, since students should refine their prototypes, considering the feedback received from the potential users, until they arrive at a final solution. There is an iterative alignment of both spaces.

Appendix A shows the techniques and tools used in the DT course, linked with the five essential conditions for cooperative learning [18]. Positive interdependence is enhanced, since facilitators explained the grading policy at the beginning of the DT course and encouraged students to maximize their own and each other's productivity (mutual goals). Individual and group accountability was promoted by assessing students at the team and individual levels. For example, in the present intervention, project report grades consisted of an individual component based on peer assessment and each student's contribution to the project document. In oral presentations, students are assessed both individually and as a team. In all cases, facilitators provided feedback to teams or individual students to improve performance. The development of social skills was strengthened by having guided group activities in all DT class sessions and out-of-class tasks that included presenting and socializing their results, sometimes alone and other times as a group. For instance, in the class about 'observations', facilitators gave instructions to the teams to go together to different places inside the university campus, such as the library, the bus stop, or students' restaurants to perform observations, capturing pictures and videos and noticing the 'pains' students may have in those places. Next, students returned to the classroom, discussed

their findings, synthesized the collected information, and then shared it with the rest of the class. Facilitators also encouraged students to get to know and trust each other. For example, facilitators guided an activity called "Latest News", where students formed groups on the first day of classes. Each person was invited to share the three most recent positive news items or events in their life with their group. These group activities foster communication skills because students must intensively interact. Promotive interaction happened throughout the DT intervention. In the classroom, teammates sat and worked together at round tables every class session. The shared spaces used in DT settings enable teamwork [26]. Each classroom had plenty of whiteboards and other materials (post-its, markers, flip charts, etc.) for teams to use during class activities (see Figure 2). An explicit evaluation of the group processes was structured using an anonymous, eight-criteria peer assessment form. This was carried out four times during the semester. Facilitators addressed teams and individuals to review their performance explicitly as a team or team member. Facilitators also provided feedback to the teams after oral presentations, not only about the project content but also in terms of teamwork.

Figure 2. One regular class session of the DT course, where teams work cooperatively.

3.5. Participants

From a population of 910 students, data from 640 freshmen students who took the course in the specific time-window (one semester) and participated in the two data collection timepoints (t1 and t2), were considered. Most of the students (62.34%) were males. The average age was 18.83 years (SD = 1.55). Figure 3 shows the academic fields in which students were enrolled. In total, 27 sections, guided by 26 facilitators, participated in the study. The facilitators were informed about the research set-up to minimize the risk of bias. All students signed informed consent forms after ethical clearance from university authorities.

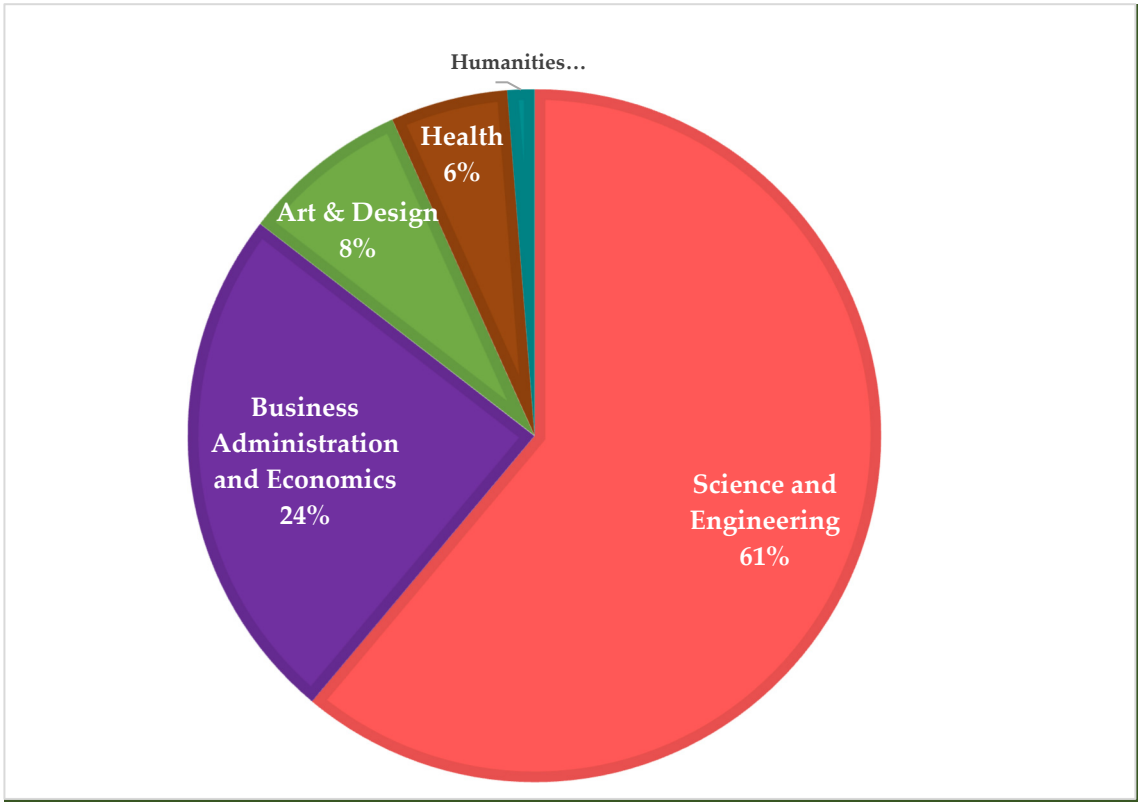

Figure 3. Academic fields in which students were enrolled (N = 640).

3.6. Measuring Teamwork

The literature reflects a range of attempts to measure teamwork, as reported by other researchers [61,66]. The review study of Baker [61] identified eight behavioral components of rubrics to assess peer performance in groups, which are: (i) attendance of group meetings; (ii) being dependable (deadlines met, kept his/her word); (iii) quality of the work submitted; (iv) exertion of effort or extra effort to complete the tasks; (v) communication with other members (getting along with others, listening); (vi) management of group conflict; (vii) cognitive contributions (applied knowledge and skills to accomplish team goals); (viii) provided structure for goal achievement (goal setting, task assignment, monitoring). Since there are many instruments available to assess teamwork, Hughes and Jones [66] recommend caution in selecting the appropriate measurement instrument, since various tests were originally designed for staffing work teams and not for educational purposes. For educational settings, Hughes and Jones suggest using the Valid Assessment of Learning in Undergraduate Education(VALUE) rubric, developed by the Association of American Colleges and Universities [19]. The VALUE rubric was selected to assess teamwork in this study because (a) the criteria (items) included in the VALUE rubric reflect most of the common teamwork behaviors assessed in other rubrics found in the literature; (b) the VALUE rubric is suitable for collecting data from multiple actors: individual student, peers, and the facilitator [19]; (c) it was not designed for summative purposes, since its design was intended to assess the quality of the process (i.e., functioning of the team) rather than to assess the quality of the final product [19]; (d) it fitted the nature of our intervention design: its administration is less time-consuming than others, which is critical due to the number of students and, consequently, the number of peers to be evaluated; (e) the rubric was different to (it did not look like) other peer assessment tools that students are familiar with for assessing teamwork. Moreover, a literature review reported by McConnell et al. [67] suggests that the VALUE rubrics map the skill and knowledge requirements that faculty and industry voices agree upon for successful participation in the global economy after graduation.

The VALUE rubrics comprise a set of rubrics for assessing essential skills; one of them focuses on teamwork (https://www.aacu.org/value-rubrics, accessed on 3 January 2022). Rhodes and Finley [68] describe the development of the rubrics by teams consisting of faculty members, academic and student affairs professionals, and other experts from the public and private sectors. The teamwork rubric helps assess the teamwork of an individual student, not the team as a whole. It builds on five criteria: (1) contributes to team meetings, (2) facilitates the contributions of team members, (3) individual contributions outside of team meetings, (4) fosters constructive team climate, and (5) responds to conflict. Each criterion is rated following performance descriptors that reflect four attainment levels. The rubric criteria invite the choice of a performance level, where A represents the highest score (4) and E the lowest (0).

The rubric was piloted at an earlier stage with DT facilitators and undergraduate students. The feedback allowed for checking the translation (from English to Spanish), the wording, and the consistency in interpretations. See Appendix B, Table A2 for a copy of the instrument used. According to Rhodes and Finley [68] and Finley [69], the validity and reliability of the VALUE rubrics are high. However, their studies did not focus on the teamwork VALUE rubric. Therefore, Table 1 shows a reliability analysis of the instrument at t1 and t2 obtaining Cronbach's alpha. The coefficients show that the items for teamwork have acceptable internal consistency.

Table 1. Cronbach's Alpha results per rater.

Outcome	Rater	t1	t2
		α	α
Teamwork	Student	0.76	0.79
	Peer	0.87	0.92
	Facilitator	0.82	0.87

Before the study, the 26 facilitators received a training session that focused on data collection and the administration of the rubrics to evaluate student teamwork. Hence, a standardized protocol was followed by all facilitators, who received specific instructions and a kit with all related documents and forms. At the beginning of the DT course, students signed an informed consent form and filled out a background questionnaire. On week 8 (t1) and week 14 (t2), students applied the rubrics to evaluate themselves and their teammates. Students filled out the self-assessment rubric version during the class session and the peer assessment version at home. Ratings were not revealed to other members of the groups. Facilitators also evaluated each student in their team based on the observed behavior in classes, group homework, and the feedback sessions.

3.7. Data Analysis

First, to test the hypothesis on whether students reflected a higher teamwork skill mastery after the DT intervention, a *t*-test was adopted, considering the students' perspectives, peers (average score obtained from 4–6 team members), and the facilitator. Effect sizes were calculated when a significant effect of the intervention within subjects was found ($p < 0.05$). Cohen [70] suggests that an effect size of about 0.10 is considered a small effect, an effect size of about 0.30 a medium effect, and an effect size of 0.50 or higher a large effect. In addition, a combined score for teamwork was calculated, which considers the scores given by each rater. To calculate this combined score at each time (t1, t2), the following formula was applied (1):

$$Combined\ score = \frac{Self\ score + Average\ Peers\ score}{2} - (Self\ score - Facilitator\ score) \quad (1)$$

Second, to analyze the effect of sex on the teamwork results, ANCOVA was applied using delta (Δ) teamwork scores (t2 − t1) as the dependent variable, sex as a fixed factor, and teamwork scores at t1 as the covariate.

4. Results

4.1. Descriptive Results

Table 2 summarizes descriptive statistics, and Table 3 presents correlations between all dependent variables. The results describe positive and significant correlations among the teamwork scores from the three raters and the combined score at t1 and t2. In addition, the attained average teamwork scores reflect an apparent improvement over time in all cases (Figure 4).

Table 2. Descriptive results N = 640.

Teamwork Scores by Rater at t1, t2; and Delta		Mean	SD	Min	Max
Self-assessment	t1	3.21	0.55	0.80	4.00
	t2	3.33	0.53	1.40	4.00
	Δ (t2 − t1)	0.13	0.51	−1.60	2.60
Peers	t1	3.35	0.45	1.08	4.00
	t2	3.51	0.43	1.10	4.00
	Δ (t2 − t1)	0.16	0.47	−1.62	1.57
Facilitators	t1	2.97	0.76	0.00	4.00
	t2	3.17	0.73	0.00	4.00
	Δ (t2 − t1)	0.20	0.77	−2.20	3.00
Combined scores	t1	3.04	0.83	0.02	4.90
	t2	3.26	0.79	0.05	4.90
	Δ (t2 − t1)	0.22	0.87	−2.52	2.98

Table 3. Correlation of all dependent variables N = 640.

Teamwork Scores by Rater at t1, t2	Self-Assessment		Peers		Facilitators		Combined Score	
	t1	t2	t1	t2	t1	t2	t1	t2
t1 Self-assessment	1.00							
t2 Self-assessment	0.55 *	1.00						
t1 Peers	0.43 *	0.39 *	1.00					
t2 Peers	0.29 *	0.39 *	0.43 *	1.00				
t1 Facilitators	0.24 *	0.23 *	0.40 *	0.24 *	1.00			
t2 Facilitators	0.20 *	0.20 *	0.26 *	0.30 *	0.46 *	1.00		
t1 Combined score	0.01	0.13 *	0.50 *	0.24 *	0.95 *	0.43 *	1.00	
t2 Combined score	0.08 *	−0.05	0.23 *	0.42 *	0.42 *	0.94 *	0.42 *	1.00

* Correlation is significant at the 0.05 level (2-tailed).

4.2. Hypothesis Testing: Impact of DT on Students' Teamwork Skills over Time

For all teamwork measurement scales, i.e., students, peers, and facilitators, and the combined scores, the within-subjects *t*-test shows a statistically significant and positive effect on teamwork skills over time, as presented in Table 4. Furthermore, there is an effect size between 0.24 and 0.35 in the change from t1 to t2. Based on these results, the following hypothesis can be accepted: students who participated in a Design Thinking intervention improved their teamwork skills during the semester.

4.3. Sex Variable: Difference between Female and Male Students at t1 and t2

After testing the hypothesis, it is time to address RQ2 (Will female students benefit more from a DT intervention than male students in terms of teamwork skills?). The first step is to check whether there is any difference between male and female students at t1, as well as at t2. Mean scores for male and female students at t1 and t2, given by each rater, are shown in Table 5. Note that female students obtained higher scores than male students at t1 and t2, by all three raters.

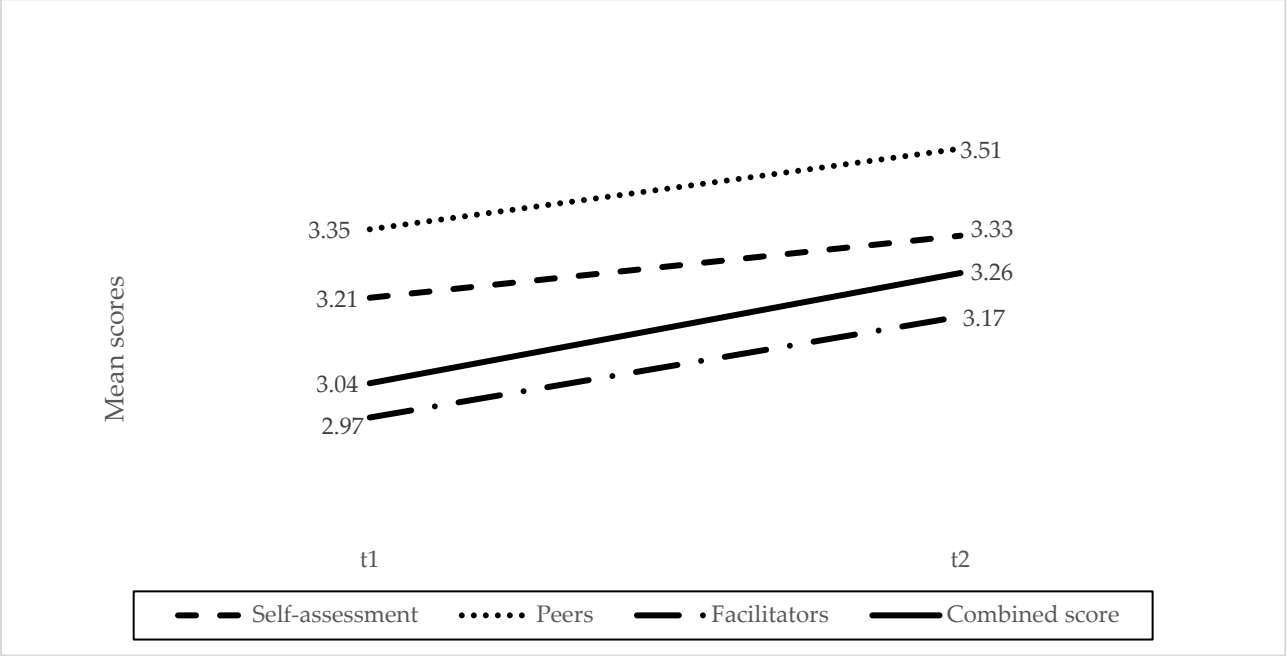

Figure 4. Mean in teamwork scores by raters over time (N students = 640).

Table 4. Within-subjects *t*-test and effect sizes results.

Dependent Variables	Mean t1	Mean t2	Difference	t	*p*-Value	Cohen's d	Hedges' Correction
Teamwork, measured by student	3.21	3.33	0.13	6.18	0.00	0.24	0.24
Teamwork, measured by peers	3.35	3.51	0.16	8.74	0.00	0.35	0.35
Teamwork, measured by facilitators	2.97	3.17	0.20	6.69	0.00	0.27	0.26
Teamwork, as a combined score	3.04	3.26	0.22	6.46	0.00	0.26	0.26

Table 5. Mean scores of male and female students at t1 and t2; ANOVA results.

Rater	Time Point	Total N	Male		Female		Anova F Test	*p*-Value
			N	Mean	N	Mean		
Self-assessment	t1	640	399	3.13	241	3.34	24.67	0.00
	t2	640	399	3.23	241	3.50	39.71	0.00
Peers	t1	640	399	3.26	241	3.48	37.43	0.00
	t2	640	399	3.43	241	3.64	39.61	0.00
Facilitators	t1	640	399	2.87	241	3.13	18.97	0.00
	t2	640	399	3.09	241	3.30	12.79	0.00

4.4. Sex Variable: Difference in Evolution between Female and Male Students over Time

The second step to address RQ2 was to apply a between-subjects analysis to investigate whether female students improved their teamwork skills more than male students. ANCOVA was used to test the sex variable effect on teamwork. The results are shown in Table 6. According to these results, the progress in teamwork skills (measured by Δ between t2 and t1) depends on the sex of the student being rated. In particular, the results show a more significant improvement for female students than for male students. Even

when controlling for the initial level of teamwork skills at t1, the sex effect is still significant (p = 0.00). The estimated marginal mean for male students = 0.06, and for female students = 0.22 (rated by students themselves), showing a higher improvement for female than for male students. This significant effect was not only found for teamwork skills measured by the students themselves, but also for teamwork skills measured by peers (p = 0.00). The results do not show a significant difference in improvement between male and female students when analyzing facilitators' rating at Alpha = 5% (p = 0.07) However, the results are significant at Alpha = 10%. According to all raters, the means show that the progress in teamwork skills is larger for female students than for male students.

Table 6. Between-subjects ANCOVA using sex variable as a fixed factor, and teamwork scores at t1 as a covariate.

Dependent Variable	Independent Variables	F-Test	p-Value	Estimated Marginal Means	
				Male	Female
ΔTeamwork score: Self	Sex	18.56	0.00	0.06	0.22
	Teamwork score at t1	229.78	0.00		
ΔTeamwork score: Peers	Sex	16.80	0.00	0.11	0.25
	Teamwork score at t1	301.00	0.00		
ΔTeamwork score: Facilitators	Sex	3.20	0.07	0.17	0.26
	Teamwork score at t1	277.91	0.00		

5. Discussion

This study aims to investigate the development of teamwork skills during a DT course and explore the role of the sex variable. The results of this study help to bridge gaps in the literature about the role and importance of DT in higher education. In addition, the results go beyond the available studies by following robust empirical research about the effectiveness of DT in terms of teamwork skills and the effect of the sex variable.

5.1. First Research Question

The analysis results provide an affirmative answer to the first research question (RQ 1: Is there any improvement over time in teamwork skills as a result of a DT intervention when considering students' self-assessment, peers, facilitators, as well as when considering a combined score among those raters?). Likewise, the results help to consistently support the hypothesis when looking at the ratings of students, peers, and facilitators, and comparing t1 vs. t2 scores, and when analyzing the combined scores. In this regard, the results show that students improved their teamwork skills. This is consistent with the theoretical assumptions presented above regarding the connection between teamwork and the DT intervention features that match the cooperative learning conditions. We also expected this result based on the earlier explanation of how DT features match various levers for team effectiveness. In addition, the impact of teamwork skills is also coherent with the underlying DT models that emphasize the importance of collaboration along the DT stages where divergent and convergent thinking are used. The results are also consistent with previous studies reporting a positive DT impact on teamwork [24,48,71–74]. However, none of those studies used a within-subjects design with multiple measurements along the DT intervention. Those previous studies addressed teamwork as a characteristic of DT (especially multi/inter-disciplinary teams) and highlight teamwork as a key skill for students; however, they do not link teamwork to a theoretical framework that support their findings. Those studies mainly report results based on students' reflections, opinions and self-reported perceptions, during or after a DT intervention. Hence, they fell short in carrying out robust research design and this impedes further comparisons with the results obtained in the present study. The above explains why researchers claim the literature lacks robust research design to assess DT effectiveness [14,15]. This study contributes to addressing that claim and has shown a positive effect of DT on teamwork skills. However,

the obtained results can also be contrasted with Ohly et al. [75], who did not report positive findings, and results from Gatchell et al. [76], who showed that, while some students found the teamwork-related activities to be positive, many of them considered the activities to be just more work. Moreover, faculty also were discontented with the new activities. It is important to point out that, in cooperative learning environments, facilitators need to be guided on how to effectively set up cooperative learning conditions in their classrooms [77]. Gatchell et al.'s study also uncovered that, while activities aimed at developing teamwork, the latter turned out to be undermined. Therefore, the researchers underline that the course syllabus, or guiding document, should explicitly encourage facilitators to discuss the teamwork activities and assessments, their relevance to the course, and the students' responses to the assessments. If not, students may underestimate the importance of teamwork. Gatchell et al.'s analysis helps explain why the current DT intervention resulted in positive outcomes. Its design reflected the latter authors' recommendations. Furthermore, the correlation between the ratings of the three actors reflects agreement throughout the study, both in the middle of the semester and at the end of the semester.

5.2. Second Research Question

Regarding the second research question (RQ 2: Will female students benefit more from a DT intervention than male students in terms of teamwork skills?), it was observed that female students outperformed male students at the end of the DT intervention. This result was expected since, in this article, it has been explained that DT is intrinsically connected to the cooperative learning elements proposed by Johnson and Johnson [18], and the literature provides evidence that women tend to perform better in cooperative environments [22,49,50]. There are personal traits, such as extraversion and feeling-type, that seem to be more aligned with cooperative learning experiences [56,57]. These traits have been more related to women [54,55]; however, this explanation may be jeopardized since this apparent connection is likely to follow gender stereotypes. There are other studies that have found that female university students score higher than men in adaptability, coordination, interpersonal development and communication, which are related to teamwork skills [59], and also have better perceived self-efficacy in teamwork than men [60]. Furthermore, Warrington et al. [78] and Tinklin [79] suggest that female students have experienced different attitudes and social pressure from men since their time at school. For instance, male students feel more pressure to be "cool" and unconcerned with schoolwork, resulting in their being ill-prepared, competitive, disruptive, and less attentive. In contrast, female pupils are encouraged to work hard and take school more seriously, be more organized and show more respectful and cooperative attitudes. The results in this study show that the DT intervention improves the teamwork skills of both male and female students, but the progress of female students is more pronounced. Finally, it is important to note that sex-related results regarding teamwork should acknowledge possible cultural context influences [80], analysis of which is beyond the scope of this study. As will be mentioned, more research is needed to find underlying explanations for the significant sex effect.

5.3. Limitations and Future Research

Despite the promising results, the current study reflects limitations and opens opportunities for future research. First, this study did not include a control group. Only a pr-test–post-test-design was implemented. In particular, to address the evolution in teamwork skills (first objective of this paper), the current study implemented a within-subjects design, where the evolution of teamwork skills was rated by three different actors, at two different points in time. To address the differences in evolution between male and female students (the second objective of this paper), a between-subjects design was used, to compare the evolution in teamwork skills between male and the female students. Elaborating on this study with a control group was not possible, because the DT course is mandatory for all freshmen students at the university at which the intervention was set up. Adding a control group (without DT intervention) would not be allowed from an ethical perspective

in this setting. Future research might consider a pre-test–post-test control group design when starting a DT course to elaborate on the findings of the current large-scale empirical study. Second, the research questions have only been answered from a quantitative point of view. Although we included different actors to evaluate the improvement in teamwork skills, the results are only shown as a quantitative analysis. Qualitative studies should help to enrich the interpretation of the quantitative findings, for instance, to find explanations as to why the evolution in teamwork skills differed between the male and the female students. The noted differences between the raters, in combination with the sex variable, could be investigated more in depth in future qualitative studies, as well. Third, while the current results show that, during the DT intervention, students significantly improved the teamwork skills (as noted by different actors), the current study did not investigate which particular elements of the DT course caused the improvement. The DT course was set-up as a semester course, with 28 class sessions over 14 weeks, covering different activities. In future research, it would be interesting to explore what specific elements of DT are the most effective for the development of teamwork. This could require observational studies, followed by empirical studies to test the different versions with and without specific design components. The current study is only a starting point to further explore DT and the development of teamwork skills. Fourth, the current study only addresses differences between students in terms of sex. No other contingency variables were included to find out which particular group of students achieved more progress in the development of skills during the DT intervention. The role of the other individual differences in the learning outcomes as a result of a DT intervention can be explored more profoundly in subsequent studies, next to the current focus on sex. Finally, the current study was only implemented in one setting at a public university in Ecuador. The course was set up for all undergraduate students in the first year, covering science and engineering, business and economics, arts and design, health and humanities, resulting in a huge number of participants (N = 640). The advantage of not varying the setting (university, culture, language) and organizing the course in the same semester contributed to ensure high internal validity. However, in terms of external validity, future research could focus on replicating this study in other settings (e.g., other cultures), to produce further empirical evidence of whether the results can be generalized to other settings and other students, to generalize the results to a broader context.

6. Conclusions

This study investigated the effects of DT on one of the main core skills pursued by higher education institutions: teamwork. A detailed theoretical background was put forward, and the study aimed to address critical gaps in the available literature. This resulted in a strong focus on empirical research that was based on operational research instruments. In addition, a multi-actor perspective was adopted, and a grounded design of the DT intervention was established to define how teamwork was fostered. The study also contributes to the literature by analyzing the role of sex. The findings suggest that future research can start from the current observation that female students show more significant progress than male students. Furthermore, the essential role of facilitators during the process must be highlighted, and the use of a multi-actor assessment during the intervention is highly recommended for monitoring and reinforcing teamwork skills. Finally, the researchers are open to exchanging their approach, materials, procedures, and research instruments to facilitate the wider adoption of DT in higher education.

Author Contributions: Conceptualization, P.E., K.C. and M.V.; Data curation, S.G.-Q.; Formal analysis, S.G.-Q.; Investigation, S.G.-Q.; Supervision, P.E., K.C. and M.V.; Writing–original draft, S.G.-Q.; Writing–review & editing, P.E., K.C. and M.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by Escuela Superior Politecnica del Litoral (not specific grant number applicable) and VLIR Network Ecuador (not specific grant number applicable).

Institutional Review Board Statement: Permission for conducting this study was granted by the Vice-rector of Academic affairs of the university where the intervention was carried out since in this university, at the time of the study, no ethical board had yet been installed.

Informed Consent Statement: Informed consent was obtained from the students involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We would like to acknowledge ESPOL's i3lab-Entrepreneurship and Innovation Center for administrative support. Also, our acknowledgment to facilitators and students for the participation and valuable feedback to carry out the study. Furthermore, we thank the valuable feedback received in previous versions of this study during the BAFA (British Accounting and Finance Association) annual conference; and during the FEB research day organized by Ghent University.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Connection between the Techniques and Tools Used during the DT Course with the Conditions for Cooperative Learning.

DT Stages	Techniques and Tools [28,30,81]	Description	Conditions That Make Cooperative Learning Work in the Classroom [18]					Examples about How the Techniques/Tools Promote at Least One of the Elements for Cooperative Learning
			1	2	3	4	5	
Research	Secondary research	Students start looking for existing information about the problem regarding context, benchmark cases, and trends.		✔				
	Stakeholder Map	Teams use this visual tool to obtain a broader picture, identifying internal and external stakeholders or organizations and individuals (aka, actors) with a stake in the problem.				✔		
	Interview for empathy	An interview for empathy aims to see the world through one user's eyes (person's thoughts, emotions, and motivations), overcoming existing thinking patterns. Students prepare and conduct interviews with different stakeholders to understand a person's thoughts, emotions, and motivations. By understanding the choices that the person makes and the behaviors the person engages in, students become more capable of identifying and designing for their needs.	✔	✔	✔	✔	✔	First, students must prepare and interview the main stakeholders in the problem (distributed task). Then, they bring the results of those interviews to the team to discuss and analyze the collected information, and make decisions. Moreover, since all teams must have interviews with their sponsors throughout the semester, and sponsors are invited to the final presentations, each team has a potent incentive to perform well and present a good project.
	Observation	Facilitators guide students in preparing to observe users in the context of the problem. Students are encouraged to move from concrete observations of the happenings in a particular situation to the more abstract potential emotions and motives that are at play in the situation they observe.		✔	✔	✔		
Empathy	Forced Ranking	Based on the information collected in the previous stage, teams need to agree on a single, ranked list of items about a relevant question or topic, where a clear, prioritized list is required. Then, they ask pertinent stakeholders (e.g., users) to rank those elements. Forced ranking obligates the person to rate each item relative to the others.	✔	✔		✔		
	Customer's Journey Map	This tool helps students develop empathy with users by visualizing their behaviors, ideas, emotions, and sentiments before, during, and after an experience using a customer journey map. Creating a journey map is a way to think systematically about the steps or milestones of a process.		✔		✔		
	Customer's Empathy Map	An empathy map is a tool for empathetic target group analysis. It is used to synthesize the collected information and understand the demands of present or potential users and customers by identifying their feelings, thoughts, and attitudes.				✔	✔	

Table A1. *Cont.*

DT Stages	Techniques and Tools [28,30,81]	Description	Conditions That Make Cooperative Learning Work in the Classroom [18]					Examples about How the Techniques/Tools Promote at Least One of the Elements for Cooperative Learning
			1	2	3	4	5	
Define	Saturate and Group for insights generation	Students cover a whiteboard with post-its highlighting interesting information of users they encountered in the field and related scenarios. The purpose is to assist teams in translating their thoughts and experiences into tangible and visual data. Then, each team groups these findings to explore which themes and patterns emerge and to determine people's important needs and insights.	✔	✔	✔	✔	✔	
	Persona/User profile	A persona is a fictional figure, designed to represent a user or other relevant stakeholder. It can be used to infer goals, needs, and concerns. This fictional figure should be described to the best of the team's ability. It has a name, gender, and basic demographic information. Information on the persona's personality and attributes is also included.				✔		
	Point of View (POV)	POV is an actionable problem statement based on the understanding and discoveries of the problem context and its main stakeholders using a human-centered approach. A POV is a unique design vision that teams should define based on what they learned during their empathy work. It is structured as follows: [USER] needs to [USER'S NEED] because [SURPRISING INSIGHT].			✔	✔	✔	
	Design Principles	Teams generate a collection of principles that describe the key rules for developing successful design solutions. Those principles should capture students' understanding of the context and user and provide a framework for reporting actionable solution criteria and communicating their design intentions to others.				✔		
Ideation	Brainstorming	Brainstorming is a strategy for generating ideas in which all participants can share their knowledge (quantity is more important than quality). Good brainstorming sessions encourage innovation and allow all participants to offer their ideas, regardless of their position in the team. There are no restrictions when it comes to brainstorming. All ideas are accepted.	✔		✔	✔		Before this activity, students are explicitly instructed to be respectful of each other's ideas, not interrupt, and to judge and contribute their ideas based on others' input. This is one of those sessions where teams are encouraged to use plenty of sticky notes to share their ideas, and all team members can easily see these notes and establish agreements based on the generated insights. This promotes everybody to stand up, see each other, discuss and work collaboratively around their whiteboards or tables.

Table A1. *Cont.*

DT Stages	Techniques and Tools [28,30,81]	Description	Conditions That Make Cooperative Learning Work in the Classroom [18]					Examples about How the Techniques/Tools Promote at Least One of the Elements for Cooperative Learning
			1	2	3	4	5	
	Analogies as inspiration sources for ideas	Analogies (or benchmarks) are used to generate ideas and approaches by looking at the 'worlds' that appear to exist separately in the context of the problem statement. Analogies aid in the development of new ideas and stimulate creativity by shifting the approach to the problem. Analogies might be derived from another industry, animals, people, or organizations.		✔		✔		
	Upside Down	Students are asked to list all the common assumptions (or elements) associated with the problem they are working on. Then, students are asked to turn those elements upside down, i.e., to imagine the exact opposite. They then choose the things they want to keep from the traditional context and what they want to change. The result is a brand new type of product/service/process.		✔		✔		
	Systematic Inventive Thinking (SIT)	The SIT consists of a toolkit of five thinking tools for creative ideation: Task Unification, Subtraction, Attribute Dependency, Qualitative Change, Attribute Value Mapping. Students applied the first three to rethink existing solutions or improve their own generated ideas. (For further information about these thinking tools visit https://www.sitsite.com/method/ accessed on 3 January 2022)				✔		
	Importance—Difficulty matrix	This is a 2 × 2 matrix for visually categorizing ideas where the 'X' axis is for Importance (impact) level, and the 'Y' axis is for Difficulty (complexity) level. First, each idea is written on a post-it; then, one team member starts by reading each idea aloud to the team and asking in which quadrant the idea should be placed. In the end, all ideas are placed in the matrix according to both criteria (importance and difficulty) and considering the other ideas. This matrix helps to quickly determine which ideas should be pursued and which should be rejected.				✔		
	Insight, Principles, Opportunities, Solution (IPOS) table	This tool consists of a 4-column table for filtering and checking the applicability of ideas in terms of the key findings of the problem context. First, each of the selected solution ideas from the Importance-Difficulty matrix are placed in a row. Then, students should evaluate the extent to which insight(s) and design principles (previously determined) are aligned with that solution idea; additionally, they have to identify at least one opportunity that may represent an advantage for that idea. Finally, teams adjust/improve their ideas or discard them by using this tool.				✔	✔	

Table A1. *Cont.*

DT Stages	Techniques and Tools [28,30,81]	Description	Conditions That Make Cooperative Learning Work in the Classroom [18]					Examples about How the Techniques/Tools Promote at Least One of the Elements for Cooperative Learning
			1	2	3	4	5	
Prototype	Low-fidelity prototypes: Sketching, Mock-Ups, Storyboards, RolePlay, Turkish automaton, Smokescreen, One-night performance, false interface	By building prototypes, teams make the selected ideas tangible and perceptible. From a modest critical function prototype to the final prototype, prototypes come in many shapes and sizes. Students learn these low-fidelity prototyping techniques employing inexpensive materials to make prototypes that are good enough to test a function or an experience. The results of the tests are utilized to obtain a better understanding of the user and to enhance (mid-fidelity prototypes) or discard the present prototype. The "Prototype" phase is intertwined with the "Validation" phase that follows. Facilitators guide students to see early failure as an excellent opportunity to learn from mistakes and improve their prototype in the next iteration.	✔		✔	✔	✔	Facilitators promote complementary roles through specific activities, such as prototyping and validation using role-play, where students are encouraged to assign roles among team members. Moreover, the radical collaboration nature of DT, and specifically the DT course, where each group has members from different field programs (engineering, business, tourism, graphic design, etc.), are some examples of shared resources, as well as the use of each member's best abilities for building outcomes such as prototype. Teams generate outputs such as storyboards and mock-ups that provide a common ground, a shared reference, for better alignment among team members, while discussing ideas, clarifying ambiguities, and constructive decision-making.
	Mid-fidelity prototypes: 3D printing, mock-ups app or website, a recreation of environments, Oz Wizard.		✔		✔	✔	✔	
Validation	Testing with users	Students use their prototypes with real potential users and other relevant stakeholders, from lo-fi to mid-fi, to assess whether the user's needs were met by the implemented ideas. Students are advised to let the user experience the idea and observe how they interact with the prototype, acquiring feedback on the various dimensions of desirability, feasibility, and practicability.	✔	✔	✔	✔	✔	
	Feedback capture grid	This tool supports the testing by helping students to straighforwardly document their test results. First, students ask the tester (user/customer) to think aloud while using the prototype. Then, students fill in the fields of the grid with these thoughts. Next, in the upper left field, students note what the user liked; on the right, they note what he might not like so much. In the lower left field, students include the questions that were asked by the tester, and in the lower right field, they document the new ideas that they or the user observed during the testing.				✔	✔	

1 Positive interdependence; 2 Individual accountability; 3 Social skills; 4 Promotive interaction; 5 Group processing.

Appendix B

The following rubric, adapted from Rhodes (2010), was used by facilitators, who rated students as team members. Students also used the same rubric to rate themselves and their teammates.

Table A2. Teamwork Rubric used in the study, based on the VALUE Rubrics.

Item	A	B	C	D	E
Contributes to Team Meetings	Helps the team move forward by articulating the merits of alternative ideas or proposals.	Offers alternative solutions or ideas that build on the ideas of others.	Offers new suggestions to advance the work of the group.	Shares ideas but does not advance the work of the group.	None of the alternatives because you consider that your performance does not reach what is described in any column.
Role as the facilitator of the contributions of team members	Engages team members in ways that facilitate their contributions to meetings by both constructively building upon or synthesizing the contributions of others as well as noticing when someone is not participating and inviting them to engage.	Engages team members in ways that facilitate their contributions to meetings by constructively building upon or synthesizing the contributions of others.	Engages team members in ways that facilitate their contributions to meetings by restating other team members' views and asking questions for clarification.	Listens to others without interrupting.	None of the alternatives because you consider that your performance does not reach what is described in any column.
Individual Contributions Outside of Team Meetings	Completes all assigned tasks by the deadline; work accomplished is thorough, comprehensive, and advances the project. Besides, proactively helps other team members achieve their assigned tasks to a similar level of excellence.	Completes all assigned tasks by the deadline; work accomplished is thorough, comprehensive, and advances the project.	Completes all assigned tasks by the deadline; work accomplished advances the project partially.	Completes all assigned tasks by deadline.	None of the alternatives because you consider that your performance does not reach what is described in any column.
Fosters Constructive Team Climate	Supports a constructive team climate by doing all of the following: -Treats team members respectfully by being polite and constructive in communication. -Uses positive vocal or written tone, facial expressions, and/or body language to convey a positive attitude about the team and its work. -Motivates teammates by expressing confidence about the importance of the task and the team's ability to accomplish it. -Provides assistance and encouragement to team members.	Supports a constructive team climate by doing any three of the following: -Treats team members respectfully by being polite and constructive in communication. -Uses positive vocal or written tone, facial expressions, and/or body language to convey a positive attitude about the team and its work. -Motivates teammates by expressing confidence about the importance of the task and the team's ability to accomplish it. -Provides assistance and/or encouragement to team members.	Supports a constructive team climate by doing any two of the following: -Treats team members respectfully by being polite and constructive in communication. -Uses positive vocal or written tone, facial expressions, and/or body language to convey a positive attitude about the team and its work. -Motivates teammates by expressing confidence about the importance of the task and the team's ability to accomplish it. -Provides assistance and/or encouragement to team members.	Supports a constructive team climate by doing only one of the following: -Treats team members respectfully by being polite and constructive in communication. -Uses positive vocal or written tone, facial expressions, and/or body language to convey a positive attitude about the team and its work. -Motivates teammates by expressing confidence about the importance of the task and the team's ability to accomplish it. -Provides assistance and/or encouragement to team members.	None of the alternatives because you consider that your performance does not reach what is described in any column.
Responds to Conflict	Addresses destructive conflict directly and constructively, helping to manage/resolve it in a way that strengthens overall team cohesiveness and future effectiveness.	Identifies and acknowledges conflict and stays engaged with it without necessarily solving it.	Redirects the focus toward conflict to another common theme related to the task in question (away from conflict).	Simply accepts alternate viewpoints/ideas/opinions.	None of the alternatives because you consider that your performance does not reach what is described in any column.

References

1. Adams, R.S.; Daly, S.R.; Mann, L.M.; Dall'Alba, G. Being a professional: Three lenses into design thinking, acting, and being. *Des. Stud.* **2011**, *32*, 588–607. [CrossRef]
2. Passow, H.J. Which ABET Competencies Do Engineering Graduates Find Most Important in their Work? *J. Eng. Educ.* **2012**, *101*, 95–118. [CrossRef]
3. World Economic Forum. *Future of Job Report 2020*; World Economic Forum (WEF): Geneva, Switzerland, 2020.
4. Binkley, M.; Erstad, O.; Herman, J.; Raizen, S.; Ripley, M.; Miller-Ricci, M.; Rumble, M. Defining Twenty-First Century Skills. In *Assessment and Teaching of 21st Century Skills*; Griffin, P., McGaw, B., Care, E., Eds.; Springer: Dordrecht, The Netherlands, 2012; pp. 17–66. ISBN 978-94-007-2323-8.
5. Shuman, L.J.; Besterfield-Sacre, M.; McGourty, J. The ABET "Professional Skills"—Can They Be Taught? Can They Be Assessed? *J. Eng. Educ.* **2005**, *94*, 41–55. [CrossRef]
6. Luka, I. Design Thinking in Pedagogy. *J. Educ. Cult. Soc.* **2020**, *5*, 63–74. [CrossRef]
7. Noweski, C.; Scheer, A.; Büttner, N.; von Thienen, J.; Erdmann, J.; Meinel, C. Towards a Paradigm Shift in Education Practice: Developing Twenty-First Century Skills with Design Thinking. In *Design Thinking Research: Measuring Performance in Context*; Plattner, H., Meinel, C., Leifer, L., Eds.; Springer: Berlin/Heidelberg, Germany, 2012; pp. 71–94. ISBN 978-3-642-31991-4.
8. Bross, J.; Noweski, C.; Meinel, C. Reviving the Innovative Process of Design Thinking. In Proceedings of the ICIW 2011: The Sixth International Conference on Internet and Web Applications and Services, St. Maarten, The Netherlands, 20–25 March 2011; pp. 142–149.
9. Pande, M.; Bharathi, S.V. Theoretical foundations of design thinking—A constructivism learning approach to design thinking. *Think. Ski. Creat.* **2020**, *36*, 100637. [CrossRef]
10. Brown, T. Design Thinking. *Harv. Bus. Rev.* **2008**, *86*, 84–92.
11. Scheer, A.; Noweski, C.; Meinel, C. Transforming Constructivist Learning into Action: Design Thinking in education. *Des. Technol. Educ. Int. J.* **2012**, *17*, 8–19.
12. Wrigley, C.; Straker, K. Design Thinking pedagogy: The Educational Design Ladder. *Innov. Educ. Teach. Int.* **2015**, *54*, 374–385. [CrossRef]
13. Panke, S. Design Thinking in Education: Perspectives, Opportunities and Challenges. *Open Educ. Stud.* **2019**, *1*, 281–306. [CrossRef]
14. Spee, J.; Basaiawmoit, R.V. Design Thinking and the Hype Cycle in Management Education and in Engineering Education. In Proceedings of the DS 84: Proceedings of the DESIGN 2016 14th International Design Conference, Cavtat, Croatia, 16–19 May 2016; Marjanovic, D., Storga, M., Pavkovic, N., Bojcetic, N., Skec, S., Eds.; DESIGN SOC: Glasgow, UK, 2016; pp. 2111–2124.
15. Lake, D.; Flannery, K.; Kearns, M. A Cross-Disciplines and Cross-Sector Mixed-Methods Examination of Design Thinking Practices and Outcome. *Innov. High. Educ.* **2021**, *46*, 337–356. [CrossRef]
16. Steinbeck, R. Building creative competence in globally distributed courses through design thinking. *Rev. Comun.* **2011**, *19*, 27–34. [CrossRef]
17. Opdecam, E.; Everaert, P.; Van Keer, H.; Buysschaert, F. Preferences for Team Learning and Lecture-Based Learning among First-Year Undergraduate Accounting Students. *Res. High. Educ.* **2014**, *55*, 400–432. [CrossRef]
18. Johnson, D.W.; Johnson, R.T. Making cooperative learning work. *Theory Pract.* **1999**, *38*, 67–73. [CrossRef]
19. Rhodes, T.L. *Assessing Outcomes and Improving Achievement*; Association of American Colleges and Universities: Washington, WA, USA, 2010; ISBN 9780911696615.
20. Vasquez, E.S.; Dewitt, M.J.; West, Z.J.; Elsass, M.J. Impact of Team Formation Approach on Teamwork Effectiveness and Performance in an Upper-Level Undergraduate Chemical Engineering Laboratory Course. *Int. J. Eng. Educ.* **2020**, *36*, 491–501.
21. Matthews, J.H.; Wrigley, C. Design and design thinking in business and management higher education. *J. Learn. Des.* **2017**, *10*, 41–54. [CrossRef]
22. Rodger, S.; Murray, H.G.; Cummings, A.L. Gender Differences in Cooperative Learning with University Students. *Alberta J. Educ. Res.* **2007**, *53*, 157–173.
23. Johansson-Sköldberg, U.; Woodilla, J.; Cetinkaya, M. Design Thinking: Past, Present and Possible Futures. *Creat. Innov. Manag.* **2013**, *22*, 121–146. [CrossRef]
24. Benson, J.; Dresdow, S. Design for Thinking: Engagement in an Innovation Project. *Decis. Sci. J. Innov. Educ.* **2015**, *13*, 377–410. [CrossRef]
25. Carlgren, L.; Rauth, I.; Elmquist, M. Framing Design Thinking: The Concept in Idea and Enactment. *Creat. Innov. Manag.* **2016**, *25*, 38–57. [CrossRef]
26. Camacho, M. An Integrative Model of Design Thinking. In Proceedings of the 21st DMI: Academic Design Management Conference, London, UK, 1–2 August 2018; pp. 627–641.
27. Fleury, A.; Stabile, H.; Carvalho, M. An Overview of the Literature on Design Thinking: Trends and Contributions. *Int. J. Eng. Educ.* **2016**, *32*, 1704–1718.
28. Hasso Plattner Institute of Design at Stanford University (d.School) (Archival Resource) Design Thinking Bootcamp Bootleg. Available online: https://dschool.stanford.edu/resources/the-bootcamp-bootleg (accessed on 1 December 2021).

29. Dam, R.F.; Siang, T.Y. Design Thinking: Select the Right Team Members and Start Facilitating. Available online: https://www.interaction-design.org/literature/article/design-thinking-select-the-right-team-members-and-start-facilitating (accessed on 28 December 2020).
30. Lewrick, M.; Link, P.; Leifer, L. *The Design Thinking Toolbox*; Wiley: Hoboken, NJ, USA, 2020; ISBN 978111962945.
31. Goldman, S.; Kabayadondo, Z.; Royalty, A.; Carroll, M.P.; Roth, B. *Design Thinking Research*; Leifer, L., Plattner, H., Meinel, C., Eds.; Springer: Cham, Switzerland, 2014; ISBN 978-3-319-01302-2.
32. Salas, E.; Sims, D.E.; Burke, C.S. Is there a "Big Five" in Teamwork? *Small Group Res.* **2005**, *36*, 555–599. [CrossRef]
33. Katzenbach, J.R.; Smith, D.K. *The Discipline of Teams*; Harvard Business Review; Harvard Business Press: Boston, MA, USA, 1993.
34. Nilson, L.B. *Teaching at Its Best: A Research-Based Resource for College Instructors*, 4th ed.; Jossey-Bass: San Francisco, CA, USA, 2016; ISBN 9781119096320.
35. Kozlowski, S.W.J.; Ilgen, D.R. Enhancing the Effectiveness of Work Groups and Teams. *Psychol. Sci. Public Interest* **2006**, *7*, 77–124. [CrossRef] [PubMed]
36. Wang, L.; MacCann, C.; Zhuang, X.; Liu, O.L.; Roberts, R.D. Assessing Teamwork and Collaboration in High School Students: A Multimethod Approach. *Can. J. Sch. Psychol.* **2009**, *24*, 108–124. [CrossRef]
37. Wagner, S.L.; Moffett, R.G. Assessment Methodology, Context, and Empowerment: The Ace Model of Skill Development. *J. Manag. Educ.* **2000**, *24*, 424–444. [CrossRef]
38. Andrade, H.L. A Critical Review of Research on Student Self-Assessment. *Front. Educ.* **2019**, *4*, 87. [CrossRef]
39. Ohland, M.W.; Loughry, M.L.; Woehr, D.J.; Bullard, L.G.; Felder, R.M.; Finelli, C.J.; Layton, R.A.; Pomeranz, H.R.; Schmucker, D.G. The Comprehensive Assessment of Team Member Effectiveness: Development of a Behaviorally Anchored Rating Scale for Self- and Peer Evaluation. *Acad. Manag. Learn. Educ.* **2012**, *11*, 609–630. [CrossRef]
40. Kijima, R.; Yang-Yoshihara, M.; Maekawa, M.S. Using design thinking to cultivate the next generation of female STEAM thinkers. *Int. J. STEM Educ.* **2021**, *8*, 14. [CrossRef]
41. Duffy, T.M.; Cunningham, D.J. Constructivism: Implications for the design and delivery of instruction. In *Handbook of Research for Educational Communications and Technology*; Macmillan Library Reference: New York, NY, USA, 1996; pp. 170–198.
42. Jonassen, D.; Davidson, M.; Collins, M.; Campbell, J.; Bannan, B. Constructivism and Computer-Mediated Communication in Distance Education. *Am. J. Distance Educ.* **1995**, *9*, 7–26. [CrossRef]
43. Murphy, E. *Constructivism: From Philosophy to Practice*; Educational Resources Information Center (ERIC): Columbus, OH, USA, 1997.
44. Bene, R.; McNeilly, E. Getting Radical: Using Design thinking to Tackle Collaboration Issues. *Pap. Postsecond. Learn. Teach.* **2020**, *4*, 50–57.
45. Hasso Plattner Institute of Design at Stanford University (d.School) Design Thinking Bootleg. Available online: https://dschool.stanford.edu/resources/design-thinking-bootleg (accessed on 12 March 2019).
46. Durham, C.C.; Knight, D.; Locke, E.A. Effects of Leader Role, Team-Set Goal Difficulty, Efficacy, and Tactics on Team Effectiveness. *Organ. Behav. Hum. Decis. Process.* **1997**, *72*, 203–231. [CrossRef]
47. Lindberg, T.; Meinel, C.; Wagner, R. Design Thinking: A Fruitful Concept for IT Development? In *Design Thinking: Understand-Improve-Apply*; Plattner, H., Meinel, C., Leifer, L., Eds.; Springer: Berlin/Heidelberg, Germany, 2011; pp. 3–18.
48. Taajamaa, V.; Kirjavainen, S.; Repokari, L.; Sjoman, H.; Utriainen, T.; Salakoski, T. Dancing with ambiguity design thinking in interdisciplinary engineering education. In Proceedings of the 2013 IEEE Tsinghua International Design Management Symposium, Shenzhen, China, 1–2 December 2013; pp. 353–360.
49. Ellison, C.M.; Wade Boykin, A. Comparing outcomes from differential cooperative and individualistic learning methods. *Soc. Behav. Personal. Int. J.* **1994**, *22*, 91–103. [CrossRef]
50. Johnson, C.; Engelhard, G. Gender, Academic Achievement, and Preferences for Cooperative, Competitive, and Individualistic Learning Among African-American Adolescents. *J. Psychol.* **1992**, *126*, 385. [CrossRef] [PubMed]
51. Jordan, J.V.; Walker, M.; Hartling, L.M. (Eds.) *The Complexity of Connection: Writings from the Stone Center's Jean Baker Miller Training Institute*; Guilford Press: New York, NY, USA, 2004; ISBN1 1-59385-026-3. ISBN2 1-59385-025-5.
52. Sheldon, A. Conflict Talk: Sociolinguistic Challenges to Self-Assertion and How Young Girls Meet Them. *Merrill Palmer Q.* **1992**, *38*, 95–117.
53. Budaev, S. V Sex differences in the Big Five personality factors: Testing an evolutionary hypothesis. *Personal. Individ. Differ.* **1999**, *26*, 801–813. [CrossRef]
54. Feingold, A. Gender differences in personality: A meta-analysis. *Psychol. Bull.* **1994**, *116*, 429–456. [CrossRef]
55. Costa, P.T.; Terracciano, A.; McCrae, R.R. Gender differences in personality traits across cultures: Robust and surprising findings. *J. Pers. Soc. Psychol.* **2001**, *81*, 322–331. [CrossRef]
56. Ramsay, A.; Hanlon, D.; Smith, D. The association between cognitive style and accounting students' preference for cooperative learning: An empirical investigation. *J. Account. Educ.* **2000**, *18*, 215–228. [CrossRef]
57. Emerson, T.L.N.; English, L.; McGoldrick, K. Cooperative learning and personality types. *Int. Rev. Econ. Educ.* **2016**, *21*, 21–29. [CrossRef]
58. Takeda, S.; Homberg, F. The effects of gender on group work process and achievement: An analysis through self- and peer-assessment. *Br. Educ. Res. J.* **2014**, *40*, 373–396. [CrossRef]
59. De Prada, E.; Mareque, M.; Pino-Juste, M. Teamwork skills in higher education: Is university training contributing to their mastery? *Psicol. Reflex. Crít.* **2022**, *35*, 5. [CrossRef]

60. Peinado Pérez, J.E.; Zueck Enríquez, M.D.C.; Gastélum Cuadras, G.; Rangel Ledezma, Y.; Blanco Vega, H. Perceived Self-Efficacy in Teamwork and Entrepreneurship in University Students. A Gender Study. *Sci. J. Educ.* **2015**, *3*, 1. [CrossRef]
61. Baker, D.F. Peer Assessment in Small Groups: A Comparison of Methods. *J. Manag. Educ.* **2007**, *32*, 183–209. [CrossRef]
62. Simeon, M.I.; Samsudin, M.A.; Yakob, N. Effect of design thinking approach on students' achievement in some selected physics concepts in the context of STEM learning. *Int. J. Technol. Des. Educ.* **2020**, *32*, 185–212. [CrossRef]
63. John, C.; Staubitz, T.; Meinel, C. Performance of Men and Women in Graded Team Assignments in MOOCs. In Proceedings of the 2019 IEEE Learning With MOOCS (LWMOOCS), Milwaukee, WI, USA, 23–25 October 2019; pp. 30–35.
64. Santos Ordóñez, A.; González Lema, C.; Puga, M.F.M.; Párraga Lema, C.; Vega, M.F.C. Design thinking as a methodology for solving problems: Contributions from academia to society. In Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology, Boca Raton, FL, USA, 19–21 July 2017. [CrossRef]
65. Design Council. *Eleven Lessons: Managing Design in Eleven Global Companies. Desk Research Report*; Design Council: London, UK, 2007.
66. Hughes, R.L.; Jones, S.K. Developing and assessing college student teamwork skills. *New Dir. Inst. Res.* **2011**, *2011*, 53–64. [CrossRef]
67. McConnell, K.D.; Horan, E.M.; Zimmerman, B.; Rhodes, T.L. *We Have a Rubric for That. The VALUE Approach to Assessment*; Association of American Colleges and Universities: Washington, WA, USA, 2019.
68. Rhodes, T.L.; Finley, A. *Using the VALUE Rubrics for Improvement of Learning and Authentic Assessment*; Association of American Colleges and Universities: Washington, WA, USA, 2013; ISBN 9780989097208.
69. Finley, A.P. How reliable are the VALUE rubrics. In *Peer Review*; Association of American Colleges and Universities: Washington, WA, USA, 2012; pp. 31–33.
70. Cohen, J. A Power Primer. *Psychol. Bull.* **1992**, *112*, 155–159. [CrossRef]
71. Arnab, S.; Clarke, S.; Morini, L. Co-creativity through play and game design thinking. *Electron. J. E-Learn.* **2019**, *17*, 184–198. [CrossRef]
72. Sándorová, Z.; Repáňová, T.; Palenčíková, Z.; Beták, N. Design thinking—A revolutionary new approach in tourism education? *J. Hosp. Leis. Sport Tour. Educ.* **2020**, *26*, 100238. [CrossRef]
73. Palacin-Silva, M.; Khakurel, J.; Happonen, A.; Hynninen, T.; Porras, J. Infusing Design Thinking into a Software Engineering Capstone Course. In Proceedings of the 2017 IEEE 30th Conference on Software Engineering Education and Training (CSEE&T), Savannah, GA, USA, 7–9 November 2017; pp. 212–221.
74. Valentim, N.M.C.; Silva, W.; Conte, T. The Students' Perspectives on Applying Design Thinking for the Design of Mobile Applications. In Proceedings of the 2017 IEEE/ACM 39th International Conference on Software Engineering: Software Engineering Education and Training Track (ICSE-SEET), Buenos Aires, Argentina, 20–28 May 2017; pp. 77–86.
75. Ohly, S.; Plückthun, L.; Kissel, D. Developing Students' Creative Self-Efficacy Based on Design-Thinking: Evaluation of an Elective University Course. *Psychol. Learn. Teach.* **2016**, *16*, 125–132. [CrossRef]
76. Gatchell, D.W.; Ankenman, B.; Hirsch, P.L.; Goodman, A.; Brown, K. Restructuring teamwork pedagogy in a first-year engineering design program: Lessons learned and future plans. In Proceedings of the 121st ASEE Annual Conference and Exposition: 360 Degrees of Engineering Education; American Society for Engineering Education, Indianapolis, Indiana, 15–18 June 2014.
77. Keramati, M.R.; Gillies, R.M. Advantages and Challenges of Cooperative Learning in Two Different Cultures. *Educ. Sci.* **2022**, *12*, 3. [CrossRef]
78. Warrington, M.; Younger, M.; Williams, J. Student Attitudes, Image and the Gender Gap. *Br. Educ. Res. J.* **2000**, *26*, 393–407. [CrossRef]
79. Tinklin, T. Gender Differences and High Attainment. *Br. Educ. Res. J.* **2003**, *29*, 307–325. [CrossRef]
80. Schneid, M.; Isidor, R.; Li, C.; Kabst, R. The influence of cultural context on the relationship between gender diversity and team performance: A meta-analysis. *Int. J. Hum. Resour. Manag.* **2015**, *26*, 733–756. [CrossRef]
81. Seelig, T. *Insight out: Get Ideas out of Your Head and into the World*; HarperCollins: New York, NY, USA, 2015; ISBN 9780062301321.