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Evaluating the Effect of Applying Interdisciplinary Collaboration Methods in the Process of Solving Design Problems by Industrial Design Undergraduates in Iranian Universities

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Abstract

In today's design education, interdisciplinary collaboration offers significant advantages for industrial design students. Among the most important benefits are the development of critical thinking and problem-solving skills, increased innovation, better handling of complex, multi-faceted issues, and improved preparation for entering the professional design field. This study examines the impact of interdisciplinary collaboration on the comprehensiveness of design solutions. Based on the main hypothesis, incorporating interdisciplinary collaboration in design education enhances students' ability to provide comprehensive solutions in the problem-solving process. This research follows an experimental approach based on hypothesis testing, employing a mixed-methods (quantitative and qualitative) approach. The main hypothesis was tested through comparative analysis on two groups of undergraduate students (interdisciplinary and non-interdisciplinary) in their sixth semester at Bu-Ali Sina University, Hamedan, selected using a non-probability sampling method. The students were asked to generate ideas using brainstorming and mind mapping techniques for a design problem. To quantify qualitative data, five factors were defined: integration of diverse perspectives, alignment with the design problem, consideration of various user needs, diversity in idea generation, and comprehensiveness. A five-point Likert scale was used for expert evaluation of different levels of integration for each qualitative factor. Subsequently, an independent t-test was conducted using SPSS software to compare the mean scores of the two groups. The significance level of 0.000 (less than 0.05) indicates a significant difference between the means of the two groups, confirming the study's main hypothesis and rejecting the null hypothesis.

Keywords

Interdisciplinary Collaboration, Design Education, Problem-Solving Process, Comprehensive Understanding.

Introduction

Problem Statement and Significance of the Research

In the evolving field of industrial design, addressing complex design problems often requires more than a single-disciplinary approach. Traditional design methods can sometimes limit creativity and fail to address all aspects of a problem, especially in the face of diverse user needs and interdisciplinary challenges. The need for comprehensive, multifaceted solutions has led to the growing importance of interdisciplinary collaboration in the design process. However, integrating different fields of knowledge and expertise in design education and practice presents several challenges. Many universities still rely on a traditional disciplinary structure that emphasizes narrow, specialized areas of study, making it difficult for students to engage in collaborative, cross-disciplinary problem-solving. Overcoming these challenges calls for the rethinking of design curricula and methods to include interdisciplinary practices, enabling students to explore the broader implications of their design solutions. Interdisciplinary collaboration is essential for preparing students to address the complex challenges of the 21st century. The rapid advancements in technology, globalization, and sustainability require designers who can navigate interdisciplinary domains and tackle multifaceted problems (Ahmed-Kristensen & Maier, 2017). Despite the growing recognition of its significance globally, in Iranian universities, industrial design education still predominantly relies on traditional methods, which emphasize non-interdisciplinary collaboration. This approach restricts students' access to alternative problem-solving approaches and limits the development of comprehensive solutions (Cross, 2006). Without interdisciplinary collaboration, students miss the opportunity to integrate diverse perspectives, which can sometimes result in incomplete or suboptimal solutions (Ulrich & Eppinger, 2011).

This research explores the role of interdisciplinary collaboration in the ideation and problem-solving processes of industrial design students. Specifically, it examines how collaboration with students from other disciplines can foster greater idea diversity, improve problem comprehensiveness, and create more holistic solutions to complex design problems. By leveraging diverse viewpoints, students can propose innovative solutions that would not be achievable through the expertise of a single discipline alone (Dori & Tal, 2000). In turn, this collaborative approach enhances creativity, critical thinking, and problem-solving skills, preparing students for real-world complexities and equipping them with the teamwork and communication skills necessary for professional environments.

Research Questions and Hypothesis

1. *Research Questions*

This study explores the following key research questions:

- How does interdisciplinary collaboration in design education impact students' problem-solving skills and design thinking?
- How can interdisciplinary collaboration better prepare students to tackle complex design challenges and develop comprehensive solutions in real-world contexts?
- To what extent does interdisciplinary collaboration in the problem-solving process influence the alignment of initial ideas with design problems and improve students' ability to create effective designs?
- How does interdisciplinary collaboration in design education affect the generation of creative and innovative ideas in solving design problems?

2. *Research Hypothesis*

The main hypothesis of this study suggests that incorporating interdisciplinary collaboration in design education enhances students' ability to integrate diverse perspectives and develop comprehensive solutions in the problem-solving process.

Research Objectives

The primary objective of this research is to explore the impact of interdisciplinary collaboration on design education by fostering dialogue, interaction, and cooperation among disciplines. This approach aims to enhance creativity, critical thinking, and problem-solving skills by integrating diverse perspectives into the design process (Beane, 1997; Hennessey & Amabile, 2010). It also seeks to improve the comprehensiveness of design solutions by offering alternative frameworks and addressing a broader range of user needs (Cross, 2006). Ultimately, the research aims to demonstrate how interdisciplinary collaboration can strengthen teamwork, increase adaptability, and lead to more innovative and effective design outcomes (Liedtka, 2015; Liu, 2021).

1. *Interdisciplinary Collaboration*

Interdisciplinary collaboration refers to the process of engaging individuals from different fields to work together, integrating their unique knowledge and skills to address complex problems or achieve a common goal. This approach emphasizes the integration and interaction of diverse disciplinary perspectives, fostering synergy and innovation (Repko, 2008). Given the various definitions of interdisciplinary collaboration, this study defines it as the interaction between industrial design students and students from other disciplines during their undergraduate education to engage in collective problem-solving, gaining a holistic understanding of the subject by considering multiple perspectives and working collaboratively. Interdisciplinary collaboration is particularly crucial for addressing complex real-world challenges, as these often require insights and expertise from multiple domains. By bringing together individuals with diverse academic backgrounds, collective knowledge is utilized to develop a deeper understanding of the problem and generate comprehensive and practical solutions (Boix-Mansilla & Dawes Duraisingh, 2007). Additionally, interdisciplinary collaboration can significantly enhance public well-being and advance collaborative research efforts (Chen et al., 2020).

2. *Interdisciplinary Collaboration in Design Education*

Interdisciplinary interactions, creativity, innovative thinking, and engagement with real-world communities are key factors in fostering interdisciplinary collaboration in 21st-century education (Skywark et al., 2021). Interdisciplinary collaboration in design education refers to the collective brainstorming and interaction between students, professors, and professionals from different fields working on a shared design project or problem. This approach emphasizes integrating diverse perspectives, skills, and knowledge to develop innovative solutions for tackling complex real-world challenges (Brandt et al., 2010).

According to the Association for Interdisciplinary Studies (AIS), interdisciplinary collaboration involves the integration of two or more academic disciplines, each with its own cognitive framework, to achieve a broader understanding of complex problems. Interdisciplinary collaboration in design education can take various forms, including:

- Project-based learning,
- Design thinking workshops,
- Co-creation labs, and
- Transdisciplinary research initiatives.

These approaches aim to cultivate a culture of collaboration, experimentation, and innovation (Kolko, 2010).

Literature Review

In general, interdisciplinary collaboration in design education fosters a holistic perspective among students and offers multiple benefits, which have been highlighted in various studies and academic papers. These sources provide insights into the importance, advantages, and challenges of interdisciplinary design education for students. Some of the key benefits identified in the literature include:

- Enhancing problem-solving skills,
- Increasing creativity,
- Improving communication skills by exposing students to various ways of thinking,
- Developing a deeper understanding of user needs, and
- Raising awareness of ethical considerations (Table 1).

Table 1: *Benefits of Implementing Interdisciplinary Collaboration Methods in Design Education (Source: Author).*

Type of Benefit	Title of Article	Author's Perspective on the Benefit
Enhancing complex problem-solving skills & raising awareness of ethical considerations	*The Impact and Value of Interdisciplinary Collaboration on Higher Education Art and Design Courses* by Wan (2023).	This article discusses the impact and value of interdisciplinary collaboration in higher education art and design courses, showing how it can enhance complex problem-solving skills and raise awareness of ethical considerations.
Boosting creativity and advanced innovation	*Interdisciplinary in design education: benefits and challenges* by McDermott et al. (2022).	This paper explores the benefits and challenges of interdisciplinary collaboration in design education, demonstrating how such collaborations can enhance creativity and innovation in design processes.
Improving communication skills	*Interdisciplinary Collaboration in Design Education: An Exploratory Study of Design and Engineering Students' Perceptions* by Lee et al. (2020).	Highlights the importance of communication in interdisciplinary collaboration and the advantages of developing communication skills among design students.
Enhancing understanding of user needs	*Science and design collide: Benefits of interdisciplinary research and collaboration* by University of Hawaii Sea Grant (2022)	This paper highlights the benefits of interdisciplinary research and collaboration in science and design, showing how such collaboration can enhance understanding of user needs.
Improving communication skills	*Coding IxD: Enabling Interdisciplinary Education by Sparking Reflection* by Sörries et al. (2022).	This article discusses how sparking reflection can enable interdisciplinary education and shows how these methods can improve communication skills.

Methodology

This research is based on the application of an experimental method and is hypothesis-driven. A mixed-method approach (both quantitative and qualitative) has been employed. The data collection method for the quantitative part includes a questionnaire, observation of students during the problem-solving and ideation process, while the qualitative part includes focus groups. In this study, to test and evaluate the main hypothesis (evaluating the impact of interdisciplinary collaboration on achieving multi-faceted ideas in design problem-solving), a comparative analysis method was used. The statistical population in this study includes all undergraduate students in industrial design programs at universities in Iran (approximately 850 students). Participants were selected using non-probability sampling (voluntary sampling), through an invitation sent via social media among sixth-semester undergraduate industrial design students at Bu-Ali Sina University in Hamedan.

Initially, two groups of 5 students (each group consisting of two female and three male students) from the sixth-semester students were selected with the aim of demonstrating the impact of interdisciplinary collaboration on the comprehensiveness of design solutions during the ideation phase. The reason for selecting students from this specific semester was their completion of courses related to the design process and problem-solving, and their familiarity with related methods. Group one was defined as the non-interdisciplinary group (consisting of five industrial design students), while group two was defined as the interdisciplinary group (consisting of two industrial design students, one graphic design student, one painting student, and one management student). In this experiment, the factor of *comprehensiveness of design solutions* was considered as the main variable, which was measured to assess the impact of interdisciplinary collaboration.

Before the experiment began, using a one-on-one interview method, participants' familiarity with the problem-solving process was assessed, and the equal distribution of student abilities and relative equality within each group were ensured. Both groups were provided with a similar design problem titled *Proposing solutions (concepts) to increase public happiness in society*.

The reason for choosing this problem was its broad scope and the potential for ideation from various perspectives, the need for a comprehensive understanding, integrating viewpoints, and teamwork, so that students from disciplines other than industrial design could also easily participate in suggesting proposed concepts.

In the first phase of the experiment, both groups were asked to ideate on the given topic for a fixed time (10 minutes) using the brainstorming method. Then, in the second phase, they were asked to select four concepts from the ideas generated during the brainstorming session and create a cognitive mapping diagram in a fixed time (20 minutes). Before starting the experiment, explanations were given to the students regarding the rules and how to use brainstorming and create the cognitive mapping diagram to ensure their familiarity with both methods. Despite the participating students from other disciplines (painting, graphic design, management) not being familiar with the conventional ideation methods used in industrial design, the level of participation in group work for both groups were assessed as acceptable.

Figure 1: *Exploring Design Problem-Solving: Interdisciplinary vs. Non-Interdisciplinary Groups in Action.*

Cognitive mapping is a method of visually presenting information, which serves as a tool for understanding information and making decisions based on it. This method's layout and structure are designed so that no main concept is required as a focal point in the visual presentation, and it rarely involves images. Instead, the nodes in the cognitive map are exactly formed from words and phrases derived from the conversation between participants (Hanington & Martin, 2012). The purpose of employing this method in this study was to demonstrate how students think about the problem space and visualize how they process it. In the cognitive map diagram, students' mental patterns in the problem-solving process and their prioritization of concepts were revealed through the size of the drawn circles and the relationships between the factors, which could expose the fundamental nature of the problem. Additionally, since the essence of the connections between the elements of the cognitive map is based on causal relationships, students were asked to indicate the relationships between ideas and key phrases using one-way arrows so that, in addition to clarifying how the connections were made, the extent to which references were made to different ideas could be identified. In fact, by using this method, the process of recording qualitative data obtained from the brainstorming phase throughout the experiment was more effective and occurred in a shorter time. Figure 2 shows the cognitive map diagram from the control group (non-interdisciplinary group), and Figure 3 shows the cognitive map diagram from the interdisciplinary group.

After the experiment time was completed, the ideas generated by each group were collected, and the maps were used as an effective tool to summarize students' opinions and evaluate the ideas in the next phase.

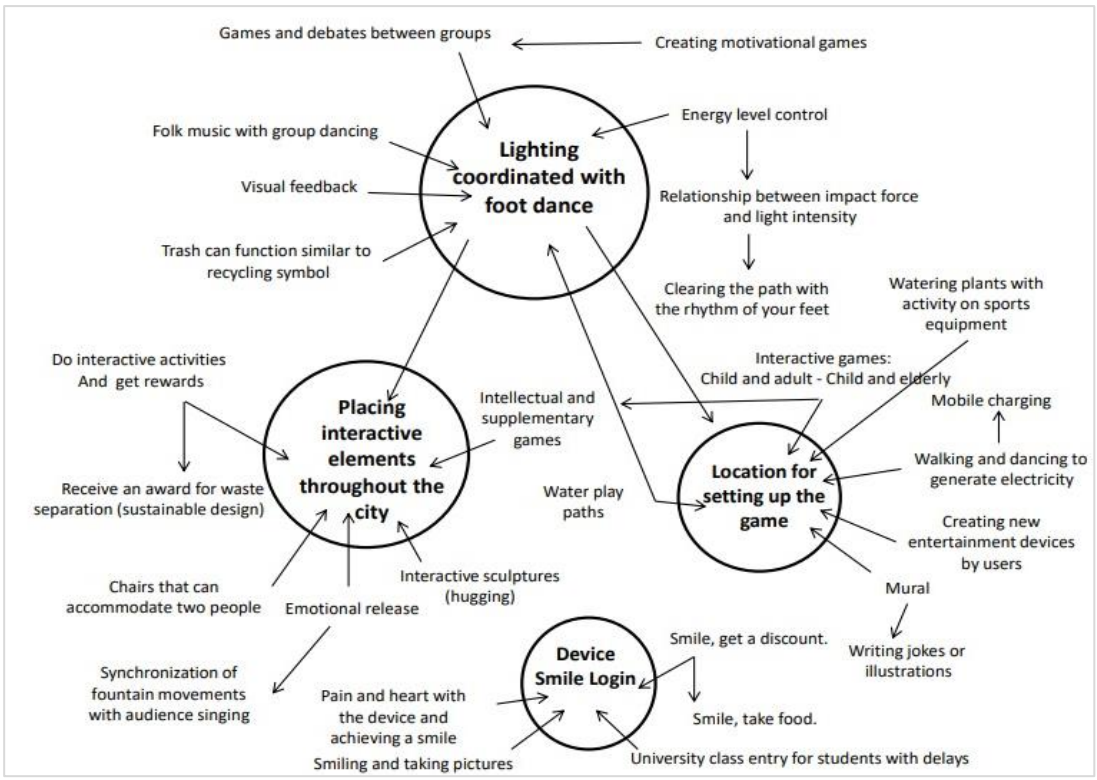

Figure 2: *Cognitive Mapping Diagram of the Control Group (Source: Author).*

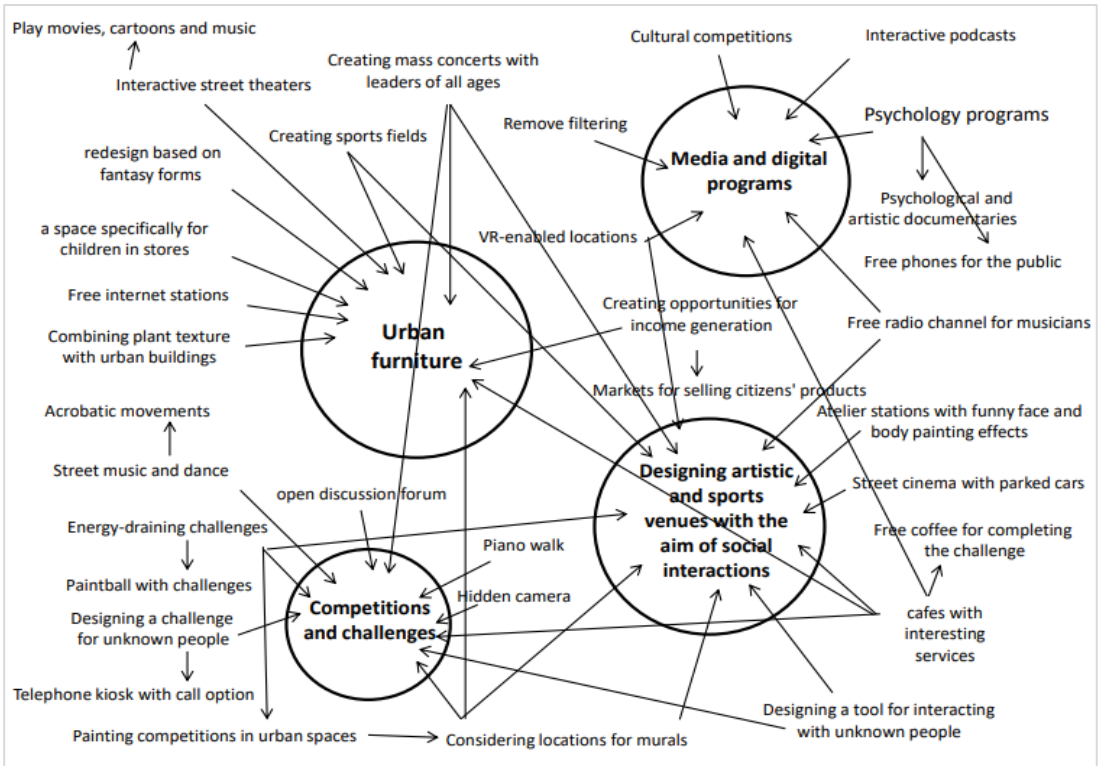

Figure 3: *Cognitive Mapping Diagram of the Interdisciplinary Group (Source: Author).*

Data Collection

The data obtained from this experiment includes two phases of the study (Phase 1: Brainstorming and Phase, 2: Cognitive Mapping). In the brainstorming phase, the ideas generated by the interdisciplinary group were quantitatively greater, and the percentage of concepts related to service design (58.8%) compared to product design was significantly higher than that of the non-interdisciplinary group (11.1%; Table 2). In the second evaluation phase, the qualitative data obtained from the cognitive mapping phase, which was organized as a written diagram by each group, was quantitatively analyzed using the expert evaluation method.

Table 2: *Ideas Obtained from Both Groups in the Brainstorming Phase (Source: Author).*

Brainstorming (First 10 Minutes of the Experiment)	Ideas Related to Product Design	Idea Related of Service Design	Total Ideas
Group 1 (Non-Interdisciplinary)	8	1	9
Group 2 (Interdisciplinary)	7	10	17

Data Analysis and Interpretation

In this phase, to measure the level of integration of various perspectives in ideation, which was defined as one of the main benefits of interdisciplinary collaboration in the research study phase, a set of qualitative factors aligned with the research objectives was defined. These factors included five main criteria: *integration of diverse perspectives, alignment with the design problem, consideration of different user needs in ideation, diversity in ideation, and comprehensiveness (whether the students had a complete and comprehensive understanding of the problem and considered all aspects of the topic)*. Using a 5-point Likert scale, different levels of integration for each qualitative factor were identified (For example, the number *1* represents minimum diversity in ideation, while the number *5* represents high diversity in ideation).

The evaluation of ideas was conducted using the expert evaluation method by a team of three senior industrial design experts actively involved in research and professional design. Since this method is largely dependent on the evaluators' subjective judgment, a two-hour session was held with all members of the evaluation group before the assessment and scoring of ideas. This was to ensure a shared understanding of the rating scale and criteria for each qualitative factor and to resolve any potential ambiguities. Subsequently, each evaluator individually assessed the four ideas presented in the cognitive map of each group, and finally, by merging and summarizing the tables from all three experts and calculating the average for each factor, the scores obtained for each group were presented separately (Tables 3 and 4).

Table 3: *Table Obtained from the Expert Evaluation of Ideas from Group 1 (Non-Interdisciplinary Group).*

Idea number	Integration of Diverse Perspectives	Alignment with the Design Problem	Considering Different User Needs in the Idea	Ideation Diversity	Comprehensiveness
1	2	2	2	1	2
2	3	4	3	3	3
3	4	3	3	4	3
4	3	4	3	3	3
Total	**12**	**13**	**11**	**11**	**11**

In this phase, an independent t-test was used with the help of SPSS statistical software to compare the means obtained from the two groups. The t-test is a statistical method used to compare the means of two groups. This method allows for analyzing the level of integration of various perspectives in ideation between the two groups (interdisciplinary students and industrial design students) and comparing the results obtained from them. This test is commonly used in studies where the goal is to compare two groups with each other. Table 5 presents the descriptive information obtained from the two groups, including the mean, number of variables, and standard deviation.

Table 4: *Table Obtained from the Expert Evaluation of Ideas from Group 2 (Interdisciplinary Group).*

Idea number	Integration of Diverse Perspectives	Alignment with the Design Problem	Considering Different User Needs in the Idea	Ideation Diversity	Comprehensiveness
1	4	3	3	4	4
2	3	4	4	3	3
3	5	5	5	4	5
4	4	3	3	3	3
Total	**16**	**15**	**15**	**14**	**15**

Table 5: *Descriptive Data of the Two Participating Groups (Source: Author).*

VAR0002		N	Mean	Std. Deviation	Std. Error Mean
VAR00004	1	5	11.6000	.89443	.40000
	2	5	15.0000	.70711	.31623

A necessary condition for conducting this test is the equality of variances between the two groups. To test the equality of variances, Levene's test was used in SPSS software. A value of 0.318 (greater than 0.05) indicates that there is no significant difference between the variances of the two groups (i.e., the variances of the two groups are equal). Therefore, the t-test can be used to compare the means of the two groups (Table 6).

Table 6: *ndependent t-test to Compare the Means of the Two Groups (Source: Author).*

		Levenes's Test for Equality of Variances		t-test for Equality of Means				95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR0004	Equal variances assumed	1.133	.318	-6.668	8	.000	-3.4000	.50990	-4.57584	-2.22416
	Equal variances not assumed			-6.668	7.596	.000	-3.4000	.50990	-4.58683	-2.21317

The significance level (sig) in this test is 0.000 (less than 0.05), which indicates a significant difference between the means of the two groups participating in the test. This means that the main hypothesis is accepted, and the null hypothesis is rejected. (The null hypothesis in this study is: interdisciplinary collaboration does not affect the comprehensiveness of ideas in the problem-solving process).

Ideation and Development of Proposed Undergraduate Industrial Design Program

Based on the findings of this study, it is evident that interdisciplinary collaboration enhances the comprehensiveness and diversity of design solutions in problem-solving processes. Therefore, this section proposes a refined undergraduate industrial design program that incorporates interdisciplinary methodologies to foster holistic and innovative design thinking among students.

Key Elements of the Proposed Program

1. Integration of Interdisciplinary Collaboration: To ensure students benefit from diverse perspectives, interdisciplinary teamwork should be systematically embedded into the curriculum. This can be achieved by introducing collaborative projects with students from fields such as graphic design, management, and engineering.

2. Incorporation of Design Thinking & Systems Thinking: Given the cognitive mapping analysis, students demonstrated better structuring of ideas when engaging in systems thinking. Thus, courses focusing on design thinking methodologies should be reinforced, emphasizing problem-framing, iterative ideation, and user-centric solutions.

3. Balance Between Product and Service Design: The experiment indicated a significantly higher inclination toward service design in interdisciplinary groups. This suggests that modern industrial design education should place equal importance on service design alongside product design to better align with contemporary industry demands.

4. Collaborative Ideation and Cognitive Mapping: The study demonstrated that cognitive mapping helped students better visualize relationships between design elements. Therefore, integrating cognitive mapping as a standard tool for ideation sessions in coursework would enhance students' ability to develop comprehensive design solutions.

Implementation Strategy

To implement this program, universities can:

- Modify existing curricula to introduce interdisciplinary courses and collaborative projects.
- Encourage faculty from various disciplines to co-teach certain design subjects.
- Develop assessment methods that evaluate both individual creativity and team-based problem-solving skills.

Discussion and Conclusion

The results of the experiment indicate that the use of interdisciplinary collaboration in design education improves students' ability to provide comprehensive solutions in the problem-solving process (confirming the main hypothesis of the research). The significant difference between the means of the two groups, obtained from the independent t-test, shows that the interaction and collaboration between students from different fields is effective in increasing diversity and creativity in the design process, which ultimately leads to an improvement in students' ability to provide comprehensive solutions in the problem-solving process.

According to the expert evaluation conducted, interdisciplinary students performed better than non-interdisciplinary students in the five main factors defined in this study, including factors such as integration of diverse perspectives, alignment with the design problem, consideration of different user needs, ideation diversity, and comprehensiveness. This indicates the potential of interdisciplinary collaboration in producing comprehensive and holistic solutions in design. Based on the cognitive mapping drawn by both groups, the expansion of the topic and the establishment of connections between various elements of an idea and other ideas in the interdisciplinary group were better and more structured. This demonstrates a more precise alignment of ideas with the design problem and the ability to connect different elements of ideation in the design process. In other words, the collaboration between designers and individuals from other disciplines, by leveraging a broader spectrum of knowledge and combining skills, leads to more creative solutions and improves the quality of proposed solutions. In the interdisciplinary group, the need to establish connections between the elements of an idea with other ideas and expand the topic by encouraging systems thinking in students led to a better understanding of how different factors influence one another, thereby improving the design process.

Additionally, interdisciplinary collaboration can serve as an effective factor in generating ideas related to service design. This collaboration facilitates considering the perspectives and needs of various users, resulting in an increase in the number and diversity of ideas in this area. In the experiment conducted, the ratio of service design-related ideas to product design ideas in the non-interdisciplinary group was 1.11, while in the interdisciplinary group, it was 58.8.

The greater number of service design-related ideas compared to product design ideas indicates that in today's world, focusing on service design and providing comprehensive solutions in this area is very important and essential. These results can ultimately contribute to the development and improvement of existing services, leading to increased user satisfaction.

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