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From Active Learning to Innovative Thinking: The Influence of Learning the Design Thinking Process among Students

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Abstract: Active learning is a set of activities that allow the student to actively participate in the learning process. Active learning can be implemented using various methods and strategies. design thinking is a creative human-centric approach used for innovation. In this article, the authors consider learning the design thinking process as a strategy for active learning. After performing a thorough literature review, the authors display the results of pilot research conducted with business economics graduate students enrolled in the Disruptive Innovations and Design Thinking elective course. The research consisted of a survey and an experiment, and it was executed as part of the project "a/AR-Learning: Active learning by applying augmented reality". The goal was to study the effects of learning the design thinking process and whether it could be used as an active learning method in order to influence the development of innovative thinking among students. The research question was, "How does learning the design thinking process affect the development of students' innovative way of thinking?" The results of the pilot study confirmed all three hypotheses (H1 = *After learning the design thinking process, students recognize the main characteristics of innovation*; H2 = *Active learning of the design thinking process affects critical assessment*; H3 = *The innovative way of thinking developed through active learning of the design thinking process differs among students*), as well as showing effectiveness and a change in critical assessment, but also the need for an even more active approach. The authors suggest that broader research be undertaken involving a bigger scale.

Keywords: active learning; innovation; innovative thinking; design thinking course; students

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1. Introduction

Bonwell and Eison defined strategies that promote active learning as "instructional activities involving students in doing thinks and thinking about what they are doing" [1]. Active learning allows students to "do something other than taking notes or following directions . . . they participate in activities" [2]. According to Letina, active learning aims to achieve a higher degree of independence among students and, by applying different thinking strategies, attempts to develop specific cognitive skills, thus "enabling (students) to notice the important, analyze and compare information, connect it with existing knowledge and critically assess their meaning" [3]. Various approaches and strategies have been considered over the years in regard to active learning, ranging from active class discussions to decision making based on case studies [1], as well as new approaches such as the application of augmented reality (AR) and virtual reality (VR) in higher education teaching [4].

This article studies the effects of active learning through learning the design thinking process. design thinking is a process used in solving "wicked problems" [5]: multidimensional, complex, open problems that require creative solutions based on collaborative methodologies and non-linear thinking. Design thinking is not the only approach for this type of problem, but it is the approach that was considered in this article. The design thinking process consists of five steps: defining the problem, need finding and synthesis, ideation, prototyping, and testing [6]. It is a non-linear iterating process, meaning that after

the testing phase, the process starts over by (re)defining the problem. Design thinking can also be described as a future-oriented innovation method based on examples [6]. According to an article from 2017, "design and design thinking have been identified as making valuable contributions to business and management", and the presence of design thinking in higher education programs is growing [7]. Various studies have been conducted in regard to design thinking and higher education; however, they rarely consider the impact on student learning performances, and according to an article from 2021, "design thinking, supported by transformative learning theory, can be conducive for developing higher order thinking skills and meaningful learning experiences" [8].

The pilot research elaborated on in this article has been carried out as part of the project "a/AR-Learning: Active learning by applying augmented reality", which focuses on how active learning influences students. The problem was considered in regard to the insufficient activity of students during classes and the possibility of using the design thinking process as a strategy for active learning. The pilot research was conducted with business economics graduate students enrolled in the Disruptive Innovations and Design Thinking elective course. The sample was deliberate and available, participation was anonymous and voluntary, and the pilot research consisted of a survey and an experiment. The research was conducted online using digital tools.

The purpose of this article is to establish the effects of learning the design thinking process and whether it could be used as an active learning method in order to influence the development of innovative thinking among students. The research question is "How does learning the design thinking process affect the development of students' innovative way of thinking?" In order to answer the research question, the following hypotheses were put forward:

H1. *After learning the design thinking process, students recognize the main characteristics of innovation.*

H2. *Active learning of the design thinking process affects critical assessment.*

H3. *The innovative way of thinking developed through active learning of the design thinking process differs among students.*

This article contains both primary and secondary data; the primary data were obtained through the pilot research, and the secondary data are related to the literature, obtained through research and analysis, both printed and online.

This article is structured in six sections, beginning with the Introduction. The Introduction gives background and context on the topic and provides an overview of the research approach as well as the article's purpose, research question, hypotheses, and structure.

The second section is the literature review, which provides an overview of the literature considering design thinking, active learning, students, and innovation. This section is split into a few subsections for ease of presenting the information.

The following section is the Methodology section, which contains information about the approach used in regard to the pilot research and provides information about the research design, sampling strategy, and data collection methods.

The next two sections are the Results section, which displays the results of the pilot research, and the Discussion section, which contains the authors' interpretation of the displayed results.

Finally, the article ends with the Conclusion, which summarizes the main findings and their implications, including limitations and future research directions as well as the contribution to the field and its broader implications.

2. Literature Review

Design thinking has been present in the literature since the second half of the 20th century. Starting with MIT and Stanford professor John E. Arnold in the 1950s, who first introduced the concept in his Creative Engineering seminars at Stanford [9], the term design thinking has evolved from the fields of art and architecture to engineering, business, management, and education. Given its origins, there is a vast amount of literature from a variety of fields, both academic and practical, on the nature, methods, and application of design thinking.

Placing design thinking in relation to active learning, students, and innovation, by researching the Scopus database, reading and eliminating all non-pertinent articles, and adding the relevant literature from other sources, the authors identified 138 literature sources divided into five main areas of interest, namely: theoretical, designer, education, business, and metrics (see Figure 1).

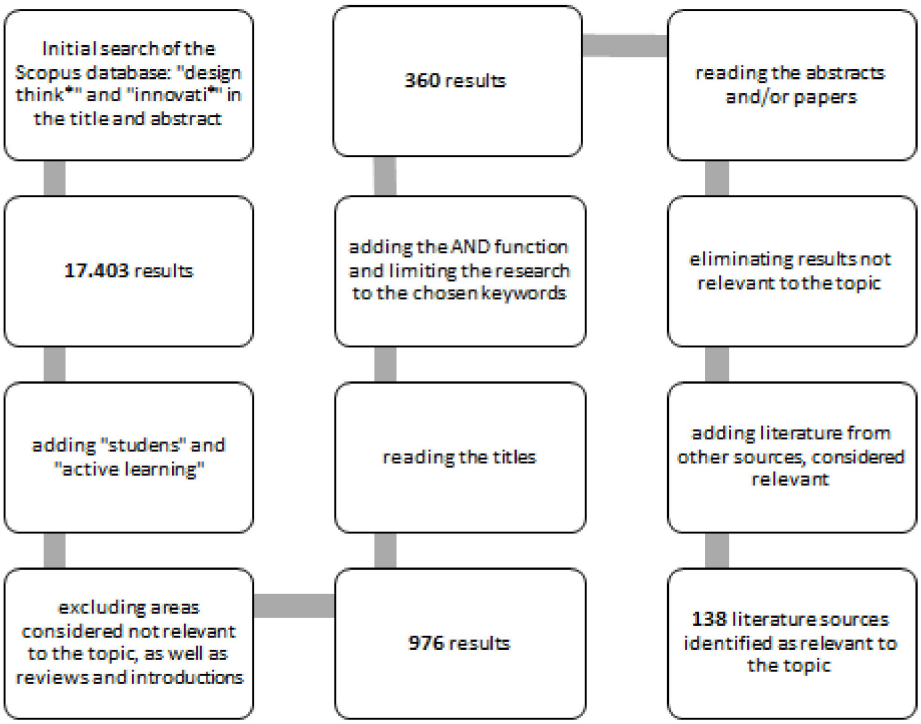


Figure 1. The process of searching and identifying the relevant literature.

The years of publication of the literature relevant to the topic at hand range from 2007 to 2022, with a significant spike from 2016 onward, as displayed in Figure 2. Due to the fact that the literature regarding the topic has more than doubled in the last seven years, it can be concluded that the topic is both current and relevant.

By country, the literature mostly originates from Europe and North America, although there is a noticeable global interest. The greatest interest in the topic is present in the United States and Germany, with, respectively, 30 and 19 literature sources considering design thinking, learning, and innovation. Some other countries with high interest are India, Ireland, Sweden, Switzerland, Australia, Brazil, Canada, Denmark, and Norway (see Figure 3).

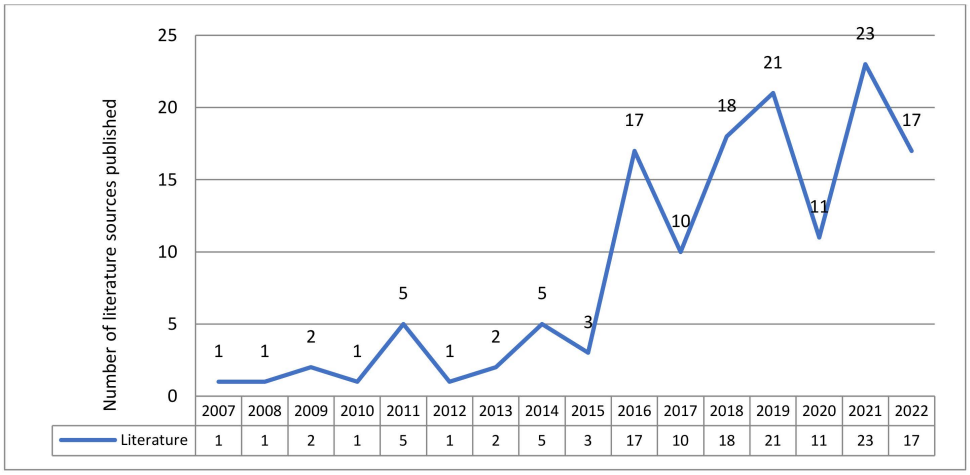


Figure 2. Visualization of the literature by year.

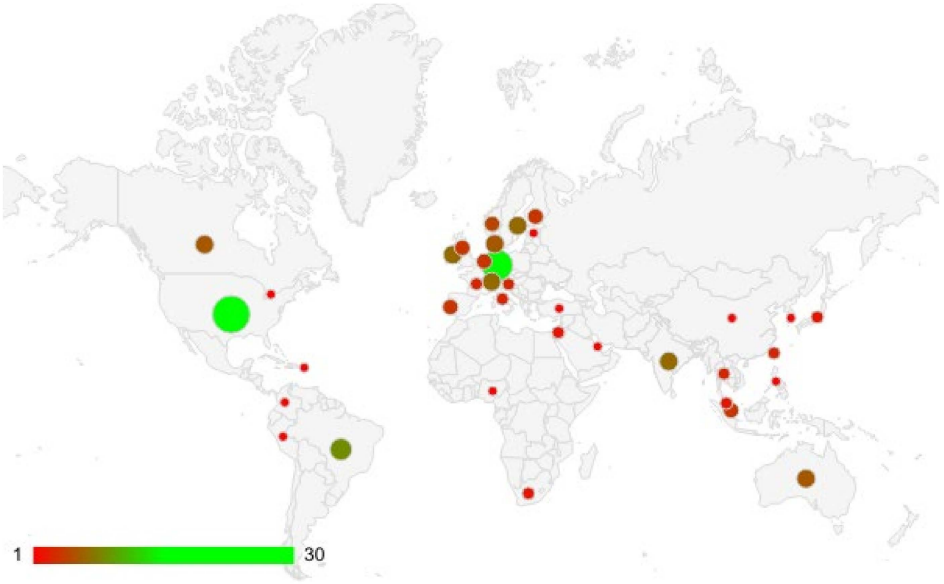


Figure 3. Visualization of the literature by country.

The literature consists almost entirely of articles and conference papers, with a slightly higher percentage of the latter. Less than 10% corresponds to books and chapters. With the topic being intrinsically interdisciplinary and multi-disciplinary, the literature consists of a wide range of subject areas, the most frequent of which are: engineering, social sciences, computer science, and business, management, and accounting.

Considering the five main areas of interest identified by the authors, the highest number of literature sources relates to education, followed by business, theory, metrics, and the designer themself. A visualization of the literature, divided into areas of interest, can be found in Figure 4.

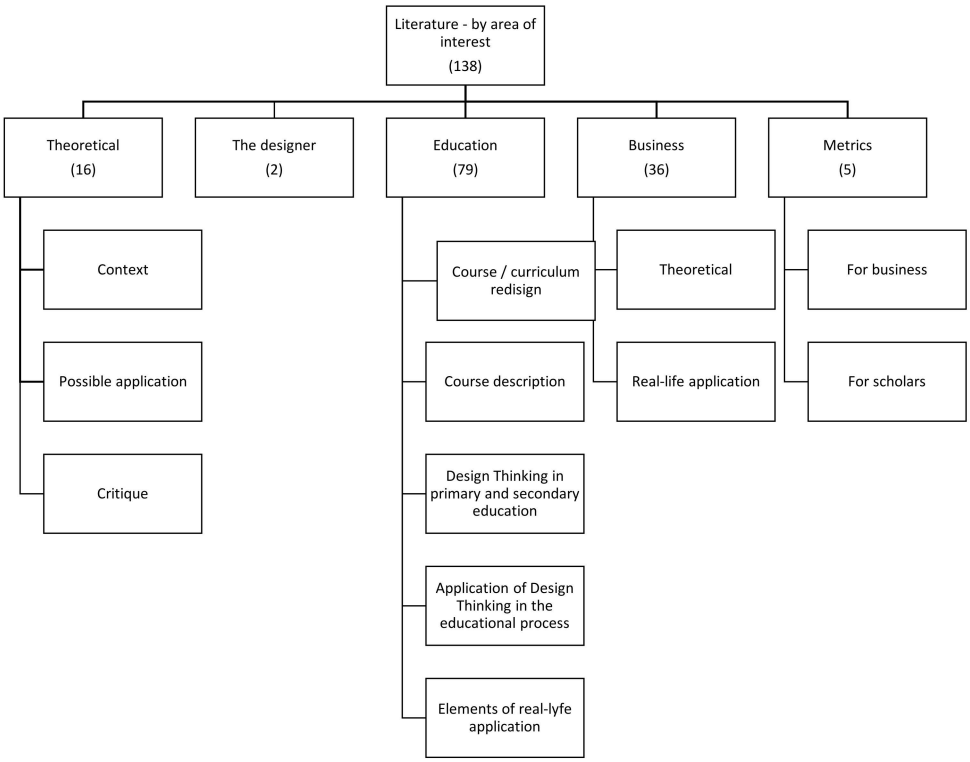


Figure 4. Visualization of the literature, divided into areas of interest.

2.1. Theoretical

Considering the theory, 16 literature sources were identified related to the topics of design thinking and innovation from a predominantly theoretical aspect. Nine of those were written between 2015 and 2022, of which one is a book chapter, five are conference papers and three are articles. They provide an introduction to design thinking, highlight it "as a tool for "problem solving" and innovation" [10], analyze possible purposes and limitations, variables, and critical success factors, and put it in the context of new product development and sense-making. Several literature sources also provide a review of the relevant literature. Two chapters of a 2016 book written on the basis of experiences and research at the University of St. Gallen in Switzerland consider design thinking as "a way of thinking, a process and a set of tools" and propose the application of design thinking phases in research projects for information systems [6]. Two other literature sources, from 2021 and 2022, consider, from a theoretical point of view, the possible application of design thinking in the innovation and development of software and systems. They point out that "design thinking is a way of thinking that is suitable in situations involving innovation, uncertainty, and changes within organizations" [11]—situations that regularly appear during the creation and implementation of new software. Finally, three literature sources, one older and two recent contain a critical review of design thinking. A book chapter from 2011 considers the ethical implications, while the recent ones, from 2019 and 2022, consider cultural and social influences as decisive elements for successful innovation and the effective contribution of design thinking to the former. In his book, Tim Seitz concludes that "design thinking is more about the introduction of a new work culture than the creation of superior products and services" [12].

2.2. The Designer

Considering the designer themself, two conference papers were identified to place the focus on designers, as people who innovate through creativity and prototyping. The papers highlighted mentality and the way of thinking as key to creating innovation, particularly emphasizing the application of design thinking in order to change the perception of design-

ers [13]. The paper written by Ge and Leifer [13] considers the process from a theoretical aspect, while the paper written by Jordan and Lande [14] builds on real-life applications and highlights the connection between prototyping and innovation.

2.3. Education

In relation to the area of education, and particularly due to the key focus of this paper, most of the identified literature sources are connected to education—79 of them to be precise—with their years of publication ranging from 2008 to 2022.

On the topic of course or curriculum redesign by introducing design thinking as a driver of innovation and creativity, 17 papers were written in the period from 2009 to 2021. They are mostly related to college-level courses connected to engineering and entrepreneurship. The 2014 article by Ulibarri et al. cites the use of design thinking to improve (doctoral students') problem-solving abilities and to develop creative confidence and emotional well-being [15]. The 2019 article by Linton and Klinton describes the use of design thinking in teaching entrepreneurship, emphasizing that the entrepreneurial process (as well as the design thinking process itself) is not linear, and therefore creativity and finding structure are an unstructured process [16]. Two more papers on subject or course redesign were identified, with a focus on active learning and innovation. They both originate from the US: one is from 2019, and the other is from 2022. The 2019 paper emphasizes the need to persistently encourage innovation as the opposite of sporadic flares of creativity, pointing out that "innovation can also come through students by way of purposely developed or enhanced courses, pedagogy, and experiences designed to create a spark or foster an existing spark, fan the flames, and fuel them to help them grow" [17]. It also stresses the need to incorporate learning and real-life experiences, pointing out that the courses, to match the real world, "need to be interdisciplinary, multi-disciplinary, transdisciplinary, and multi-college/multi-school (engineering, business, arts & sciences, architecture, etc.)" [17].

In addition to the topic of course redesign, there are also literature sources describing specific courses where active learning and principles of design thinking are applied, along with observations and experiences. There are 14 sources in total, written from 2014 to 2021, with both conference papers and articles. The 2018 paper by Levy points out that the learning experience gained while practicing the design thinking method can encourage empathy and other skills needed in modern digital culture, describing it as "a combination of technology, knowledge and culture" [18]. The 2021 paper by Silla elaborates on the findings of a novel hands-on approach combining active learning and design thinking implemented in teaching students how to evaluate the initial stages of a startup [19].

Although a predominant part of the literature refers to learning design thinking at the higher education level, there are also literature sources on design thinking in the context of primary and secondary schools. There are a total of five sources, with their years of publication ranging from 2019 to 2021, elaborating on the learning outcomes and application of design thinking. The 2019 article by Marks and Chase points out how learning about the iterative prototyping process and mindset can encourage students to dare to fail early and often [20]. Another article from 2019, *design thinking,* explores the benefits of empathy skills in project-based learning and as a tool for stimulating a positive classroom culture of collaboration and teamwork [21].

Furthermore, 30 literature sources consider learning and the application of design thinking in the educational process, of which 11, written from 2011 to 2022, consider the issue from a theoretical aspect, while the other 19 are aimed at educational staff. The 2018 article by Bourgeois-Bougrine, Latorre, and Mourey proposes a theoretical approach to increasing the presence of design thinking in the educational environment in order to promote a radical, innovative way of thinking [22]. The 2021 article by Tsai proposes the use of design thinking in psychology courses in order to "stimulate the students' competence in higher-order thinking skills, interactive collaboration, their characteristics (i.e., empathy, personality, self-confidence, self-worth), and their learning strategies" [23]. Papers aimed at

educational staff, written from 2016 to 2022, are more practical and focus on how to teach design thinking, such as the conference paper by McLuskie, which contains methodology, models, critical thinking, and efficiency assumptions [24]. Others are focused on educators as the bearers of the innovation process, such as the conference paper by Gachago et al., which conveys observations from a course for academic staff at a South African university. It points out that after the course, the participants showed a growing understanding of student diversity, complexity, and needs, as well as creative problem-solving, increased flexibility, and appreciation of interdisciplinary cooperation [25].

Finally, in the area of education, there are also 11 literature sources from 2008 to 2020 that, in addition to teaching, contain real-life applications as well. The oldest literature source found for education, a 2008 paper, elaborates on a course called "Real-world problem-solving", which emphasizes solving wicked problems using active learning for developing design thinking skills [26]. The 2016 conference paper by Artiles and Lande describes the development of students' innovation abilities using design thinking [27], while the 2020 conference paper by Traifeh et al. conveys the positive outcomes for students of a design thinking workshop, such as creativity, self-confidence, and cooperation with multi-disciplinary teams [28]. The 2019 conference paper by Bouwman et al. [29] examines the learning and application of design thinking in academia and industry.

2.4. Business

From a business aspect, 36 literature sources were identified, with their years of publication ranging from 2007 to 2022, dealing either with a theoretical aspect or observations from real life. From a theoretical aspect of applying design thinking in business and connecting it with innovative thinking, 15 sources were found, dealing with creating strategies, encouraging growth, improving performance, developing organizational culture, and quickly adapting to changes. The 2022 article by Radnejad et al. considers the use of design thinking in the development of strategies in response to disruptive innovation and the use of design thinking for process innovation [30]. As for a real-life application, 18 literature sources were found, with their years of publication ranging from 2012 to 2022, in which entrepreneurs and companies successfully applied design thinking principles and processes, innovating not only products but also the software development process, services, brands, management and leadership styles, employees' way of thinking and their attitude towards change and innovation within the organization. In the 2019 conference paper by Dobrigkeit and De Paula, their case study suggests that exposure to design thinking changes the way employees think [31]. The 2022 article by Lehtonen et al. provides an example of using design thinking in a large government agency to improve collaboration, define problems better, and design solutions [32]. There are also three literature sources from 2021 that consider the application of design thinking in the public sector. The conference paper by Malik et al. [33] proposes the application of design thinking in the public sector to ease adaptation to changes and minimize employee resistance.

2.5. Metrics

Lastly, five literature sources were written on the topic of the metrics and benefits of design thinking. They were written from 2015 to 2019, four of which relate to business, while a paper from 2017 is intended for scholars.

3. Methodology

The development of innovative thinking among students, as well as how it is influenced by learning the design thinking process, was observed during the pilot research for the course Disruptive Innovations and Design Thinking.

The course Disruptive Innovations and Design Thinking is an elective summer course of the Digital Economics and Innovation study track of the Business Economics graduate study program at the University North in Varaždin. The course deals with disruptive innovations and the reasons for the collision and resistance between technology and

culture, which ultimately often undermine promising innovations. During the course, the design thinking process is taught, and it is studied and applied as a possible approach to finding an effective solution for a defined problem. The course Disruptive Innovations and Design Thinking is an on-site course in the sense that the student-educator interaction is face-to-face. It consists of theory lectures, a design thinking workshop, and seminars in which the students present their own solutions created using the design thinking approach, mentored by professors and staff.

The pilot research was carried out as part of the project "a/AR-Learning: Active learning by applying augmented reality", which focuses on how active learning influences students. In this case, learning the design thinking process was considered a strategy for active learning. Therefore, students enrolled in the aforementioned design thinking class that went through the process of learning design thinking were the focus of the pilot research. Consequently, it can be said that the sample was both deliberate since it included only students going through the process of learning design thinking and available since they were the only students at the University North going through the process of learning design thinking while the pilot research was ongoing.

Regarding the research design, a quasi-experimental design was chosen since the outcomes were measured before and after learning the design thinking process, but there was no possibility of randomly selecting the sample, and no control group was used.

The research question was "How does learning the design thinking process affect the development of students' innovative way of thinking?", and in order to answer it, three hypotheses were put forward:

H1. *After learning the design thinking process, students recognize the main characteristics of innovation.*

H2. *Active learning of the design thinking process affects critical assessment.*

H3. *The innovative way of thinking developed through active learning of the design thinking process differs among students.*

The aim was to establish the effects of learning the design thinking process and whether it could be used as an active learning method in order to influence the development of innovative thinking among students.

The research consisted of a survey and an experiment, both in written form, filled out online using Google Forms. The survey was conducted twice with a time lag in between: before the very beginning of the course (12 May 2022) and at the end of the course (from 7 to 10 June 2022).

As mentioned before, the sample was both deliberate and available. Out of 19 students enrolled in the course, 14 students participated in the first initial survey, which makes up 74% of the total enrolled in the course. In the second survey, at the end of the course, out of a total of 19 students enrolled in the course, ten students took part, making up 53% of the total enrolled in the course. Finally, five students participated in the course ideation experiment using design thinking at the end of the course. Before taking part in the pilot research, students were informed for the purpose of conducting the surveys and the experiment, anonymity, voluntary participation, and for what purpose the data would be used.

Regarding the variables used in the pilot research, the second part of the survey was composed of questions with a Likert scale. A total of 44 variables were included, divided into four questions with 11 variables each. Answers were given on a scale of 1 to 5 (1 being the lowest and 5 being the highest).

The first question (Q1) is connected to H1 and refers to the characteristics associated with innovation, and the participants had to rate the extent to which the listed terms were related to innovation. The items, i.e., the variables of Q1, were: *creativity, curiosity, empathy, analyticity, inclusivity, cooperation, leadership, bravery, experimentation, agility, and mistakes.*

The second question (Q2) is connected to H3 and refers to the characteristics of the participants, mirroring the characteristics from the previous question. The participants had to evaluate how much the affirmations described them on a scale from 1 to 5, of which 1 meant the affirmation did not describe them at all, and 5 meant the affirmation described them completely. They were as follows:

- I am creative;
- I am curious;
- I empathize with others;
- I like to think logically;
- I often involve other people in my plans;
- I like to cooperate with others;
- I make decisions with ease;
- I do not back down from a challenge;
- I like to try new solutions;
- I quickly adapt to changes;
- I believe that mistakes are a way of learning.

The third question (Q3) is connected to H3 and refers to the characteristics that were developed by learning the design thinking process. The participants had to evaluate the extent to which the listed traits were developed by learning the design thinking process. The listed traits were: *insight, reducing preconceptions, a new way of perception, inclusiveness, not linear thinking, logical thinking, focus, teamwork, risk-seeking, practical use, and curiosity.*

The fourth question (Q4) is connected to H2 and refers to claims related to design thinking. The participants had to evaluate the extent to which certain statements are related to, and true of, design thinking. The statements were as follows:

- Design thinking helps with focus.
- Design thinking brings added value to users.
- In design thinking, it is crucial to identify the user's needs.
- Design thinking helps to find the best solution for every need.
- Design thinking always leads to one answer.
- In design thinking, one should always follow the leader.
- Design thinking is connected with disruptive innovations.
- The solutions we arrive at using design thinking are always very complex.
- For a design thinking solution, it is not important that it is applicable, only that it is well thought out.
- Design thinking contributes to organizational agility.
- Design thinking is only related to the process of creation, not to consumers.

Based on the 44 listed variables, the reliability of the measurement scale was checked using the Cronbach alpha coefficient. The results are displayed in the Table 1 below. Based on the obtained coefficients, it can be concluded that the reliability of both surveys is high enough for the results to be accepted.

Table 1. Cronbach alpha coefficient for 44 items, for the first and second surveys.

	Items (Variables)	**Cronbach Alpha Coefficient**
First survey (n = 14)	44	0.8664
Second survey (n = 10)	44	0.9036

Regarding the primary data collected through the surveys, the analysis was conducted through a comparison of the middle value (median), most frequent value (mode), and average value (mean) of participants' answers before and after learning the design thinking process, in order to determine whether there was a positive shift present. Furthermore, by using descriptive and inferential statistics, a conclusion about the hypotheses was made.

The statistical analysis was performed, and the data is displayed using MS Excel and Google Sheets.

4. Results

4.1. Survey Results

The participants were all women between 18 and 50 years old. In the first survey in May, most of the participants were in the age group 18–25, accounting for 43%, while in the second survey in June, the largest number of participants, in addition to the age group 18–25 (40%), belonged to the age group 35–50 years (40%). Not a single participant in either survey belonged to the 50–65 age group. According to the undergraduate program type, in both surveys, the majority of participants completed professional undergraduate programs, which are typically more practical and focused on real-life applications: 79% in the first survey and 80% in the second. In terms of work experience, including summer and student jobs, all participants have work experience. In both surveys, about 30% of participants have up to 3 years of work experience, while about 70% of participants have more than 3 years of work experience.

After the initial socio-demographic structure, prior experiences in innovation and prior knowledge of design thinking were considered. To the question "*Did you ever come up with a change and implement it?*", in both surveys, 50% of participants answered they did not have any prior experience in the ideation and implementation of changes.

When considering prior knowledge about and exposure to design thinking processes and methodology, participants of the first survey were asked, "*Are you familiar with the design thinking process?*" and "*Have you listened to any lectures about design thinking?*" Additionally, out of the participants who took part in the first survey, 78.6% answered they were not familiar with the design thinking process, and 92.9% answered they had not listened to any lectures about design thinking. In the second survey, at the end of the course, when asked, "*Are you familiar with the design thinking process?*", all of the participants confirmed they were familiar with the process.

Regarding the Likert scale questions, conceptually, they were divided into two units to establish the effectiveness of learning the design thinking process and to enquire whether traits associated with innovation and innovative thinking increased with exposure to the design thinking processes and principles.

Regarding H1 (*After learning the design thinking process, students recognize the main characteristics of innovation*) and the effectiveness of learning the design thinking process, it was considered whether students recognize the main characteristics of innovation.

The results of Q1 show that after learning the design thinking process, students' ability to recognize the main characteristics of innovation increased.

Figure 5 visualizes the most frequent answers given to Q1 by the participants, with the blue columns representing the first and the orange columns the second survey answers.

Observing Figure 5, it can be seen that the orange columns are, in general, higher than the blue ones, indicating an increase in recognizing the main characteristics of innovation after learning the design thinking process.

Furthermore, a descriptive analysis was performed on the Q1 answers of the second test. The results are shown in the table below. Answers were given on a Likert scale with values from 1 to 5, of which 1 indicates that the terms are unrelated to innovation at all and 5 indicates that they are completely related. The table for each individual characteristic (variable) shows the sample (n), the lowest response, the highest response, the average values (mean, median, mode), the standard deviation, i.e., the deviation from the average value, and the variance.

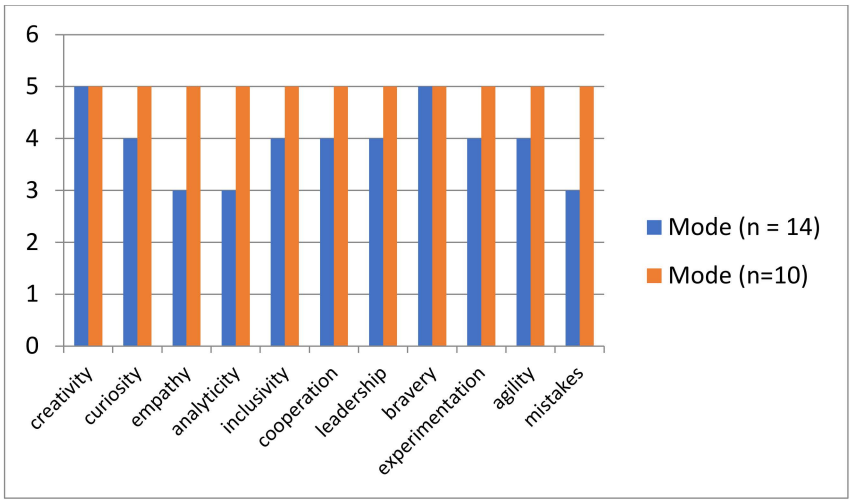


Figure 5. Visualization of the most frequent answers regarding the main characteristics of innovation, in the first (blue) and second (orange) surveys.

Table 2 shows the descriptive statistics related to Q1. It can be observed that empathy, courage, and experimentation have the highest arithmetic mean, which is 4.70, while inclusiveness has the lowest arithmetic mean, which is 4.20. The average value for all variables is significantly greater than 3, and the standard deviation is less than 1. Finally, a *t*-test was performed on the listed variables, with a hypothesized mean difference greater than 0 and $\alpha = 0.05$. Based on the results, it can be considered that hypothesis H1 (*After learning the design thinking process, students recognize the main characteristics of innovation*) is confirmed for *creativity*, *curiosity*, *analyticity*, *inclusivity*, *cooperation*, *leadership*, *bravery*, and *experimentation*.

Table 2. Descriptive statistics of Q1.

Variable	n	Min	Max	Mean	Median	Mode	Standard Deviation	Variance
creativity	10	4	5	4.60	5	5	0.516	0.267
curiosity	10	3	5	4.50	5	5	0.707	0.500
empathy	10	4	5	4.70	5	5	0.483	0.233
analyticity	10	3	5	4.40	5	5	0.843	0.711
inclusivity	10	3	5	4.20	4	5	0.789	0.622
cooperation	10	3	5	4.40	5	5	0.843	0.711
leadership	10	3	5	4.40	4.5	5	0.699	0.489
bravery	10	4	5	4.70	5	5	0.483	0.233
experimentation	10	4	5	4.70	5	5	0.483	0.233
agility	10	4	5	4.50	4.5	5	0.527	0.278
mistakes	10	4	5	4.50	4.5	5	0.527	0.278

When considering the effectiveness of learning design thinking as a method for active learning, the answers to Q4 were analyzed. Two things were taken into consideration: the ability to distinguish true claims from false ones, and the change due to learning the design thinking process. This is connected to the increased critical assessment being an outcome of active learning and is considered in H2 (*Active learning of the design thinking process affects critical assessment*).

Below, a visualization of the average answers (mean) given to Q4 by the participants can be found, with the blue columns representing the first and the orange columns the

second survey answers. The false claims are marked with an asterisk. The claims are listed in Table 3 and displayed in Figure 6.

Table 3. List of claims in Q4.

	Claims
1	Design thinking helps with focus.
2	Design thinking brings added value to users.
3	In design thinking, it is crucial to identify the user's need.
4	Design thinking helps to find the best solution for every need.
5	* Design thinking always leads to one answer.
6	* In design thinking one should always follow the leader.
7	Design thinking is connected with disruptive innovations.
8	* The solutions we arrive at using design thinking are always very complex.
9	* For a design thinking solution, it is not important that it is applicable, only that it is well thought out.
10	Design thinking contributes to organizational agility.
11	* Design thinking is only related to the process of creation, not to consumers.

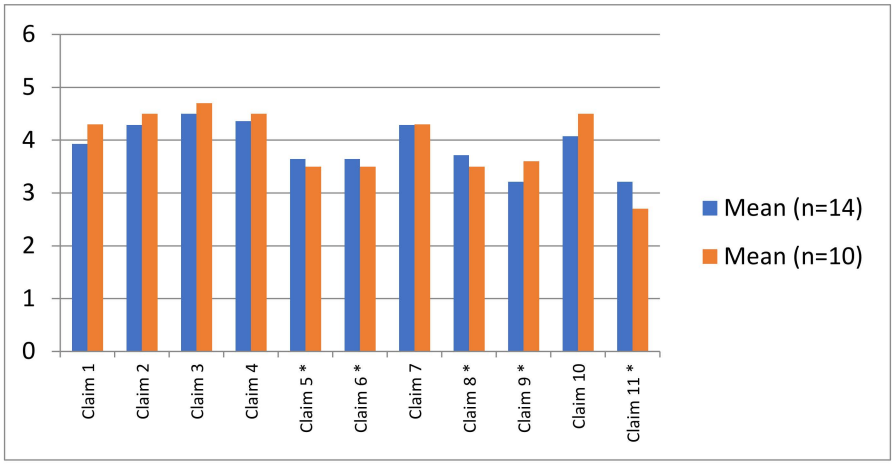


Figure 6. Visualization of the average answers regarding claims about design thinking, in the first (blue) and second (orange) surveys.

Observing Figure 6, two things can be noticed. First of all, for almost all claims, there is variation in the answers given during the first and second surveys, thus indicating that learning the design thinking process had an effect and caused a change in the understanding of its principles and outcomes. Furthermore, the change was positive in regard to true claims and negative regarding false claims, indicating that students not only learned about design thinking but also processed and understood its principles and outcomes.

One exception needs to be pointed out, which is particularly pertinent to the topic of this article. Claim 9 (*For a design thinking solution, it is not important that it is applicable, only that it is well thought out*) is a false claim, which, in contrast to all other false claims, had an increase in the response value in the second survey. The implication of this will be discussed further in the article.

A descriptive analysis was performed on the Q4 answers of the second test. The results are shown in the table below. Answers were given on a Likert scale with values from 1 to 5, of which 1 indicates the participants completely disagree and 5 indicates they completely agree. The table for each individual characteristic (variable) shows the sample

(n), the lowest response, the highest response, the average values (mean, median, mode), the standard deviation, and the variance.

Table 4 shows the descriptive statistics related to Q4. Claims marked with an asterisk (*) are false and will not be taken into account to prove the hypothesis. The highest arithmetic mean, which is 4.70, is found for Claim 3, while the lowest one, which is 4.30, is found for Claim 1 and Claim 7. The average value for all true variables is greater than 3, and the standard deviation is less than 1. Finally, a *t*-test was performed on the listed variables, with a hypothesized mean difference greater than 0 and $\alpha = 0.05$. Based on the results, it can be considered that H2 (*Active learning of the design thinking process affects critical assessment*) is confirmed for all true variables.

Table 4. Descriptive statistics of Q4.

Variable	n	Min	Max	Mean	Median	Mode	Standard Deviation	Variance
Claim 1	10	3	5	4.30	4	4	0.675	0.456
Claim 2	10	3	5	4.50	5	5	0.707	0.500
Claim 3	10	3	5	4.70	5	5	0.675	0.456
Claim 4	10	3	5	4.50	5	5	0.707	0.500
Claim 5 *	*10*	*1*	*5*	*3.50*	*4*	*4*	*1.434*	*2.056*
Claim 6 *	*10*	*1*	*5*	*3.50*	*4*	*4*	*1.269*	*1.611*
Claim 7	10	3	5	4.30	4	4	0.675	0.456
Claim 8 *	*10*	*2*	*5*	*3.50*	*3.5*	*3*	*0.850*	*0.722*
Claim 9 *	*10*	*1*	*5*	*3.60*	*4*	*5*	*1.506*	*2.267*
Claim 10	10	3	5	4.50	5	5	0.707	0.500
Claim 11 *	*10*	*1*	*5*	*2.70*	*2*	*2*	*1.636*	*2.678*

Regarding the traits associated with innovation and innovative thinking and whether they increased with exposure to the design thinking processes and principles, answers from Q2 and Q3 were considered. In relation to the participants' self-evaluation about their characteristics, which mirrored the characteristics associated with innovation, only a small change in the answers was observed, mostly regarding creativity and empathy. Regarding the characteristics developed by learning the design thinking process, a positive change was observed in four traits, as displayed in Figure 7. A negative change was also present regarding the trait focus, the implication of which will be discussed further in the article.

A descriptive analysis was performed on the Q3 answers of the second test. The results are shown in the table below. Answers were given on a Likert scale with values from 1 to 5, of which 1 indicates the traits do not develop at all and 5 indicates they develop a lot. The table for each individual characteristic (variable) shows the sample (n), the lowest response, the highest response, the average values (mean, median, mode), the standard deviation, and the variance.

Table 5 shows the descriptive statistics related to Q3. The highest arithmetic mean, which is 4.90, is found for the trait "*a new way of perception*", while the lowest arithmetic mean, which is 4.10, is found for *risk seeking*. The average value for all variables is significantly greater than 3, and the standard deviation is less than 1 for all but one variable. Finally, a *t*-test was performed on the listed variables, with a hypothesized mean difference greater than 0 and $\alpha = 0.05$. Based on the results, it can be considered that H3 (*The innovative way of thinking developed through active learning of the design thinking process differs among students*) is confirmed for *reducing preconceptions, inclusiveness, logical thinking, risk-seeking, practical use,* and *curiosity.*

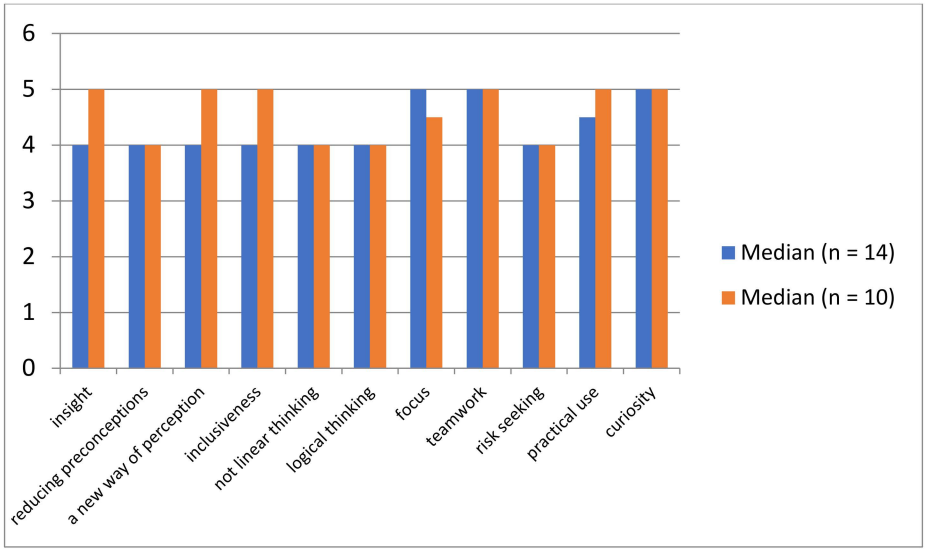


Figure 7. Visualization of the middle values of answers regarding traits developed by learning design thinking, in the first (blue) and second (orange) surveys.

Table 5. Descriptive statistics of Q3.

Variable	n	Min	Max	Mean	Median	Mode	Standard Deviation	Variance
insight	10	4	5	4.70	5	5	0.483	0.233
reducing preconceptions	10	3	5	4.20	4	4	0.632	0.400
a new way of perception	10	4	5	4.90	5	5	0.316	0.100
inclusiveness	10	4	5	4.60	5	5	0.516	0.267
not linear thinking	10	4	5	4.40	4	4	0.516	0.267
logical thinking	10	3	5	4.20	4	4	0.632	0.400
focus	10	3	5	4.30	4.5	5	0.823	0.678
teamwork	10	2	5	4.30	5	5	1.059	1.122
risk seeking	10	2	5	4.10	4	4	0.994	0.989
practical use	10	3	5	4.50	5	5	0.707	0.500
curiosity	10	3	5	4.50	5	5	0.707	0.500

4.2. Experiment

As part of the pilot research, along with the surveys, an experiment was conducted as well. The experiment was conducted in written form with business economics graduate students of the University North, and enrolled in the elective course Disruptive Innovations and design thinking in the summer semester of 2022. The goal of the experiment was to evaluate whether a positive effect on active learning was achieved. The experiment was conducted after the course (from 7 to 10 June 2022), and five students decided to take part in the experiment. Participation was anonymous and voluntary.

The experiment consisted of innovation on a given topic, specifically: *Through the process of design thinking, coming up with what an innovative course would look like (lectures, exercises, exams)*. The experiment was divided into four steps, taken from the design thinking process (empathy, define, ideate, solution), and there was a part for self-assessing the proposed solution. Given the impossibility of interviewing the stakeholders in the empathy step, the topic was chosen in a way to allow the participants to have prior and intimate knowledge of the users' needs (being part of the stakeholder group themselves). The self-assessment part was related to Tim Brown's steps for assessing the possible

implementation of an innovation [34], and consisted of the following questions: *Is it innovative?*, *Is it technically feasible?*, *Can it be replicated in other courses* (i.e., is it marketable)? The disadvantage of the experiment was that it was not possible to incorporate the elements of creation (prototyping, testing) and iteration.

The participants proposed five different solutions, two of which had common elements. An overlap of 10% was estimated at the experiment level. Table 6 summarizes the responses and presents the proposed innovations.

Table 6. Proposed course innovations (certain aspects or the entire course).

	Participants	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**
	Stakeholders	Part-time students	Part-time students	All academic course staff *(+students)*	Part-time students, course instructors	Full-time students, part-time students, all academic course staff
	Identified need	Occasional need for online classes/seminars, as well as practical exams	Remote class attendance	To create an innovation and "anticipate" expectations (*of the academic course staff*)	Limited duration of the course versus the scope of the course content	Passing the exam/evaluating the students
	Proposed solution	Theory classes: online Seminars: face to face Grading: based on solving a real-life business problem	Classes online or face to face with the possibility of joining remotely	Creative workshops	Podcasts An online library with digitized material available to students	An application that "examines" students
Self-assessment	**Is it innovative?**	YES	NO	YES	YES	YES
	Is it technically feasible?	YES	YES	YES	YES	YES
	Can it be replicated?	NO	YES	YES	YES	YES

As displayed in Table 6, Participant 1 considered a solution for part-time students. The identified need was an occasional need for online classes/seminars as well as exams that are practical as opposed to the mnemonic. The proposed solution was to hold theory classes online and seminar classes face-to-face. For the exam part, solving a real-life business problem was proposed as a means of grading. Participant 1 self-assessed their solution to be innovative and technically feasible, but not replicable.

Participant 2 considered a solution for part-time students as well. The identified need was for remote-class attendance, similar to Participant 1, and the proposed solution was online or face-to-face classes with the possibility of joining remotely. Participant 1 self-assessed their solution not to be innovative, but to be technically feasible and replicable.

Participant 3 considered a solution for all academic staff and students. The identified need was to create an innovation and anticipate expectations, and the proposed solution was a creative workshop. Participant 3 self-assessed their solution to be innovative, technically feasible, and replicable.

Participant 4 considered a solution for part-time students and course instructors and identified the need to deliver voluminous course content more efficiently with the resources available. The proposed solution was podcasts accessible online where professors or other guests could elaborate in more detail on a particular segment discussed in class, and students could access it when needed. An additional solution was proposed in the form of an online library with digitalized material available remotely for student view. Participant 4 self-assessed their solution to be innovative, technically feasible, and replicable.

Participant 5 proposed a solution for full-time students, part-time students, and all academic course staff. The identified need was passing the exam, on one hand, and evaluating the students, on the other, to which the proposed solution was an application that examines students. Participant 4 self-assessed their solution to be innovative, technically feasible, and replicable.

In regard to the answers in Table 6, it can be observed that the stakeholders are aligned with the proposed solutions, needs are recognized, and innovations are proposed. Considering the proposed innovations, elements of creativity and novelty can be identified, but for possible implementation, the proposed solutions should be better elaborated and contain more details and practical elements. Although not enough details were included for possible implementation, in the self-assessment portion, the participants realistically assessed the possible implementation, which indicates that they recognized the elements but did not realize the need to formulate a solution with concrete application.

5. Discussion

In this article, the authors wanted to elaborate on how learning the design thinking process, a non-linear human-centric approach to innovation, would influence students, and whether it could be used as an active learning strategy to influence the development of innovative thinking among students. For this purpose, pilot research was conducted with business economics graduate students at the University North, enrolled in the elective course Disruptive Innovations and Design Thinking in the summer semester of 2022. The choice to research economics students, rather than engineering or computer science students, was made in part because of the lack of such research and in part because of the intrinsic business choices connected with innovation. Additional future research on the topic would be advised. The pilot research consisted of a survey and an experiment, intended to establish the effectiveness of learning the design thinking process and to enquire whether the design thinking process could be used as an active learning method in order to influence the development of innovative thinking among students. The implications of the results are discussed below.

5.1. Theoretical/Conceptual Implications

The results of the survey, performed in two parts with a time lag, showed the clear effectiveness of learning the design thinking process, through not only traditional classes but also workshops, individual and group assignments, and practical solutions. The participants were able to recognize the main characteristics of innovation and apply critical assessment by distinguishing true claims about design thinking from false ones. This elaborates on the ideas stated in Avsecs' 2021 article [8] which, even though his experiment focuses on other aspects, "considers design thinking conductive for developing higher order thinking skills and meaningful learning experiences".

Interestingly, there was one exception. Claim 9 (*For a design thinking solution, it is not important that it is applicable, only that it is well thought out*) is a false claim, since applicability is one of the main goals for a design thinking solution. The aforementioned claim, in contrast to all other false claims, had an increase in the response value in the second survey, meaning the participants did not recognize the importance of applicability in the design thinking process.

5.2. Empirical Implications

Design thinking is a creative, non-linear process, but it is a process in the sense that some steps need to be followed for it to have its effect. During the course Disruptive Innovations and design thinking, even though active learning techniques were used, it was not possible to execute all the steps of the design thinking process. Therefore, the effects of *prototyping* and *testing*, particularly early prototyping and testing, as well as the effects of *iteration*, were neither processed nor present in the participants. The result of this is shown in the answers to Claim 9, where the participants did not recognize applicability as a crucial factor for a design thinking solution.

The absence of the final *create* steps of the design thinking process was also accentuated in the experiments' proposed solution. The proposed solutions stopped in the *ideation* step. They were not elaborated or detailed and did not contain any practical elements, making them intriguing ideas as opposed to executable solutions. Given the

self-assessment portion of the experiment, it is obvious that the participants recognized the possibility of implementation but lacked the necessary elements to move from ideation to implementation. The issues regarding design thinking practices and how they translate in the classroom, particularly considering *prototyping* and *experimentation*, were elaborated on in a study regarding design thinking teaching and learning in higher education. The study is described in a 2022 research article by McLaughlin et al. [35] and it explores the experiences across four US universities.

Another element of the design thinking process that was not included in the course Disruptive Innovations and Design Thinking was the design team. Design thinking solutions are not meant to be the product of a single mind. They come into being out of the collaboration of individuals with different backgrounds and different points of view. This is what gives depth to this type of solution, making it flexible and durable. Since it was not possible to include this element in the course, it too did not have its effects. Working in a team brings discussion, disagreement, and conflict, but it also pushes boundaries, stimulates creativity, and creates synergy. The role of the design thinking team leader is to set the pace and bring focus to the group. As it is shown in the answers to Q3, the traits stimulated by working in a team did not manifest as much as expected, and *focus* had a decrease in value in the second survey.

5.3. Pedagogical Implications

From the aforementioned results, the authors conclude that, even though learning the design thinking process influenced the development of innovative thinking among students, a more active approach is needed to reach its full potential. Therefore, the authors propose a new elective course, which would be the natural successor of the Disruptive Innovations and Design Thinking course, focused exclusively on active learning and practical application. The proposed course would have a case study approach, allowing students to interact with companies and experts to propose applicable solutions to actual real-life problems. This would allow students to gain all the positive effects of the design thinking process as well as working knowledge of business expectations and the process of implementing innovation. It would allow students to graduate having gained skills such as adaptability, complexity, agility, collaboration, problem-solving, and non-linear thinking, making them sought-after candidates and, hopefully, tomorrow's business leaders.

6. Conclusions

This article explored the effects of learning the design thinking process and the possibility of using the process as an active learning method in order to influence the development of innovative thinking among students. The research question was "How does learning the design thinking process affect the development of students' innovative way of thinking?", and in order to answer it, pilot research was performed. Upon analyzing the results, all three hypotheses were confirmed, and the conclusion was drawn that learning the design thinking process shows clear effectiveness and affects critical thinking. Additionally, the outcomes of the process differed among students. On the other hand, a need for a more active and practical approach was identified. The implications of the findings suggest a need for changes and additions to class syllabi, as well as a need for a brother study of the topic.

The limitations of this pilot study were the number of participants and the scale of the study, as well as the absence of a control group. As a future research direction, the authors propose a broader study and, to correct the aforementioned limitations, the inclusion of an interview, both with an expert and with a student focus group.

The authors believe the study elaborated in this article, with its implications, contributes to the field by exploring the effects of using the design thinking process as an active learning strategy, and by studying the effects on economics students, as opposed to students from other fields that are more present in the literature. The broader implications of this

study are the need for more research focused on active learning methods and strategies, as well as the active use of the results of said research to modify or improve class syllabi.

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Institutional Review Board Statement: Ethical review and approval were waived for this study due to the fact the study deals with students, not medical patients, and doesn't include any medical research or medical information. Both the survey and the experiment were conducted in written form. The students were provided information about the research. The survey is anonymous, participation is voluntary, and the answers will be used for the purpose of conducting research for writing a graduate and a scientific paper.

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

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