DESIGN THINKING AS AN INNOVATIVE PEDAGOGICAL TOOL

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ABSTRACT

The transformation of educational systems requires pedagogical approaches that move beyond the conventional format of learning by transmission of content. It is pressing to address the challenges deriving from the changing landscape of the workplace. Diverse, hybrid, technologically enhanced, focused on 21st century skills, and an advocate of innovation, the contemporary workplace requires a labour force that is prepared for these demands. Design thinking has been implemented in educational settings with significant success in the development and practice of creativity, problem-solving, critical thinking, resilience and other important transferable competences. This paper aims to explore the role of design thinking as an innovative pedagogical approach, by reporting on a study with undergraduate students that were asked to use design thinking on an innovation-based project. The students completed a pre-session and project questionnaire and a post-session and project questionnaire to assess their experience, having reported important progress and significant learning benefits from the incorporation of design thinking. Design thinking imported structure and method into the problem-solving process and endowed it with empathy, allowing the students to have a better understanding of the human perspective of the problem.

KEYWORDS

Design thinking, innovation, pedagogical tool, higher education.

1. INTRODUCTION

The educational system seems to remain insufficiently committed to the development of key competences such as creativity and innovation and still harbours a vision where error is a stigma. The promotion of innovation and entrepreneurship requires individuals to work past the impediment of failure and learn from it to be successful (Rhaiem & Amara, 2021). The adaptation to new and digitalised settings requires learners to develop a creative, collaborative and experimental mindset where the novel problems that arise from these transformations can be addressed (Androutsos & Brinia, 2019). The search for innovative pedagogical approaches has led many educators to think outside the box and implement methodologies not intrinsically connected to education, such as design thinking (Razzouk & Shute, 2012). Design thinking, in the words of Brown (2008), is a "discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (p.2). Previous studies have reported the successful implementation of design thinking in different subjects and courses, such as economics and business (Androutsos & Brinia, 2019), medicine (Thakur et al., 2021) and engineering (Jiang & Pang, 2023). This paper frames design thinking within two theories: experiential learning theory (Kolb, 1984) and IDEO/Stanford d.school's design thinking approach (Brown, 2008) as 21st century skills gain an increasing importance in the professional landscape, educational institutions seek novel pedagogical approaches to guide their students in the development of these skills. Design thinking has raised the interest of educators for its capacity to assist learners in the acquisition and practice of 21st century skills (Romero Caballero et al., 2025; Luka, 2019).

This paper aims to report the findings of two online questionnaires that were distributed among higher education students that were enrolled in a bioinformatics course, before and after their participation in a design thinking session and an innovation-based project. More specifically, this paper aims to examine the following research questions: a) How did design thinking contribute to the students' decision-making process; b) What design thinking's aspects/tools did the students incorporate in their project?; and c) How do students perceive the contribution of design thinking in various domains and in their academic/professional lives. It begins by reflecting on the incorporation of design thinking in educational setting and its role as a pedagogical strategy. The methodology will follow with the description of the data collection and analysis and the results will present the findings of the two questionnaires.

2. DESIGN THINKING AS A PEDAGOGICAL TOOL

Kolb (1984) justifies his theory's denomination of experiential as the result of its conceptual background derived from Dewey, Lewin and Piaget, and because this term highlights the centrality of experience in learning. Experiential learning gives prevalence to the process rather than the result. Knowledge is mutable and it is shaped by experience. Hence it is created through the personal experiences of the individual. According to the author, in an effective learning process, individuals should ideally have four core skills: concrete experience, which refers to the ability to engage fully and unbiasedly in novel experiences; reflective observation, with which one is able to regard and reflect on their own experiences from different viewpoints; abstract conceptualisation, which allows for the creation of concepts that construct robust theories derived from their observations; and active experimentation, with which individuals can apply these theories in decision making and problem solving (Kolb, 1984). Experiential learning and these competences can be articulated within design thinking's phases in problem solving. Hence, concrete experience is related to empathy, reflective observation is aligned with the definition phase, abstract conceptualisation with ideate, and active experimentation with prototyping and testing. With respect to IDEO their design thinking framework entails seven unique mindsets that distinguish design thinkers: "empathy, optimism, iteration, creative confidence, making, embracing ambiguity, and learning from failure" (Brown, 2008, p. 10)

Several studies, originated by different entities have underlined the importance of promoting the development of skills that are becoming increasingly important in the labour market, such as flexibility in the face of change, teamwork, digital literacy, communication and problem solving. Competences like critical and creative thinking, innovation and initiative are essential and their development requires a different approach to teaching (Luka, 2019). Design thinking is a valuable resource for educational practice, because it promotes students' engagement with a more proactive method of problem solving, where they can, via experimentation and collaboration, become responsible for the solution creation process. Through design thinking, learners can identify real-world problems and propose a solution (Androutsos & Brinia, 2019). Design thinking has been the focus of a rising interest to academics as a methodology to address innovation and problem solving (Mayer & Schwemmle, 2025).

3. DESIGN THINKING, CREATIVE SENSEMAKING AND DIGITAL TECHNOLOGY

Design thinking can be used as an innovative method to develop students' creativity with concern to problem solving (Foster, 2021). There are many techniques that can be deployed with the use of technology to support design thinking. In the digital era, design thinking, can benefit from the use of technology. The design thinking process can be supported by the use of technology, in all its phases (Androutsos & Brinia, 2019). Tools such as Miro, a digital whiteboard (Skywark et al., 2022) can assist students to digitally collaborate with their peers.

Design thinking can assist in the creative resolution of problems, by deploying a user-centred method that uses ideation as well as a cyclic process of prototyping. Design thinking has somewhat evolved at the margin of other innovation management methodologies and, as a consequence, some still associate it with the general practice of design and are uncertain as to its contribution to innovation (Verganti et al., 2021). Questions as to design thinking's capacity to remain a valuable methodology to address the changing landscape of business, marked deeply by the use of technology, rise with the increased digitalisation of the various areas of society.

Recent studies have demonstrated that design thinking is a valuable approach to harness the opportunities provided by technological development. It can be an important resource as it is focused on the users and it can provide a unique perspective about their needs and how technology can best serve them, envisioning useful solutions to respond to their, particular, technological demands (Magistretti et al., 2021).

Design thinking can equally be interpreted as sensemaking, which places imagination as well as improvisation at the centre of its methodology, and as the foundation of its activities (Rylander Eklund et al., 2022). In a study by Matthee & Turpin (2019), undergraduate students are asked to triage problems into three groups (puzzles, problems and messes) and find suitable problem-solving methodologies. Also, in an assignment they are expected to apply to five stages of design thinking according to Stanford d.school design thinking method. Albay & Eisma (2021) study reports on the use of design thinking in the context of a performance task. The experiment conducted by the authors involved a control group using demonstration instruction and an experimental group using design thinking. Their conclusions were clear about the benefits of design thinking, with the experimental group significantly outperforming the other group, and demonstrated that design thinking can be used in education to increase creativity, interaction and support more student-centred teaching. Additionally, Skywark et al. (2022) concluded that the deployment of design thinking methods can be used for the development of an interdisciplinary design thinking course, which ideally should subsume collaborative work competences, real-world relevance and reflection based on growth.

4. METHODOLOGY

The design thinking session took place in the last weeks of the second semester of the bioinformatics course and lasted 3 hours. The project that ensued was completed in three iteration cycles with the students submitting their work for comments and improvements in each cycle. The project consisted of developing an innovative solution for a hypothetical organisation, using design thinking methodologies. This research was based on two online questionnaires: one was distributed before the session and the project and the second was completed at the end of the project. They were distributed among undergraduate students enrolled in a bioinformatics course. The first questionnaire aimed to assess the students' familiarity with design thinking. Firstly, the students completed the demographic data section including age, gender and course. Secondly, they were asked to indicate their knowledge level with regards to design thinking and innovation, and if they had ever participated in a session or project about design thinking. Thirdly, the students rated their knowledge of several design thinking tools and methods, the frequency with which they have used them and in which context.

The second questionnaire assessed their knowledge level after the session and the project and their application of the tools and methods that they had learned. It was more specific in terms of the questions regarding design thinking to evaluate different aspects of what they've learned and applied in their project. It encompassed its tools and methods as well as its different phases and how they were used among the students' teams in the completion of the project. The data that was collected was imported into IBM SPSS statistics to be analysed using descriptive statistics.

5. RESULTS

Both questionnaires received 15 responses. The students' ages vary between 19 and 24, with most students being 20 or 21 years old. Most students are male (10) with only 5 female respondents. All the students were, at the time, enrolled in a bioinformatics course.

5.1 Pre-session questionnaire

In the pre-session questionnaire, the students were, firstly, asked about their knowledge of design thinking and innovation (Figure 1).

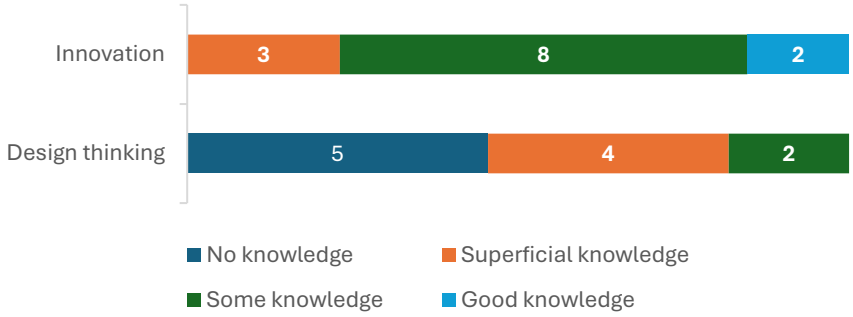

Figure 1. Student's initial knowledge about innovation and design thinking

The chart above shows an evident cleavage between the two subjects. Only 2 students stated that they had some knowledge of design thinking, while 4 had only superficial knowledge and 5 had no knowledge of it. Innovation, on the other hand, was a more familiar term. All the students had some level of knowledge about innovation. Eight had some knowledge, 3 had superficial knowledge and 2 claimed to have a good knowledge of innovation. Most students (9) had not yet participated in any session concerning design thinking, and 6 of them hadn't participated in a design thinking project either. In terms of projects, a total of 9 had not yet participated.

Design thinking can be applied with the support of a variety of tools and technologies. The students were asked to reflect about their knowledge and use of these tools. An expressive majority of the students had no knowledge or only superficial knowledge of the majority of the tools. Also, most students had never used any of the tools that were listed in the questionnaire (Figure 2).

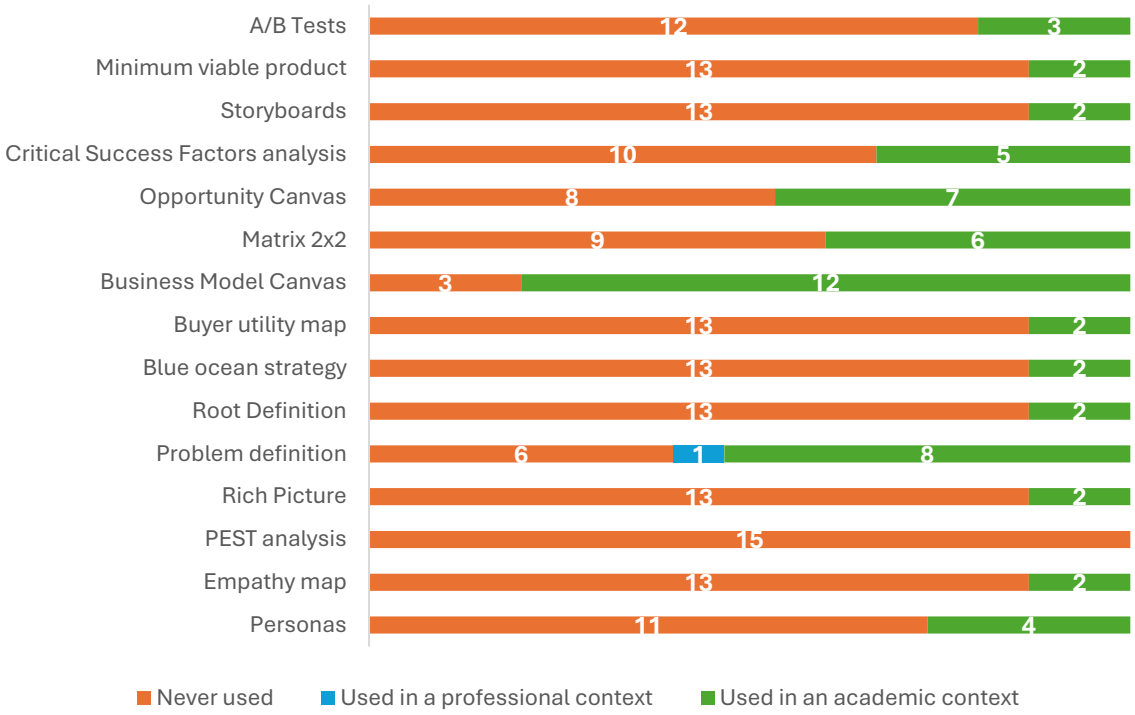

Figure 2. Students' use of design thinking tools and methods

The two mostly used tools were business model canvas, with 12 students reporting to have used it in an academic context, and problem definition, which 1 student had used in a professional context and 8 used in an academic context.

5.2 Post-session and project questionnaire

With concern to the second questionnaire, it was completed by the same students, after their participation in the session and the conclusion of the project. The students' responses to the first question, indicated that most of them had either a limited knowledge of design thinking or no knowledge. When asked if the project had improved their understanding of design thinking, 10 students answered that it had greatly improved and 4 that it had improved. They were then asked how they had used the different phases of design thinking during the completion of the project (Figure 3).

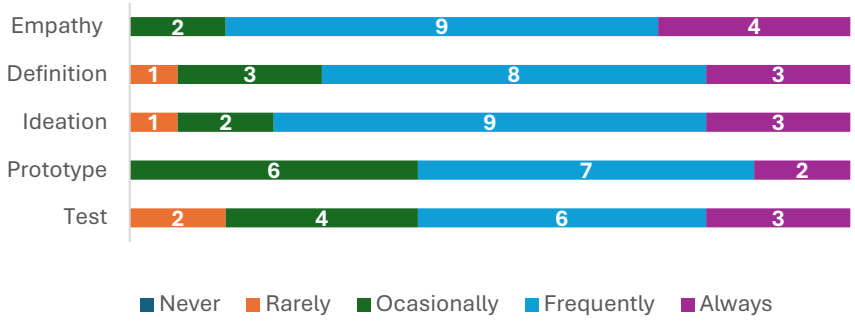

Figure 3. Frequency of use of the different phases of design thinking

As can be seen in the chart above most students used all of design thinking's phases during their project, with a particular emphasis on the empathy and prototype phases. Next, and to address the first research question (how did design thinking contribute to the students' decision-making process), it was important to understand just how these phases had concretely assisted their project, so the students were asked to identify a situation in which design thinking had supported their decision making. The students stated that it helped them to shift to an approach driven by the users' needs, to reveal hidden causes, to provide structure and direction to their work, to assist problem solving and idea management. With concern to the second research question (what design thinking's aspects/tools did the students incorporated in their project?), the questionnaire examined the different methods and techniques that can be used to support design thinking. The students indicated that they had used a wide variety (Figure 4).

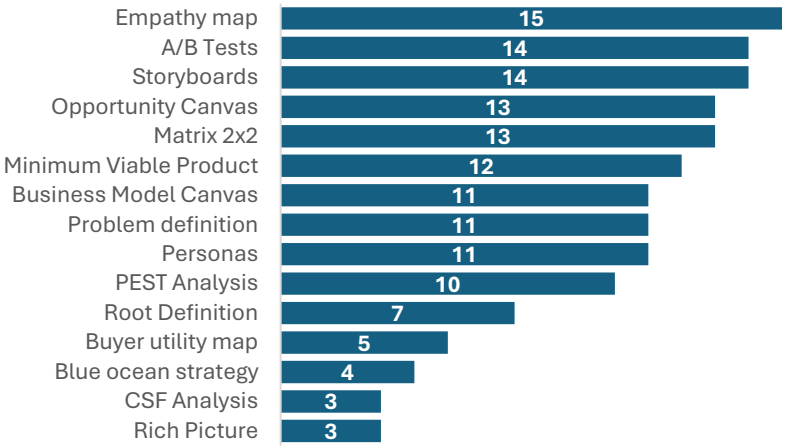

Figure 4. Use of different techniques and methods during the project

This chart represents an expressive improvement from the data collected in the first questionnaire (Figure 2). Empathy maps, A/B tests, storyboards, opportunity canvas and matrix 2X2 were the most popular techniques, while rich picture and CSF analysis were the least used.

In terms of the mentalities that were used more often among the students, focus on the people was by far the most used (11 students). The other options were fast action (1), radical collaboration (0), show don't tell

(0), experimentation (5), attention to the process (4), creative confidence (4) and dealing with ambiguity (0). Since problem solving is a fundamental part of innovation, the students were asked to explain their team's approach to problem solving. The majority, 11 students, claimed that the maintained the initial solution. The other approaches included refining once (1 student) and iteratively redefining (2). None of the students claimed to have experienced difficulties. Their justification for their responses mainly cited their initial definition as being appropriate to the problem at hand, throughout the project, regardless of the changes that occurred. As student 6 stated "although we studied the problem in depth, in the end, the definition remained the same, what changed was our perspective of the problem. We realised in the end that everything was centred on people". This was also the idea behind student 10's statement "We are able to adapt to the problems we faced and also come up with creative ideas over time".

When teams are working together on a project, different opinions can emerge. The students were asked to describe how they managed divergences or different views. The majority of the responses highlighted a strategy that avoided conflict (8 students), while the remaining students (6) said that they tried to reach consensus. Throughout the project the students reported having mixed emotions such as satisfaction, frustration, uncertainly and enthusiasm. Student 11's response seems to summarise the dominant view of the students: "enthusiasm, whenever the work was on track, and satisfaction when we realized that we were carrying out the work on a real problem and creating solutions that could help not only in the scenario hypothetically created for this project but also in real companies. There were also moments of uncertainty but more on the side of deciding the best tools to use at each stage, and also frustration because despite everything it was a very long and time-consuming work that required on our part a great deal of time management with the other tasks that we also had at the same time for other subjects". With regards to the different methods and techniques used, the students also highlighted them as being one of the causes for their moments of discovery (eureka moments) during the project, in the sense that their application improved their understanding of the problem. These discovery moments also occurred when they would find solutions to the problems that emerged.

The impact of design thinking in the perception of the process of problem solving was also evident. The students described design thinking as an important strategy to understand and solve problems in a more structured manner. Student 4 described the evolution of his/her perception "it showed that effective solutions do not arise only from logical or technical analysis, but that it also requires a deep understanding of the people involved. I used to think of the process as something more linear and focused on efficiency, now I recognize more the value of an iterative, empathetic, and collaborative approach.". Student 8 also stated that it "helped to understand the processes behind the solutions to various types of problems" and student 12 added that it assisted him/her "to analyse the situation, apply concepts to solve problems, and create ideas from scratch". When asked about design thinking contribution, most of the students (10) found design thinking to the useful in the context of machine learning and analytics projects. Also, 10 students stated that it complements analytical thinking because of the empathy it introduces in the process, the methodology and rigor it requires, the promotion of critical thinking, and the validation and optimisation of solutions.

With concern to the new concepts and perspectives that the students acquired, they identified mainly the knowledge related to the phases and tools associated with design thinking, the importance of empathy in the process of problem solving, and strategies for problem solving. The third research question (How do students perceive the contribution of design thinking in various domains and in their academic/professional lives?) looks forward into the prospective use of design thinking. Most students intend to use it, 3 said that they would definitely use it, 8 would probably use it and 3 didn't know. The versatility of design thinking also became evident when the students identified the areas/scenarios in which design thinking could be used (Figure 5).

Areas/scenarios for design thinking application	
New product development	Entrepreneurship and startups
Data visualisation	Marketing
Personalised digital health solutions	Artificial Intelligence
Health and wellness	Programming
Business	Technology
Biology	Business
Physics	Machine learning
Mathematics	

Figure 5. Areas/scenarios for design thinking application

The students also suggested some improvements to better integrate design thinking into the discipline:

- Introduce design thinking a little earlier
- Simplify the tools and templates
- Use micro projects
- Integrate practical challenges from the beginning of the semester
- Keeping the session that was held on design thinking
- More contact with design thinking
- More in-depth presentation of design thinking and tools
- Use real cases
- More hours of theory and practice
- Integration of a real project

The majority of students (10) believes that design thinking greatly contributes to the development of their academic/professional profile. Three of the students think it moderately contributes, and 1 student thinks it is essential. Their approach to interdisciplinary collaboration was also influenced by design thinking. As they've explained it, design thinking "…showed that interdisciplinary collaboration is essential to generate more complete solutions, as it combines technical, human and creative perspectives and that teamwork recognizes that different areas contribute with complementary knowledge to solve complex problems" (student 2). Also, "it allows the student to think and create ideas in other disciplines" (student 10).

The students were asked to reflect on what they would do differently in a next application/project integrating design thinking. Some highlighted the need to dedicate more time to the definition of the problem, and the empathy phase, others underlined the importance of a deeper analysis of the different techniques and methodologies to better adjust their use to the characteristics of the problems. One of the students reflected on the need to document the process. They were also asked to offer advice to future students who would apply design thinking to machine learning and analytics problems. Two contributions summarise the general perspective of the students: "start by understanding the real needs of users well before choosing algorithms and do not discard different suggestions for solutions just because you initially do not agree or do not think the best one" (student 1); and "first, that they define the problems in time and that they are relevant in order to help in the application of this methodology. A more or less well-founded general idea about how each works is also crucial" (student 7).

6. CONCLUSION

This paper intended to report on the use of design thinking by a group of undergraduate students, during an innovation-based project, to evaluate its role as an important pedagogical tool. The data collected in both questionnaires revealed a significant positive evolution on the students' knowledge about design thinking and their use of its related phases and techniques/methods. Before attending the session and completing their project they had very limited knowledge about design thinking. Afterwards they reported using design thinking to develop adequate solutions to existing problems and as a structured strategy to frame decision making and managing ideas. Their focus also shifted to a more empathetic approach to problems, by underlying the importance of considering the human perspective, the needs of the users and the underlying causes of the problems. The versatility of design thinking became evident not only in its different phases and the techniques that were used, but also in the students' stated perception that it would be suitable to use in a variety of areas, such as business, technology, health, marketing. According to the students, while it is a structured process it can be adapted to serve a panoply of fields. In future projects the students recommended introducing design thinking earlier in the semester, increasing their contact with practical challenges and real cases and a more in-depth presentation of design thinking and tools, which can also be an indication of their positive perception of design thinking as an important pedagogical tool.

The results of the post-session questionnaire align with Kolb's experiential learning (1984). Firstly, the students highlighted the importance of the empathy phase, which articulates with concrete experience. Secondly, their responses showed how they used reflective observation to redefine the problems, which in turn resulted into abstract conceptualization and the search for solutions. The findings also relate to IDEO's mindsets (Brown, 2008) in several aspects. The student's most frequently used mentality was "focus on the

people", which is connected to a core precept, empathy. Moreover, their adaptation to the problems revealed the use of iteration and embracing ambiguity. Their report of mixed emotions throughout the process can also be articulated with learning from failure. The reduced population used in the online questionnaires is one of the most relevant limitations of this study, which can be in the future, reproduced with a more numerically significant sample. Prospective research ventures can equally focus on the recommendations of the students and redesign this experience in other courses and with other learning activities.

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