The Value of Design Thinking for PhD Students:
A Retrospective Longitudinal Study

Guilherme Victorino [1*], Pedro S. Coelho [1], Roberto Henriques [1]

[1] NOVA IMS, Universidade Nova de Lisboa, 1070-312 Lisbon, Portugal.

Abstract

Doctoral studies are changing worldwide, with growing concerns about doctoral graduates' employability and ability to develop relevant links with industrial challenges. The present study aims examine the impact of Design Thinking skills on PhD students on their future academic and professional performance. Drawing on 7 years of pedagogical experimentation, we conducted a mixed methods longitudinal study to investigate the perceptions of students who attended a two-day Design Thinking workshop. Two questionnaires, with a total of 40 items measuring the quality and course impact dimensions, were given to 415 and 41 students, respectively. Finally, 12 students were chosen for in-depth interviews to learn more about how they applied their newly acquired design thinking skills in their research and work. Our findings show that developing Design Thinking skills impacts the professional lives of students of all fields of knowledge, ages, and stages of their PhD. The primary outcomes mentioned are associated with increased creative confidence and collaboration abilities. This study focuses on relevant dimensions for designing and delivering Design Thinking skills within doctoral programmes, as well as the impact of design thinking on the quality of PhD education and student employability opportunities.

1- Introduction

Doctoral education is central to the mission of universities. It creates the necessary environment for the production of knowledge and supplies the academic community and broader society in general with researchers that are capable of developing original knowledge in their fields of research [1]. The present graduate education system is founded on an apprenticeship model where lab leaders instruct junior researchers in the art and methods of conducting research. The PhD system has not altered significantly since the eighteen hundred, despite scientific enterprise having changed considerably since then [2]. Doctoral education was primarily created to meet the human resource demands of academia. However, a rising percentage of PhD holders are seeking jobs outside of academia [3], which highlights economic changes and the emergence of new types of skilled employment [4]. The world's most pressing issues require creative minds, critical thinkers, and problem solvers; nevertheless, PhD graduates may not always have the qualifications that employers are looking for, and therefore a major skill mismatch may still exist [5].

Today, Doctorate holders are expected to gain a combination of technical and soft skills and high degrees of flexibility [6]. Given this reality, there is a rise in the necessity of training in transferable skills, and the need to expand learning goals at the PhD level, which may fundamentally alter the way research doctoral programmes are structured [7]. PhD candidates are expected to network, collaborate, co-publish, pitch, and communicate their research to diverse audiences and have advanced technical and digital competencies [8]. This view has led to the incorporation of more transferable skills training into doctoral programmes [9]. Transferable skills are skills that can be deployed with little or no adaptation in a variety of social settings [10] and can be organised into 5 categories [11]:

(a) Resources (identifies, organises, plans and allocates resources),

(b) Interpersonal (works with others),

(c) Information (acquires and uses information),

(d) Systems (understands complex interrelationships) and,

(e) Technology (works with a variety of technologies)

PhD students, however, may find it challenging to identify these skills because their academic experience is not always focused on articulating skill sets. We also frequently find that PhD students, understandably, struggle to demonstrate the transferability of their academic experiences to non-academic contexts. The transmission of these skills may be influenced by a number of variables, including the trainee's attributes [12], the training programme, the supervisor's and workgroup's support, and the trainee's voluntary engagement [13]. One way of addressing this challenge is to create a multidisciplinary learning approach and a cross-fertilisation environment. In Europe, several universities have created specific structures like "Doctoral Schools" [14] that offer complementary activities and courses to enhance the development of transferrable skills [15], teamwork, and communication among students in international settings [16]. Accordingly, the value of transferrable skills is gradually becoming evident, and the argument that academics are more concerned with how to teach skills efficiently rather than whether interest should be manifested in the first place has progressed.

New pedagogical techniques are necessary to keep up with the changes in economic, environmental and business landscapes and to give students the abilities that employers value today [17]. One of the pedagogical innovations introduced in higher education is design thinking [18], which is a versatile approach for problem-based learning, allowing the articulation of opposing viewpoints, pinpointing specific requirements and shared objectives, applying the strengths of people from different backgrounds, fostering empathy, and creating a shared vision for action.

The present work aims to contribute to the discussion on the uses of design thinking to foster new transferable skills in higher education. This study examines the experience of a design thinking intervention in a doctoral education programme in Europe through a retrospective longitudinal mix methods approach [19] that answers three distinct questions:

1. What is the perceived value of design thinking training for PhDs?

2. How is design thinking related to a PhD student's creative confidence and collaboration skills?

3. What is the impact of design thinking training on the PhD student's professional life?

This study describes the design and evaluation of a learning experience conceived to help students understand design thinking principles. Firstly, it discusses the design of the learning experience, describing the collaborative process of addressing a design challenge in a two-day workshop using a challenge-based learning approach. Secondly, the study evaluates the effectiveness of the learning experience by examining the students' feedback and reflections. Thirdly, we demonstrate that participation in the learning experience encouraged collaboration and creative problem solving. As a result, this research highlights how design thinking training in a doctoral school setting can develop new transferable skills for PhDs.

1-1- Design Thinking and Education

Many scholars have focused on describing the skills that PhD students believe they developed or improved during the doctoral process, as well as how these skills were developed and contributed to their personal and professional development [20–22]. In many cases, students' informal learning in areas unrelated to their PhD positively impacted the skills they developed while working on their PhD [20]. Similarly, Design Thinking is a tool that responds to the increasing complexity that modern organisations face today, with technologies playing a key role [23]. Organisations increasingly recognise Design Thinking as a systematic process for coming up with original solutions with the aim of fostering innovation [24]. Its application is becoming more popular due to its potential to clarify problems and examine their contexts, and as a thought process that brings design principles, approaches, methods, and tools to problem-solving [25]. Design thinking can be defined as "a human-centred innovation process that emphasises observation, collaboration, fast learning, visualisation of ideas, rapid concept prototyping and concurrent business analysis" [26]. In contrast to the conventional narrow, technically oriented way of thinking, it should be considered as a means to develop overall innovation capabilities, implemented as an overarching approach that combines the analytic and synthetic phases of innovation [27].

Design has played a pivotal role in the success of businesses at both strategic and operational levels [28]. Education leaders should reflect on the design dimensions mentioned above [29] and integrate Design Thinking into their curriculum by taking an empathic, adaptable, and iterative approach [30] that fosters innovation and creativity. The Design Thinking methodology grants the sensitivity and reasoning of a designer, as well as some of its practices, to connect the user's needs with the organisational strategies, resources and technologies [31]. Because these links are rooted in human-centred considerations, Design Thinking can help to envision meaningful opportunities that may be

useful for a diverse range of stakeholders [32], encouraging interdisciplinarity and teamwork, and allowing for the blending of arts, sciences, and technology to develop assertive and creative solutions [23, 24].

Students' exposure to Design Thinking practices as learning strategies enables new perspectives that are generative of new approaches to problem-solving challenges [33] and assist technical communicators in becoming stronger user advocates [34]. In addition, this strategy fosters the necessary empathy to deal with ambiguity and uncertainty, which is something which scientific thinking often views as a potential threat [35]. Students will be better equipped to face problems and develop innovative solutions if their Design Thinking skills are improved [36] through processes and methods that designers use to ideate and experience how they approach and solve problems. Design thinking may be considered a great tool to be used in the teaching/learning processes [37] because it promotes integrative developing habits of mind that give students a sense of agency as an individual learner, with the self-efficacy to apply their learning in daily life [38]. Integrative learning demands more than just content and skill development. From a pedagogical standpoint, Design Thinking is a methodology that engages and transforms students in a unique way by challenging them to think and act differently [39]. The main goal is to combine their technical and analytical skills, which provide them with an understanding of what is going on, with Design Thinking skills, which assist them in understanding why things happen and what should be done about them [40].

1-2- Design Thinking Workshop Case Study

The Design Thinking Workshop is one of the 14 transferable skills courses promoted by a Doctoral school in Europe with more than 3,000 students enrolled from 86 PhD programs from 9 different faculties: engineering, social sciences, business and economics, information management, medical school, law, public health, tropical medicine, life sciences and chemistry. The two-day course is based on real-world challenges and has had 24 editions from 2014 to 2021. The workshop is structured according to the three phases of Design Thinking defined by Brown [31]: Inspire, Ideate and Implement and ends with a final pitch presentation to the class. Table 1 summarises the objective of each phase and the essential tools used.

Table 1. Design Thinking stages and used tools

Stage	Goal	Design Thinking Tools used
Inspire	Empathise with users, understand user needs, formulate design problems	Exploratory research (benchmarking, trend analysis, parallel universes, literature research), ethnographic research (interviews, user journey mapping), visualisation (capture of ideas and concepts in a whiteboard, mind mapping) and synthesis (finding patterns in research, identify personas, formulate insights).
Ideate	Apply creative and divergent thinking techniques to generate and refine ideas	Brainstorming, divergent thinking techniques, visualisation (capture of ideas and concepts in a whiteboard), idea prioritisation (scoring and selecting ideas for implementation based on their desirability, feasibility and viability).
Implement	Prototype and test assumptions	Prototyping (storyboards, digital or physical mockups), user testing (synchronous and asynchronous).

The workshop goal is that students can understand key aspects of Design Thinking and develop a deeper and more holistic understanding of users and their needs, motivations, and behaviours. The process will promote creative thinking and problem-solving. It allows students to learn from failure and understand that innovation entails taking risks and trying new things. Students will integrate Design Thinking principles into their PhD process and professional activities by the end of the workshop. The process as a whole prepares participants to use Design Thinking in other contexts and compare it to the rational approach of problem solving [41].

The advantages of Design Thinking as a method of creativity and problem-solving have been outlined in the literature relevant to the field [42]. Two of the primary factors contributing to its popularity as a cutting-edge strategy are the fact that it may be applied successfully by novice teams [43] and both by designers and non-designers [25]. The goal of this workshop is threefold: 1) to increase the students' creative confidence [44], 2) to lessen possible cognitive bias [45] towards the solutions presented, 3) and to nurture the group's task reflexivity and discussion which is connected to more successful outcomes [43].

The first day of the workshop follows a problem-based learning approach [46] where groups of 4 to 6 students are invited to tackle a problem case or scenario with the Design Thinking principles previously made available for self-directed study on a learning management platform. The assumption is that the crucial soft skills can be most effectively acquired through a combination of practical experience, timely and constructive feedback from peers in a community of practice, and highly focused and relevant formal instruction where the results of our actions can be clearly seen and understood [47]. Therefore, by the end of day one, students have been through the three stages of a Design Thinking process and received peer feedback from other groups and workshop tutors on each step as well as the final idea/solution presented.

During the second day of the workshop, students pair up and choose a corporate, social, or research-based challenge to address the goal of fostering creativity, inclusion, and sustainability. At the end of the day, they will pitch their idea to the class and receive feedback regarding their project's viability, feasibility, and desirability. In order to leverage this

diversity to produce richer outcomes in the innovation project [48], students should pair up with researchers from different areas ensuring maximum heterogeneity of educational backgrounds, work experiences, and personality traits.

2- Research Methodology

Given that soft and transferable skills are progressively being included in higher education and doctoral trainings programmes throughout the world [49], there is growing concern regarding their assessment [50]. However, there is a critical need to obtain longitudinal data on soft skills assessment, and evidence from quantitative survey data and case studies [51] that can help inform programme leaders. Due to the complex requirements of soft skills assessment standards [50], we used a retrospective longitudinal mixed methods design [19]. This approach combined a variety of research techniques, including methods often associated with both "positivist"/quantitative and "interpretive"/qualitative paradigms. In this study, 7 years of data collection enabled the evaluation of variation over time from a longitudinal perspective. We have collected quantitative data at multiple points in time and qualitative data concurrent with the quantitative data at the study's final timeline (Figure 1).
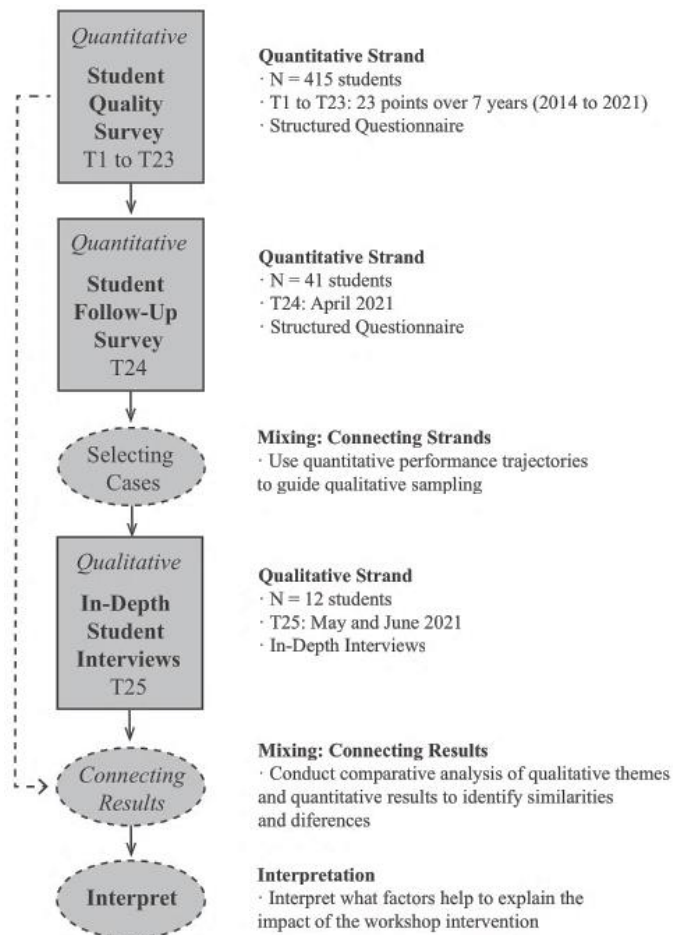

Figure 1. Mix methods longitudinal study (adapted from [19])

This retrospective component was crucial for gathering the data required to address the study's complex and potentially linked themes and concerns to give a rigorous account of students' views throughout their PhD. Instead of relying solely on one paradigm or technique, this blended approach offered additional chances for mapping, analysis, and interpretation to produce comprehensive research insights [52]. Therefore, the authors integrated their two data sets during analysis and interpretation to substantiate the quantitative results with the qualitative findings.

The study's primary focus was the impact assessment of the Design Thinking workshop. It deployed 3 main types of evidence: quality control surveys handed out at the end of every workshop; follow-up survey handed to all students who attended the workshop; in-depth interviews with a selected group of participants of the follow-up survey. The final interviews were used to investigate how students evaluate their creative confidence and collaboration skills and the elements that influence it throughout their PhD and careers.

2-1- Workshop Participants

The Design Thinking workshop presented in this study had 491 participants distributed over 24 editions of the course running from 2014 to 2021. The average number of participants in the workshop was 20 and the students came from

different backgrounds: 15 nationalities and 77 different doctoral programmes. Among the 491 participants, 314 (62%) were female and 177 were male (36%), coming from different faculties, PhD programs (Figure 2) and stages in the doctoral degree - from students starting their PhD to Post-Docs with research experience.
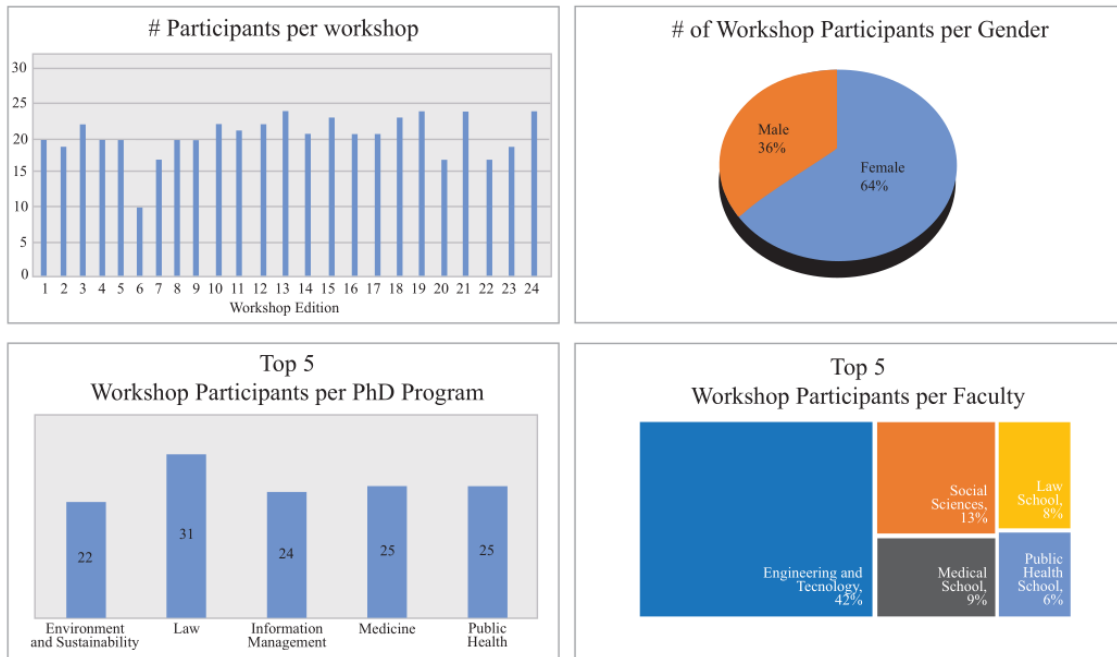

Figure 2. Design Thinking Workshop Participants Characterisation

2-2- Instruments

Different research instruments were used to collect, measure, and analyze data to ascertain the internalisation of knowledge and professional impact of the intervention, in particular, two self-administered questionnaires and in-depth semi-structured interviews:

2-2-1- Student Quality Control Survey

Since the workshop's inception in 2014, the quality control survey has been distributed at the conclusion of each edition. The constructs were chosen based on learner-content and learner-instructor interaction, as well as overall satisfaction and recommendation of the workshop [53]. The Student Quality Control Survey questionnaire (Table 2) has 11 items that respondents rate on a 6-point Likert scale [54] ranging from (1) Strongly Disagree to (6) Strongly Agree. The first set of statements assesses students' overall satisfaction with their learning experience. The second set of statements rate how much students believe their instructors exhibit specific behaviours. These two sets of statements are followed by a "Perceived Value" section in which students are asked to rate the workshop's importance in their personal and professional lives. The final statement intends to assess the workshop's likelihood of being recommended.

Table 2. Design Thinking stages and used tools

Dimensions	Items	Scale
General	- I was able to understand the contents of the workshop clearly - I was satisfied with the learning experience of this workshop - This workshop met my expectations	Likert: From 1 (strongly disagree) to 6 (strongly agree)
Teaching staff	- Was prepared for the workshop - Used class time in an effective way - Stimulated open discussion in class - Answered questions promptly and clearly - Stimulated my interest in the topic	
Perceived value	- The knowledge I acquired in this workshop will be useful for my personal development - The knowledge I acquired in this workshop will be useful for my professional development	
Likelihood of recommendation	Would you recommend this workshop to a friend?	Yes or No

2-2-2- Follow-Up Survey

The follow-up survey was designed to 1) measure the perceived value of the course in terms of increasing creative and collaboration confidence of the students and 2) measure how much students have applied the acquired knowledge to their PhD. The survey is divided into three parts. The first part is focused on creative confidence and contains a set of questions adapted from the creative self-efficacy survey designed by Tierney & Farmer (2002) [55]. We changed the phrasing of the questions to measure the increase in creative confidence perceived by the students following the workshop. The second part focuses on collaboration capabilities and includes a set of questions adapted from the survey designed by Orchard et al. (2012) [56]. Similarly to the previous case, the questions were adapted to measure the increase in collaboration skills perceived by the students following the workshop (Table 3). A five-point Likert scale was used, and participants were asked to rank from 1 (strongly disagree) to 5 (strongly agree) 29 different questions.

Table 3. Student Follow-up Impact Survey

Dimensions	Items	Scale
Control	Engagement: • I was able to understand the contents of the workshop clearly • I was satisfied with the learning experience of this workshop • The workshop met my expectations • The Design Thinking project was related to my field of work	
Creative Confidence	• It helped me to become more confident in expressing my ideas • It increased my confidence in the fact that I can deal with problems requiring creative thinking • It made me more confident that I could deal with unexpected events • It increased my confidence in the fact that I am good at proposing "out of the box" solutions • It made me consider myself more innovative • It made me think more of myself as a creative person • It increased my ability to solve problems efficiently, even complicated problems • It increased my confidence in the fact that, when I am confronted with a problem, I can usually find several solutions • It made me think more that my ideas are outstanding compared to my friends/colleagues • It proved that many times I can find at least one solution for any difficult situation • It made me feel more self-confident working on a problem even when others are present • It increased my trust in my creative abilities • It contributed to a positive self-image • It increased my confidence in the fact that I can develop creative ideas for almost any problem	Likert: From 1 (strongly disagree) to 5 (strongly agree
Collaboration skills	• It improved my ability to communicate my ideas • It improved my ability to listen to others • It made me more open-minded • It improved my ability to empathise with other group members • It made me appreciate others' beliefs and responsibilities more • It improved my ability to adjust my behaviour to the group's norms and rules • It improved my ability to resolve conflicts among group members	
Impact on professional life	• After this workshop, I reframed the importance of creativity in my professional activities • After this workshop, I reframed the importance of collaboration in my professional activities	
	• In the course of your PhD, how important were the learnings you took from this workshop? • For your job(s) after your Phd, how important were the learnings you took from this workshop?	Likert: From 1 (not at all important) to 5 (very important)

2-2-3- In-Depth Interviews

Finally, the in-depth interviews allowed us to substantiate how the students applied their new skills within their work. The third part focused on the impact of the acquired knowledge on the students' professional lives. The students were asked if the workshop made them rethink the importance of creativity and collaboration in their work. Upon finishing

the survey, they could volunteer for a 30-to-40-minute interview. The script (Table 4) was designed following best practices for designing in-depth interviews [4]: the questions are open-ended, inviting the student to explore his/her own thoughts and perceptions, in an unbiased way. A few warm-up questions were included at the start of the interview to build rapport with the interviewee and understand their background. The interview followed a flexible, semi-structured format: while the conversation was guided by the key questions contained in the script, the interviewer should ask additional questions to clarify his/her understanding, resolve conflicting responses and explore interesting topics that arise.

Table 4. Student in-depth interview script

Category	Questions
Warm-up	• What is the topic of study of your PhD? • What is your current job? • Why did you decide to enrol in the Design Thinking workshop at the Doctoral school? • What were your expectations? • What did you think of the workshop?
Learnings	• What surprised you more in the workshop? • Was there any moment when you felt out of your comfort zone? • In the survey you responded X for how important the learnings were to your PhD/job. Why did you choose this score? • Can you mention an example of how these learnings impacted your work? • After this workshop, what did you do differently than before?
Creativity	• How did the workshop make you feel about your creative skills? • In the survey you responded X for how you reframed the importance of creativity in your PhD/job. Can you please elaborate? • Can you mention an example?
Collaboration	• How did the workshop make you feel about your collaborative skills? • In the survey you responded X for how you reframed the importance of collaboration in your PhD/job. Can you please elaborate? • Can you mention an example?
Closing	• Any other relevant information that was not covered during our interview?

3- Results and Discussion

In this section we present the results from the three instruments used to collect data - quality control surveys, follow up survey and interviews – and establish a relationship between them.

3-1- Quality Control Surveys

The quality control survey was handed out at the end of every edition of the workshop since it started in 2014, with exception of one of the editions due to technical problems. A total of 23 surveys were collected from the 24 editions, with a total of 415 respondents. The number of respondents per edition varies between 8 and 24. The results presented in Table 5 show consistent values across all the course editions. The satisfaction with general aspects of the course and with the teaching staff was, respectively, 5,3/6,0 and 5,8/6,0. The perceived value of the workshop for the students' personal and professional lives both average 5,5/6,0 with 99% of students answering positively to the question (i.e., with a score of 4/6 or higher). We can therefore conclude that, right after finishing the workshop, most students agree that the acquired skills will be useful for their professional and personal lives.

Table 5. Average scores from the 23 quality control surveys (from 2014 to 2021)

Category	Average	Minimum	Maximum
Satisfaction: General Aspects of the Course	5,3/6,0	4,8/6,0	5,7/6,0
Satisfaction with Teaching staff	5,8/6,0	5,3/6,0	6,0/6,0
Perceived value (personal)	5,5/6,0 (99% ≥ 4,0)	4,6/6,0	5,8/6,0
Perceived value (professional)	5,5/6,0 (99% ≥ 4,0)	5,2/6,0	5,9/6,0
% of students that would recommend the workshop to a friend	98%	92%	100%

3-2- Follow-Up Survey

The follow-up survey was handed out to all participants of the 24 editions of the workshop. A total of 41 responses was received from a diverse group of students. The characterisation of the sample is detailed in Figure 3.
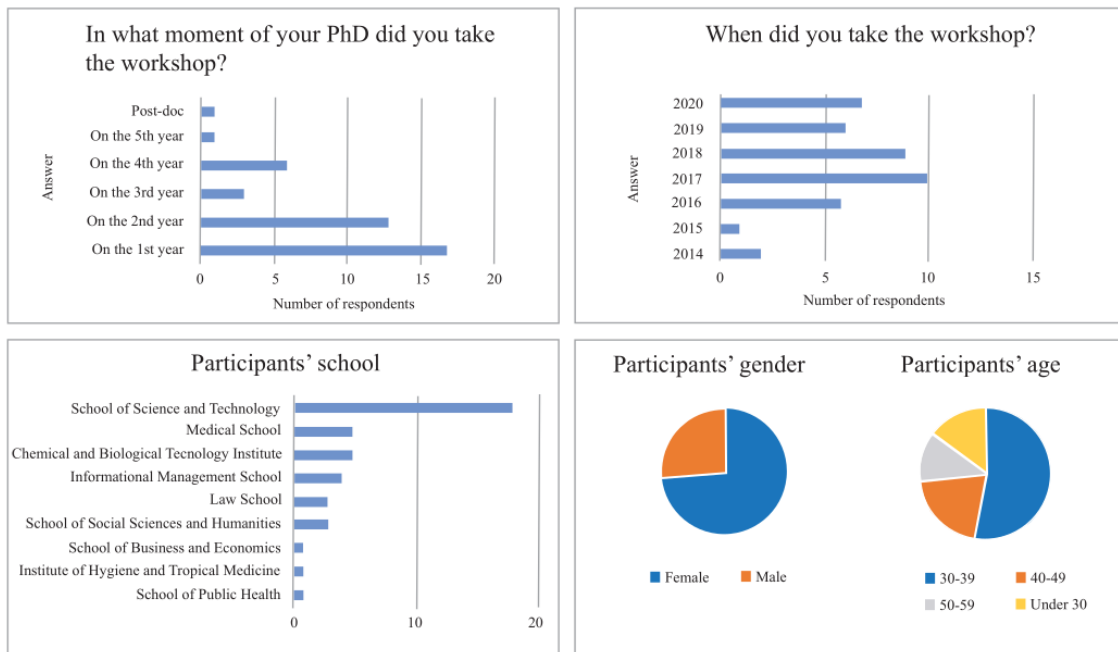
Figure 3. Sample characterisation of the 41 respondents of the follow-up survey

The students' engagement was measured to assess any influence on the remaining variables. As can be observed in Figure 4, the respondents consistently reported a high engagement. Students also reported a positive impact of the workshop on their creative confidence. While the scores vary, 90% of the respondents had a positive score on the Likert scale (over 3,0 points out of 5,0). Figure 4 shows the distribution of the creative confidence scores. Besides increasing the students' creative confidence, the workshop made most students reframe the importance of creativity in their professional activities, with 76% of respondents scoring 4 and 5 out of 5. The score distribution is detailed in Figure 4.

Figure 4. Main results from the 41 respondents of the follow-up survey

The results for collaboration show a similar pattern. 88% of the students report an increase in collaboration skills on some level following the workshop, as can be observed in Figure 5. 78% of students say they reframed the importance of collaboration in their professional activities. The workshop also made most students reframe the importance of collaboration in their professional activities, with 78% of respondents scoring 4 and 5 out of 5, as shown in Figure 4.
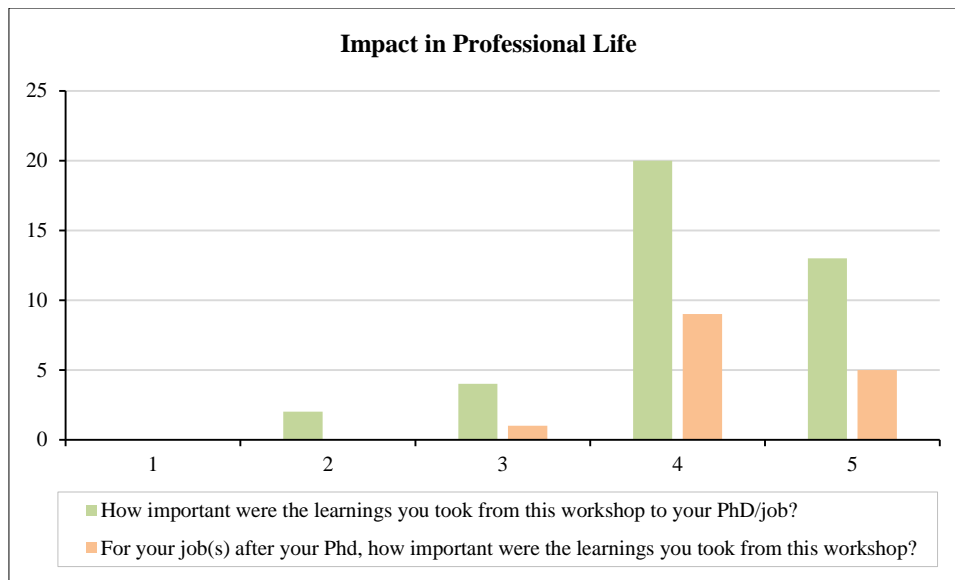
Figure 5. Impact in Professional Life score distribution

When asked about the importance of the learnings taken from the workshop on their PhD, most students reported positive impacts, with 83% of respondents scoring 4 or 5 out of 5. 96% of the 15 respondents that had a job after finishing their PhD also reported that the learnings from the workshop were important to their job. These results are illustrated in Figure 5.

We also asked students how the Design Project developed in the workshop was related to their field of study in order to determine if it had influenced other variables. Since the groups are made to be as heterogeneous as possible, it is common for some students to end up working on a topic that is outside of their comfort zone. The results show no correlation between familiarity with the topic of the project and the workshop's impact on students' personal and professional growth, as described in Table 6.

Table 6. Correlation values between how well the project related with the students' field of work and the other variables

	Increase in Creativity	-0.07
Correlation of "The Design Thinking project was related to my field of work" with	Reframed the importance of creativity	-0.02
	Collaboration	-0.05
	Reframed the importance of collaboration	-0.17

Overall, we can conclude that students still perceive the learnings taken from the workshop as valuable for their professional lives afterwards. This feeling is independent of time (present in students who did the workshop from 2014 to 2020) and familiarity with the topic of the Design Thinking project. Students who worked on projects outside of their comfort zone were just as able to acquire and transfer their new skills to their professional realities.

3-3- In-Depth Interviews

Of the 41 respondents, 12 volunteered for an in-depth interview. The results show that, independently of how they answered the question "How important were the learnings you took from this workshop to your PhD/job?", some participants could not specify how they had applied the learnings from the workshop.

Based on the examples provided by the participants, we have categorised their approach towards transferring the new knowledge and skills into three types:

1- **Type A:** intangible (feel the workshop was valuable for their professional and/or personal growth, but cannot materialise how the learnings were applied or how they are planning on applying them in the future);

2- **Type B:** indirect (reframed importance of creativity and collaboration in their work and became more confident to explore new possibilities);

3- **Type C:** direct (looked for ways to directly apply the Design Thinking mindset, process and/or specific tools to their work).

Students with the type A approach have confirmed that the course was interesting and that it somehow impacted their professional lives (as described by the results in Table 7). However, when asked to give a concrete example, they could not think of one specifically. Instead, they responded in vague/general terms. Some students mentioned that the course

allowed them to better structure their thinking, to be more open-minded or to become more confident. Some students say they still have not had the opportunity to apply the new learnings but believe they may be important at some point during their PhD.

Table 7. Examples provided by participants with type A approach to knowledge transfer (intangible: feel the workshop was valuable for their professional and/or personal growth, but cannot materialise how the learnings were applied or are planning on applying them in the future).

Field of work	How important were the learnings you took from this workshop to your PhD/job?	Example of how the workshop impacted your work
PhD in Architecture (reused plastic modules for construction)	PhD: Very important (5/5)	"During my PhD, the workshop helped me structure my thinking from problem to solution."
PhD in Biomedical Enginering	PhD: Very important (5/5)	"The mindset is useful for generating ideas, but I have not been able to directly use it in my day-to-day work yet."
PhD in Environment and Sustainability (people's perception of trash)	PhD: Important (4/5)	"It confirmed something that I already saw as important: the importance of considering as many different perspectives as possible. I have not been able to apply the tools to my work yet because at this stage I am mostly working alone."
PhD in Neuroscience	PhD: Important (4/5)	"The workshop made me more confident as a person and a scientist. I do not recall what we learned specifically about Design Thinking, but the feeling of confidence stuck with me."
PhD in Environment and Sustainability (food contaminants)	PhD: Very important (5/5)	"It helped me structure and organise my work."
PhD in Biomedic Engineering	PhD: Very important (5/5) Job: Important (4/5)	"The most surprising things I learned at the workshop were how to brainstorm (by not judging other people's ideas) and how to be objective about observations (without biasing the data with our own assumptions). I try to use that way of thinking in my work."
PhD in Neuroscience	PhD: Undecided (3/5) Job: Important (4/5)	"I feel that learning about Design Thinking has made me more open-minded and it has made me more capable of accepting my mistakes as part of the process. But while the skills I learned are interesting, it is difficult to use them in my everyday work, because old habits quickly kick in."

The students with the type B approach have not specifically used the Design Thinking process or any of the tools introduced during the workshop. Instead, by reframing the importance of creativity and collaboration in their work, together with an increased creative and collaborative confidence, students were able to approach work in a different way (as described by the results in Table 8). Students mentioned that the workshop increased their confidence and inspired them to think beyond what they labelled as "normal" in their fields. They have redesigned some aspects of their PhD work, such as the research methodology or the stakeholders involved. One student was inspired by the potential of innovative thinking and eventually created a podcast to talk about scientific work in an appealing way for non-scientists.

Table 8. Examples provided by participants with type B approach to knowledge transfer (indirect: reframed importance of creativity and collaboration in their work and became more confident to explore new possibilities)

Field of work	How important were the learnings you took from this workshop to your PhD/job?	Example of how the workshop impacted your work
PhD in Environment and Sustainability (satellite imaging for fire prevention)	PhD: Important (4/5)	"I started involving people from other areas in my PhD. For instance, I wanted to learn from civil engineers and chemical engineers, both of whom usually have different views about sustainability than environmental engineers."
PhD in Public Health (evaluation of the impact of social prescription initiative)	PhD: Very important (5/5)	"I realised I could think outside of the box. I changed the research design from a traditional survey and interview approach to a broader, more explorative, 12 month longitudinal study, where we will keep in touch with participants. I will also gather secondary data from the initiative partners and test other ways of gathering data (e.g. interviews, focus groups)." "I was programmed to think that people work in silos. The workshop made me think about how other areas link my object of study. For instance, I looked into the economic impact of the initiative, as well as the impact of technology."
PhD in Neuroscience	PhD: Undecided (3/5)	"I did not directly use the learnings from the workshop in my work directly. However, an important part of being a scientist is to communicate our findings to society in a way that is clear and interesting people. When trying to think of a human-centered way to do this, I created my podcast, where I interview other scientists and learn about their work and impact on society."
PhD in Geology (decision-making process in inactive mine rehabilitation)	PhD: Very important (5/5)	"I tried a "fail fast" approach in my research. The workshop taught me to diverge and explore topics that might not seem related. For instance, that is how I started investigating the application of blockchain in my field (it allows to register the supply chain in order to control the source of the product) as well as land management."

Finally, the third type of approach, type C, is characterised by students directly applying the Design Thinking process or some of the tools learned throughout the workshop to their work (table 9). Two participants whose work involves moderating co-creation workshops with different stakeholders have directly applied the knowledge to enrich their process. A student of International Law used the inspiration from the workshop to redesign her PhD research methodology (similar to the type-B approach). However, she decided to go further in exploring the potential application of Design Thinking to her field – and found Law Design, where she started collaborating in different projects. Another student, a Medical Doctor who is a department coordinator, changed how his team works by applying the Design Thinking mindset and its set of tools. For instance, they applied rapid prototyping to test and improve ideas proposed at the clinic, such as a new tablet application to show the inpatient's health sheet and a new process for patient screening. In the latter case, they built a paper prototype and showed it to doctors and nurses, collecting feedback and improving the interface. In the former case, they prototyped the process by simulating it with the staff team. Once the prototype seemed solid enough, it was immediately applied in the field. He mentioned that "previously we always tried to perfect this type of process «on the paper», then we would train the staff and then apply it in the field. We would only make changes afterwards if things went poorly. Now, we are much more flexible: we start with the initial version that we know is not perfect and we improve it based on our real experience." The team also started incorporating ethnographic research into their new projects. For example, when they wanted to improve the clinic's digital channels, they interviewed all the people involved in communicating with customers (through e-mail, phone or in person) to understand their difficulties with the current process and their ideas for improvement.

Table 9. Examples provided by participants with type C approach to knowledge transfer (direct: looked for ways to directly apply the Design Thinking mindset, process and/or specific tools to their work)

Field of work	How important were the learnings you took from this workshop to your PhD/job?	Example of how the workshop impacted your work
Self-employed (consultancy)	PhD: Important (4/5) Job: Very important (5/5)	"My job involves designing co-creation workshops with different stakeholders (e.g., municipal sustainability strategy involing public and private stakeholders, how to increase packaging reuse). Design Thinking was an additional tool I learned that applies to this job."
PhD in Education (financial education for teachers)	PhD: Very important (5/5)	"I moderate workshops with teachers, where I apply Design Thinking tools and methods to help teachers understand their students and design and create innovative tools to teach financial education (e.g. exercises, games). I also started to include teachers from areas other than mathematics, to get different perspectives."
PhD in International Law	PhD: Very important (5/5)	"Learning about Design Thinking opened up a whole new world for me. I learned I could be creative in my field. I started including innovation in my work. I proposed a qualitative research method in my PhD, which is not the usual methodology we use in legal sciences. Beyond my PhD, I found out about Law Design, which uses Design Thinking to generate ideas to make the law serve the citizens better, and I am working on some projects in that area."
Medical Doctor	PhD: Important (4/5)	"It changed my way of thinking. I applied some tools to my job at the clinic with great results. For instance, I apply rapid prototyping to new ideas we want to test at the clinic (e.g., a new tablet application to show showing inpatient's health data and a new process for patient screening). We also use ethnographic research tools to better understand the problems we want to solve at the clinic (e.g., when we wanted to improve the clinic's digital channels, we interviewed all employees to learn how they currently interact with customers). This new approach allowed us to better justify investments in the clinic and to accellerate innovation."

4- Discussion

Our research aimed to study how learning Design Thinking can impact the professional lives of PhD students. More specifically, we measured the value of a two-day Design Thinking workshop taught at a Doctoral school in terms of general applicability and the development of two key capabilities related to Design Thinking: creative confidence and collaboration, and drawn key takeaways for transferable skills training development in doctoral schools (Table 10).

Evidence from our study and results show that most students (99%) perceive the workshop learnings as important or very important to their professional lives. The follow-up survey sent to all students who took the course since 2014 indicates that months or years later, most respondents (83%) still find the learnings valuable in their professional lives. Our in-depth interviews revealed three patterns for how students have applied the new knowledge and skills: intangible, indirect, and direct application of the Design Thinking mindset, process, and tools. These results are independent of how students quantified the importance of the learnings for their work. i.e., two students with the same response to the question "How important were the learnings you took from this workshop to your PhD/job?" might have applied their learnings very differently and with different levels of impact.

In terms of creative confidence and collaboration skills development, our results also indicate that most students have increased these skills (90% and 88%, respectively). Furthermore, the workshop helped most students reframe the importance of creativity and collaboration in their work (76% and 78%, respectively). The results from the interviews confirm this assertion: many students mentioned that their increased confidence allowed them to expand the boundaries of what was "normal" in their field and propose innovative changes.

Table 10. Overview of results and key takeaways

Research Question	Results	Key Takeaways
1. What is the perceived value of Design Thinking training for PhDs?	▪ Three patterns for how students have applied the new knowledge and skills: (a) intangible, (b) indirect and (c) direct application of Design Thinking mindset, process, and tools.	▪ Although brief, the workshop has the potential to have a deep impact on the professional lives of the students across all fields of knowledge, ages, and moment of the PhD.
2. How is Design Thinking related to PhD students' creative confidence and collaboration skills?	▪ The majority of students feel they have increased these skills (90% and 88%, respectively). ▪ The workshop helped most students reframe the importance of creativity and collaboration within their work (76% and 78%, respectively).	▪ Increased creative confidence allowed students to expand the boundaries of what was "normal" in their field of research and conceptualise innovative changes and collaborations.
3. What is the impact of Design Thinking training on the PhD student's professional life?	▪ Most students (99%) perceive the learnings as important or very important for their professional lives. ▪ Even months or years after finishing the workshop, most respondents (83%) still find the learnings valuable for their professional lives.	▪ Education leaders should integrate Design Thinking into doctoral training curriculum because it may foster innovation and creativity by taking an empathic, adaptable, and iterative approach to problem solving.

Our results show that a two-day intensive workshop has the potential to deeply impact the professional lives of students across all fields of knowledge, ages, and PhD stages. The fact that the workshop is practice-led and engaging is crucial to its success. We believe the impact would not be the same if the students had not experienced Design Thinking first-hand, dealing with doubts and overcoming their difficulties in a real-life professional project.

Our observations suggest that what each student takes from the workshop to his/her professional life is very personal. While engagement levels are consistently high in every edition of the workshop, the extent to which students apply the learnings is layered. We also observed that the field of work is not a barrier to applying the new learnings. In a PhD, which is mostly a solitary and analytical endeavour, and even in areas that may seem traditionally conservative, such as law, some students were able to transfer their knowledge and skills into innovation and new opportunities for collaboration. In some cases, when there was a limit to what they could change in their own workplace, students sought opportunities to innovate outside of their current work.

Effective skill development depends on opportunities to practice skills with support and guidance [58], thereby encouraging reflection and, ultimately, development. The Design Thinking workshop model presented in this paper proved to be a suitable method of accelerating skill acquisition and, in some cases, increasing employment opportunities.

5- Conclusions

Design thinking has been proposed as a promising method of teaching transferable skills in doctoral programmes. This study aims to contribute to the limited body of research on this topic by investigating how students reflect on their experience of participating in a two-day Design Thinking workshop. Indeed, the results are based on a case study involving 468 students enrolled in various PhD programmes over 23 editions from 2014 to 2021, making it a sizable case. According to the data, students found the course relevant and valuable for their future career paths. There were three significant findings. First, most students feel they have increased creative confidence and collaboration skills, hence, allowing them to broaden their perspectives in their fields of research and conceptualise innovative interdisciplinary collaboration opportunities. Secondly, despite its brief duration, the workshop has the potential to have a profound impact on the professional lives of students from all fields of knowledge, ages, and stages of their PhD. Nonetheless, different knowledge transfer perceptions were observed: raging from students who do not plan on applying these skills in the future; students who reframed the importance of creativity and collaboration in their work; and students who started to directly apply a Design Thinking mindset, process, and tools. Lastly, even months after finishing the workshop, most respondents still find the learnings valuable in their professional lives. This long-term effect should persuade education leaders to incorporate Design Thinking into doctoral training curricula because it can foster innovation and creativity by taking an empathic, adaptable, and iterative approach to problem solving.

The findings shed new light on students' transferable skills training experiences and reflections related to their academic and professional paths. The paper contains useful information for both academics and practitioners. For academics, the paper expands their understanding of Design Thinking skills applied to the research skills context. This aspect adds to the Design Thinking literature and aligns with the call to make it more eligible as a theory, as well as the skills debate about how to make doctoral training more effective. For practitioners, integrating Design Thinking as a pedagogical tool for PhDs has proven useful both as a mindset and as an environment [59]. Promoting transdisciplinary research and experiential learning programmes that expose students to the value of various ways of knowing is being incorporated into an increasing number of doctoral programmes [22]. Given the growing emphasis on PhD employability, the paper highlights a Design Thinking approach that can assist in creating learning experiences based on

flexible spaces, teamwork enhancement, and the development of a deep understanding of the design process. A career in research can be complex, emotional, and intense, and students' self-perception of skills is associated with their career preferences both in and outside of the academic sector [21]. The rise of careers outside of academia is widely acknowledged in both academia and industry, but innovative PhD training is becoming increasingly important in a society facing complex challenges. This paper proposes a new way to interpret and manage transferable skills training by looking deeper into the under-researched area of Design Thinking in higher education.

Nevertheless, this research, similar to all others, has limitations. The findings of this study are generalisable to one university, but indicative of the same phenomena in similar types of universities, particularly research universities in Europe with a global perspective. Consequently, more research should be conducted, as well as more studies on the role of Design Thinking skills.

6- Declarations

6-1- Author Contributions

Conceptualisation, G.V. and R.H.; methodology, G.V.; validation, G.V., R.H., and P.C.; formal analysis, G.V.; investigation, G.V.; writing—original draft preparation, G.V.; writing—review and editing, R.H. and P.C.; supervision, R.H. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6-4- Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of NOVA Information Management School, ID OTHER-2022-9-257335.

6-5- Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

7- References

[1] Golde, C. M. (2005). The Role of the Department and Discipline in Doctoral Student Attrition: Lessons from Four Departments. The Journal of Higher Education, 76(6), 669–700. doi:10.1080/00221546.2005.11772304.

[2] Gould, J. (2015). How to build a better PhD. Nature, 528(7580), 22–25. doi:10.1038/528022a.

[3] Germain-Alamartine, E., & Moghadam-Saman, S. (2020). Aligning doctoral education with local industrial employers' needs: a comparative case study. European Planning Studies, 28(2), 234–254. doi:10.1080/09654313.2019.1637401.

[4] Santos, J. M., Horta, H., & Heitor, M. (2016). Too many PhDs? An invalid argument for countries developing their scientific and academic systems: The case of Portugal. Technological Forecasting and Social Change, 113, 352–362. doi:10.1016/j.techfore.2015.12.013.

[5] Cedefop, L. (2016). Future skill needs in Europe: Critical labour force trends. Cedefop research paper (59), Publications Office, Luxembourg.

[6] Durette, B., Fournier, M., & Lafon, M. (2016). The core competencies of PhDs. Studies in Higher Education, 41(8), 1355–1370. doi:10.1080/03075079.2014.968540.

[7] Nerad, M., & Evans, B. (2014). Globalization and Its Impacts on the Quality of PhD Education. Globalization and Its Impacts on the Quality of PhD Education, 5–30, Springer, Rotterdam, Netherlands. doi:10.1007/978-94-6209-569-4.

[8] Mantai, L., & Marrone, M. (2022). Identifying skills, qualifications, and attributes expected to do a PhD. Studies in Higher Education, 47(11), 2273–2286. doi:10.1080/03075079.2022.2061444.

[9] Lam, C. K. C., Hoang, C. H., Lau, R. W. K., Cahusac de Caux, B., Chen, Y., Tan, Q. Q., & Pretorius, L. (2019). Experiential learning in doctoral training programmes: fostering personal epistemology through collaboration. Studies in Continuing Education, 41(1), 111–128. doi:10.1080/0158037X.2018.1482863.

[10] Bridges, D. (1993). Transferable skills: A philosophical perspective. Studies in Higher Education, 18(1), 43–51. doi:10.1080/03075079312331382448.

[11] Nägele, C., Stalder, B.E. (2017). Competence and the Need for Transferable Skills. Competence-based Vocational and Professional Education. Technical and Vocational Education and Training: Issues, Concerns and Prospects, 23, Springer, Cham, Switzerland. doi:10.1007/978-3-319-41713-4_34.

[12] Baldwin, T. T., & Ford, J. K. (1988). Transfer of Training: a Review and Directions for Future Research. Personnel Psychology, 41(1), 63–105. doi:10.1111/j.1744-6570.1988.tb00632.x.

[13] Saks, A. M., & Burke-Smalley, L. A. (2014). Is transfer of training related to firm performance? International Journal of Training and Development, 18(2), 104–115. doi:10.1111/ijtd.12029.

[14] Hasgall, A., & Peneoasu, A. M. (2022). Doctoral education in Europe: current developments and trends. European UniversityAssociation, Geneva, Switzerland.

[15] Marques, J., & Rosado-Pinto, P. (2017). Doctoral Education: More a Tool than a Passport. Medicina Interna, 24(3), 178–182.

[16] Escudeiro, N., Escudeiro, P., Barata, A., & Lobo, C. (2011). Enhancing students team work and communication skills in international settings. 2011 International Conference on Information Technology Based Higher Education and Training. doi:10.1109/ithet.2011.6018683.

[17] Wrigley, C., & Straker, K. (2017). Design Thinking pedagogy: the Educational Design Ladder. Innovations in Education and Teaching International, 54(4), 374–385. doi:10.1080/14703297.2015.1108214.

[18] Panke, S. (2019). Design Thinking in Education: Perspectives, Opportunities and Challenges. Open Education Studies, 1(1), 281–306. doi:10.1515/edu-2019-0022.

[19] Plano Clark, V. L., Anderson, N., Wertz, J. A., Zhou, Y., Schumacher, K., & Miaskowski, C. (2015). Conceptualizing Longitudinal Mixed Methods Designs: A Methodological Review of Health Sciences Research. Journal of Mixed Methods Research, 9(4), 297–319. doi:10.1177/1558689814543563.

[20] Mowbray, S., & Halse, C. (2010). The purpose of the PhD: Theorising the skills acquired by students. Higher Education Research and Development, 29(6), 653–664. doi:10.1080/07294360.2010.487199.

[21] Horta, H. (2018). PhD students' self-perception of skills and career plans while in doctoral programs: are they associated? Asia Pacific Education Review, 19(2), 211–228. doi:10.1007/s12564-018-9532-y.

[22] Lazurko, A., Alamenciak, T., Hill, L. S., Muhl, E.-K., Osei, A. K., Pomezanski, D., Schang, K., & Sharmin, D. F. (2020). What Will a PhD Look Like in the Future? Perspectives on Emerging Trends in Sustainability Doctoral Programs in a Time of Disruption. World Futures Review, 12(4), 369–384. doi:10.1177/1946756720976710.

[23] Kolko, J. (2015). Design thinking comes of age. Harvard Business Review, Vol 2015, Issue September. Available online: https://cdn.fedweb.org/fed-42/2892/design_thinking_comes_of_age.pdf (accessed on June 2022).

[24] Dell'Era, C., Magistretti, S., Cautela, C., Verganti, R., & Zurlo, F. (2020). Four kinds of design thinking: From ideating to making, engaging, and criticizing. Creativity and Innovation Management, 29(2), 324–344. doi:10.1111/caim.12353.

[25] Brown, T., & Katz, B. (2011). Change by Design. Journal of Product Innovation Management, 28(3), 381–383. doi:10.1111/j.1540-5885.2011.00806.x.

[26] Cooper, R., Junginger, S., & Lockwood, T. (2009). Design Thinking and Design Management: A Research and Practice Perspective. Design Management Review, 20(2), 46–55. doi:10.1111/j.1948-7169.2009.00007.x.

[27] Magistretti, S., Ardito, L., & Messeni Petruzzelli, A. (2021). Framing the microfoundations of design thinking as a dynamic capability for innovation: Reconciling theory and practice. Journal of Product Innovation Management, 38(6), 645–667. doi:10.1111/jpim.12586.

[28] Matthews, J., & Wrigley, C. (2017). Design and Design Thinking in Business and Management Higher Education. Journal of Learning Design, 10(1), 41. doi:10.5204/jld.v9i3.294.

[29] Koh, J.H.L., Chai, C.S., Wong, B., Hong, HY. (2015). Design Thinking and 21st Century Skills. In: Design Thinking for Education. Springer, Singapore. doi:10.1007/978-981-287-444-3_3.

[30] Lor, R. (2017). Design thinking in education: A critical review of literature. Asian Conference on Education and Psychology, 24-26 May, 2017, Bangkok, Thailand.

[31] Brown, T. (2008). Design thinking. Harvard Business Review, June 2008, 1-11.

[32] Klenner, N. F., Gemser, G., & Karpen, I. O. (2022). Entrepreneurial ways of designing and designerly ways of entrepreneuring: Exploring the relationship between design thinking and effectuation theory. Journal of Product Innovation Management, 39(1), 66–94. doi:10.1111/jpim.12587.

[33] Dorland, A. (2022). That's a Good Question. Journal of Effective Teaching in Higher Education, 5(1), 30–52. doi:10.36021/jethe.v5i1.115.

[34] Tham, J. C. K. (2021). Design thinking in technical communication: Solving problems through making and collaboration. Routledge, New York, United States. doi:10.4324/9781003036760.

[35] Restructuring Science Education: The Importance of Theories and Their Development Richard Duschl. (1991). The American Biology Teacher, 53(6), 383–383. doi:10.2307/4449337.

[36] Razzouk, R., & Shute, V. (2012). What Is Design Thinking and Why Is It Important? Review of Educational Research, 82(3), 330–348. doi:10.3102/0034654312457429.

[37] Luka, I. (2020). Design Thinking in Pedagogy. Journal of Education Culture and Society, 5(2), 63–74. doi:10.15503/jecs20142.63.74.

[38] Welsh, A. A., & Dehler, G. E. (2013). Combining Critical Reflection and Design Thinking to Develop Integrative Learners. Journal of Management Education, 37(6), 771–802. doi:10.1177/1052562912470107.

[39] Lynch, M., Kamovich, U., Longva, K. K., & Steinert, M. (2021). Combining technology and entrepreneurial education through design thinking: Students' reflections on the learning process. Technological Forecasting and Social Change, 164, 119689. doi:10.1016/j.techfore.2019.06.015.

[40] Pham, C. T. A., Magistretti, S., & Dell'Era, C. (2022). The role of design thinking in Big Data innovations. Innovation: Organization and Management, 24(2), 290–314. doi:10.1080/14479338.2021.1894942.

[41] Foster, M. K. (2021). Design Thinking: A Creative Approach to Problem Solving. Management Teaching Review, 6(2), 123–140. doi:10.1177/2379298119871468.

[42] Buchanan, R. (2017). Wicked Problems in Design Thinking. Design: Critical and Primary Sources, 8(2), 5–21,. doi:10.5040/9781474282932.0019.

[43] van Aaken, D., Splitter, V., & Seidl, D. (2013). Why do corporate actors engage in pro-social behaviour? A Bourdieusian perspective on corporate social responsibility. Organization, 20(3), 349–371. doi:10.1177/1350508413478312.

[44] Kelley, T., & Kelley, D. (2013). Creative confidence: Unleashing the creative potential within us all. Currency, Redfern, Sydney.

[45] Liedtka, J. (2015). Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction. Journal of Product Innovation Management, 32(6), 925–938. doi:10.1111/jpim.12163.

[46] Wood, D. F. (2003). ABC of learning and teaching in medicine: Problem based learning. BMJ, 326(7384), 328–330. doi:10.1136/bmj.326.7384.328.

[47] McGurk, J. (2010). Using the head and heart at work: A business case for soft skills. Chartered Institute of Personnel and Development (CIPD), London, United Kingdom.

[48] Edmondson, A. C., & Nembhard, I. M. (2009). Product development and learning in project teams: The challenges are the benefits. Journal of Product Innovation Management, 26(2), 123–138. doi:10.1111/j.1540-5885.2009.00341.x.

[49] Patterson, C. A., Chang, C. N., Lavadia, C. N., Pardo, M. L., Fowler, D. A., & Butler-Purry, K. (2020). Transforming doctoral education: preparing multidimensional and adaptive scholars. Studies in Graduate and Postdoctoral Education, 11(1), 17–34. doi:10.1108/SGPE-03-2019-0029.

[50] Chamorro-Premuzic, T., Arteche, A., Bremner, A. J., Greven, C., & Furnham, A. (2010). Soft skills in higher education: Importance and improvement ratings as a function of individual differences and academic performance. Educational Psychology, 30(2), 221–241. doi:10.1080/01443410903560278.

[51] Gibb, S. (2014). Soft skills assessment: theory development and the research agenda. International Journal of Lifelong Education, 33(4), 455–471. doi:10.1080/02601370.2013.867546.

[52] Tashakkori, A., & Teddlie, C. (2015). SAGE Handbook of Mixed Methods in Social & Behavioral Research. SAGE, Thousands oaks, United States. doi:10.4135/9781506335193.

[53] Strachota, E. (2006). The use of survey research to measure student satisfaction in online courses. Midwest Research to Practice Conference in Adult Continuing and Community Education, October (2006), University of Missouri-St. Louis, St. Louis, United States.

[54] Joshi, A., Kale, S., Chandel, S., & Pal, D. (2015). Likert Scale: Explored and Explained. British Journal of Applied Science & Technology, 7(4), 396–403. doi:10.9734/bjast/2015/14975.

[55] Tierney, P., & Farmer, S. M. (2002). Creative self-efficacy: Its potential antecedents and relationship to creative performance. Academy of Management Journal, 45(6), 1137–1148. doi:10.2307/3069429.

[56] Orchard, C. A., King, G. A., Khalili, H., & Bezzina, M. B. (2012). Assessment of Interprofessional Team Collaboration Scale (AITCS): Development and testing of the instrument. Journal of Continuing Education in the Health Professions, 32(1), 58–67. doi:10.1002/chp.21123.

[57] Guion, L.A., Diehl, D.C., & McDonald, D. (2011). Conducting an In-depth Interview: FCS6012/FY393, Rev. 8/2011. Edis, 1-3, University of Florida, Florida, United States.

[58] Drummond, I., Nixon, I., & Wiltshire, J. (1998). Personal transferable skills in higher education: The problems of implementing good practice. Quality Assurance in Education, 6(1), 19–27. doi:10.1108/09684889810200359.

[59] Scheer, A., Noweski, C., & Meinel, C. (2012). Transforming constructivist learning into action: Design thinking in education. Design and Technology Education: An International Journal, 17(3), 8-19.