



Promoting Students' Scientific Thinking through Design-Oriented Activities in a Modern Educational Environment

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ABSTRACT

This study examined the effectiveness of design-oriented activities in promoting students' scientific thinking in a modern educational environment. A quasi-experimental pre-test–post-test design was applied to 60 first-year bachelor's students in Design, divided into experimental and control groups. The experimental group completed the “Design Thinking and Scientific Research” course, while the control group followed the standard curriculum. Data were collected using a scientific thinking diagnostic tool, a design thinking engagement questionnaire, and expert assessment of design projects. The results showed significant improvement in analytical skills, criticality, systematicity, hypotheticality, and evidence-based reasoning among the experimental group. The findings indicate that design thinking can strengthen scientific thinking in higher education.

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1. INTRODUCTION

The development of scientific thinking has become an essential goal of contemporary higher education (Fatmala et al., 2023; Darojah et al., 2024; Rizomatovich, 2026; Solihah et al., 2024). In an era marked by rapid technological change, complex social problems, and the increasing availability of information, students are expected not only to acquire knowledge but also to analyze problems systematically, evaluate evidence critically, formulate hypotheses, and justify conclusions through logical reasoning. Scientific thinking is therefore not limited to the mastery of scientific facts, but refers to a set of cognitive abilities that enable learners to investigate problems, question assumptions, interpret data, and construct evidence-based explanations. These abilities are particularly important in higher education because students are required to engage with open-ended problems whose solutions cannot be obtained through memorization alone.

The formation of scientific thinking requires learning environments that involve students in active inquiry, problem solving, and knowledge construction (Balleisen et al., 2024; Chang et al., 2024). Project-based learning can strengthen student development because it places learners in authentic contexts where theoretical knowledge must be applied to practical situations (Balleisen et al., 2024; Chang et al., 2024). Integrated project-based curricula can also support meaningful learning by connecting conceptual understanding with practical action (Paul et al., 2023). These findings suggest that scientific thinking develops most effectively when students are not positioned as passive recipients of information, but as active investigators who define problems, collect information, test ideas, and reflect on the outcomes of their work.

In this context, design-oriented activities offer a promising pedagogical approach. Design is not merely a professional practice concerned with the creation of visual or material products, but can also be understood as a method of inquiry that requires observation, interpretation, experimentation, and revision. Design thinking encourages learners to explore user needs, define problems, generate alternative solutions, create prototypes, test them, and improve their ideas through feedback (Razzouk and Shute, 2012; Panke, 2019). These stages are closely related to the logic of scientific inquiry because empathizing with users requires the collection of qualitative data, defining a problem requires analysis and synthesis, ideation involves hypothesis generation, prototyping allows ideas to be materialized and tested, and testing requires evidence-based evaluation.

Previous research has supported the pedagogical value of design thinking in education. Design thinking has been described as a cognitive and educational approach that combines analytical and creative processes (Razzouk and Shute, 2012). It also has the potential to support learner-centered education, problem-solving, and reflection (Panke, 2019). In educational practice, design thinking can serve as a creative approach for addressing complex problems of teaching and learning (Henriksen et al., 2017). Recent studies have shown that design thinking can improve creativity, motivation, problem-solving ability, and student engagement (Guaman-Quintanilla et al., 2023; Liu and Li, 2023; Liu et al., 2024; Yu et al., 2024). In STEM and STEAM education, design-based approaches have been used to connect scientific concepts with authentic tasks, making learning more meaningful and applicable (Cook and Bush, 2018; Galoyan et al., 2022; Kijima et al., 2021; Öztürk and Korkut, 2023). However, despite this growing body of research, the relationship between design thinking and scientific thinking remains insufficiently explored, especially in the context of higher design education. Many studies focus on creativity, innovation, problem solving, or

motivation, while fewer studies examine whether participation in structured design-oriented activities can directly strengthen the components of scientific thinking. These components include analytical skills, criticality, systematicity, hypotheticality, and evidence-based reasoning, which are the main dimensions examined in the present study. This gap is important because design students are often trained to produce creative outcomes, but their ability to justify design decisions scientifically, analyze user data, formulate hypotheses, and evaluate evidence is equally important for professional development.

The present study addresses this gap by examining the effectiveness of a structured course entitled “Design Thinking and Scientific Research” in promoting scientific thinking among first-year bachelor’s students majoring in Design. The course was based on the model of design thinking, consisting of Empathize, Define, Ideate, Prototype, and Test (EDIPT). It was designed to integrate design-oriented activities with scientific research practices. Through user research, empathy mapping, idea generation, prototyping, testing, and reflective analysis, students were expected to experience design not only as a creative process but also as a form of inquiry.

Accordingly, the purpose of this study was to theoretically substantiate and empirically examine the effectiveness of design-oriented activities in developing students’ scientific thinking in a modern educational environment. Specifically, the study investigated whether students who participated in the “Design Thinking and Scientific Research” course showed greater improvement in scientific thinking than students who followed the standard curriculum. The study also examined the relationship between students’ engagement in design thinking processes and the development of scientific thinking, as well as the extent to which expert evaluations of design projects were associated with students’ scientific thinking outcomes.

2. LITERATURE REVIEW

Scientific thinking is a multidimensional cognitive capacity that enables students to analyze problems, evaluate information, formulate hypotheses, and construct conclusions based on evidence. In higher education, scientific thinking is not limited to the acquisition of scientific facts, but also includes the ability to investigate problems, interpret data, question assumptions, and justify decisions through systematic reasoning. This capacity is important for university students because contemporary learning increasingly requires engagement with complex, open-ended problems that cannot be solved through memorization alone.

The development of scientific thinking requires learning experiences that involve students in inquiry, problem identification, data collection, analysis, and reflection. Project-based learning provides an appropriate context for this development because it connects theoretical knowledge with authentic problems and practical tasks (Balleisen *et al.*, 2024; Chang *et al.*, 2024). In project-based learning, students are encouraged to apply concepts, make decisions, collaborate with others, and reflect on the outcomes of their actions (Paul *et al.*, 2023). These learning conditions are relevant to the development of scientific thinking because they position students as active knowledge constructors rather than passive recipients of information (Balleisen *et al.*, 2024; Chang *et al.*, 2024).

Design thinking has been widely discussed as a pedagogical approach that supports inquiry, creativity, experimentation, and problem-solving. Design thinking involves understanding problems, generating possible solutions, testing ideas, and improving outcomes through

iterative processes (Razzouk and Shute, 2012). In educational contexts, design thinking provides opportunities for learner-centered problem solving, reflective practice, and creative exploration (Panke, 2019). Design thinking can also help educators and students address complex educational problems because it combines creative thinking with structured inquiry (Henriksen et al., 2017). Therefore, design thinking is relevant not only as a professional design method but also as an educational strategy for developing higher-order thinking.

Design-oriented learning usually follows a sequence of empathizing, defining, ideating, prototyping, and testing. The empathy stage requires students to understand user experiences and needs through observation, interviews, or other forms of qualitative inquiry. The define stage requires students to analyze collected information, identify patterns, and formulate a clear problem statement. The ideation stage encourages students to generate possible solutions based on the problem they have defined. The prototyping stage requires students to transform ideas into concrete and testable forms. The testing stage allows students to evaluate their ideas through feedback, evidence, and revision. These stages show that design thinking has a close relationship with scientific inquiry because both involve questioning, evidence gathering, testing, and refinement.

The connection between design thinking and scientific thinking can be explained through the alignment between design activities and research competencies. Empathy supports the ability to collect primary data and understand context. Problem definition supports analytical and systematic thinking because students must organize information and identify meaningful patterns. Ideation supports hypothetical reasoning because students generate possible responses to a problem. Prototyping supports evidence-oriented thinking because ideas must be transformed into forms that can be examined. Testing supports critical thinking because students must evaluate whether their assumptions are supported by feedback and data. The conceptual relationship between design thinking activities and the development of scientific thinking is presented in **Figure 1**.

Empirical research has shown that design thinking can produce positive educational outcomes. Design thinking has a positive effect on student learning, especially when it is implemented over a sustained period and supported by structured learning activities (Yu et al., 2024). In higher education, design thinking can support problem-solving and creativity by involving multiple actors in the learning and innovation process (Guaman-Quintanilla et al., 2023). Making-based activities can promote students' design thinking and creativity in information technology education (Liu and Li, 2023). The design thinking model can also improve creativity self-efficacy, inventive problem-solving skills, and technology-related motivation among pre-service teachers (Liu et al., 2024). These findings indicate that design thinking has potential as an educational approach for strengthening higher-order thinking.

Design thinking has also been applied in STEM and STEAM education. Integrated STEAM learning can use design thinking to connect science, technology, engineering, arts, and mathematics through meaningful activities (Cook and Bush, 2018). Design thinking can cultivate STEAM thinking by encouraging students to solve problems through interdisciplinary inquiry (Kijima et al., 2021). Science, design thinking, and computational thinking can be connected through authentic learning contexts that require students to solve real-world problems (Galoyan et al., 2022). Design thinking can also be adapted to support STEM teachers in designing and implementing learning activities for school students (Öztürk and Korkut, 2023). These studies suggest that design thinking is useful when learning requires the integration of concepts, practices, and authentic problem solving.

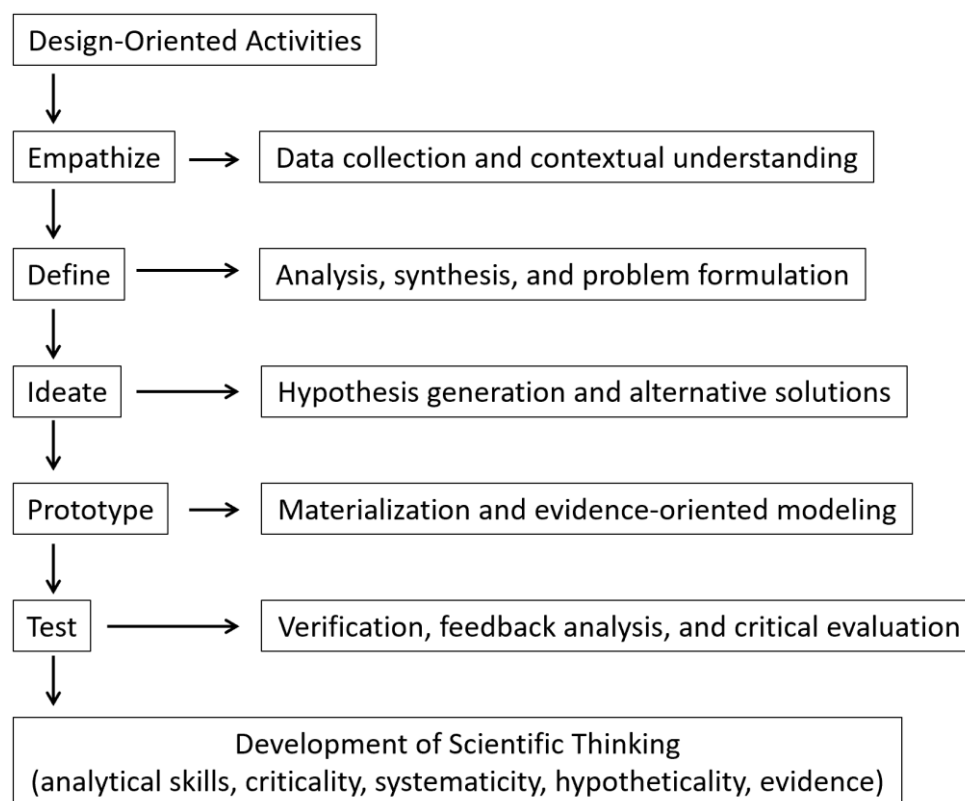


Figure 1. Conceptual framework of design thinking and scientific thinking development.

The human-centered dimension of design thinking is also important for scientific thinking. Empathy maps can support design-thinking-enhanced STEM innovation by helping students understand users' needs, perspectives, and experiences (Yeung and Ng, 2024). Empathy can help students formulate more relevant research questions because it encourages them to consider the human context of a problem (Yeung and Ng, 2024). In this sense, empathy does not replace scientific reasoning, but provides an entry point for inquiry, data collection, and problem formulation. When students understand the context and needs of users, they are more likely to collect appropriate data, evaluate evidence carefully, and develop solutions that respond to real problems.

The implementation of design thinking in education requires appropriate pedagogical conditions. Design thinking requires teachers to move from the role of knowledge transmitters to facilitators of inquiry and collaborative problem solving (Guaman-Quintanilla et al., 2023). Design thinking pedagogy also requires structured guidance, staged learning experiences, and opportunities for students to move from simple activities to more complex forms of problem solving (Wrigley and Straker, 2017). Therefore, design thinking should not be reduced to brainstorming or creative production alone. It should be organized as a systematic pedagogical process that includes problem analysis, evidence gathering, testing, and reflection.

Although previous studies have documented the positive effects of design thinking on creativity, engagement, problem solving, and STEM learning, its specific contribution to scientific thinking in higher design education remains insufficiently examined. Existing research has more frequently emphasized creativity, innovation, motivation, and problem-solving outcomes than the direct development of analytical skills, criticality, systematicity,

hypotheticality, and evidence-based reasoning. This gap is important because design students need not only to create original visual or material outcomes, but also to justify design decisions, analyze user data, formulate hypotheses, and evaluate evidence. Therefore, this study positions design thinking as a pedagogical pathway for developing scientific thinking among undergraduate design students.

3. METHODS

This study used a quasi-experimental pre-test–post-test design with a non-equivalent control group. This design was selected because the participants were organized in existing academic cohorts, so random assignment could not be applied without disrupting the normal educational process. The independent variable was the teaching methodology, namely participation in the “Design Thinking and Scientific Research” course. The dependent variables were the five components of scientific thinking: analytical skills, criticality, systematicity, hypotheticality, and evidence-based reasoning. The overall research design and procedure are presented in **Table 1**.

The study was conducted during the 2025–2026 academic year. A total of 60 first-year bachelor’s students majoring in Design participated in the study. The experimental group consisted of 30 students who completed the “Design Thinking and Scientific Research” course, while the control group consisted of 30 students from a parallel cohort who followed the standard design curriculum. Participants were selected based on enrollment in the target program, absence of previous formal training in design thinking or research methodology, willingness to participate in all stages of data collection, and full attendance during the intervention period. Baseline equivalence between groups was examined before the intervention using independent-samples t-tests.

The experimental group completed the “Design Thinking and Scientific Research” course, which was designed to integrate design thinking with scientific research activities. The course was structured around the EDIPT model, consisting of Empathize, Define, Ideate, Prototype, and Test. This model was selected because design thinking involves understanding problems, generating solutions, testing ideas, and revising outcomes through iterative inquiry ([Razzouk and Shute, 2012](#); [Panke, 2019](#)). The course lasted 120 academic hours, consisting of 60 classroom hours and 60 hours of independent work. The structure of the intervention course is presented in **Table 2**.

During the course, students completed four main projects. The first project required students to conduct user research and produce an empathy map, persona, and problem statement. The second project required students to generate ideas and create rapid prototypes based on the identified problem. The third project was a group design project in which students completed the full design thinking cycle from user research to prototype testing. The fourth project was a reflective essay in which students analyzed their learning process, changes in thinking, and professional development. These activities were intended to connect design practice with scientific inquiry through data collection, hypothesis formulation, testing, and reflection.

Table 1. Research design and procedure.

COMPONENT	DESCRIPTION
Research design	Quasi-experimental pre-test–post-test design with a non-equivalent control group
Setting	Faculty of Fine Arts and Design, Borys Grinchenko Kyiv Metropolitan University, Ukraine
Participants	60 first-year bachelor’s students majoring in Design
Experimental group	30 students who participated in the “Design Thinking and Scientific Research” course
Control group	30 students who followed the standard curriculum without design thinking integration
Pre-test	Scientific thinking diagnostic and design thinking engagement questionnaire
Intervention period	September 2025–March 2026
Post-test	Re-administration of the same instruments and expert evaluation of final design projects
Data analysis	Descriptive statistics, paired-samples t-test, independent-samples t-test, mixed-design ANOVA, chi-square test, and Pearson correlation
Ethical procedure	Informed consent, voluntary participation, anonymized data, and institutional approval

Table 2. Structure of the “design thinking and scientific research” course.

MODULE	FOCUS	MAIN ACTIVITIES	HOURS
Module 1	Empathy and problem definition	Introduction to design thinking, user observation, interviews, empathy maps, personas, data analysis, and problem formulation	40
Module 2	Ideation and prototyping	Brainstorming, SCAMPER, mind mapping, idea selection, rapid prototyping, and prototype presentation	40
Module 3	Testing and reflection	Prototype testing, feedback collection, data analysis, project revision, reflection, and final presentation	40
Total	Full EDIPT-based intervention	Classroom activities and independent project work	

Scientific thinking was measured using an adapted diagnostic instrument based on five components: analytical skills, criticality, systematicity, hypotheticality, and evidence-based reasoning. The design thinking engagement questionnaire measured five dimensions: empathy, ideation, prototyping, testing, and reflection. The expert assessment rubric was used to evaluate the quality of final design projects completed by the experimental group. The instruments and scoring criteria used in the study are summarized in **Table 3**.

The scientific thinking diagnostic consisted of 25 statements rated on a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Each component consisted of five items, with subscale scores ranging from 5 to 25 and a total score ranging from 25 to 125. The instrument was translated into Ukrainian using a forward–backward translation procedure. Content validity was assessed by five experts, and the scale demonstrated excellent internal consistency, with Cronbach’s alpha values of 0.90 at pre-test and 0.92 at post-test. Test–retest reliability over a two-week interval showed an intraclass correlation coefficient of 0.86.

Table 3. Instruments and scoring criteria.

INSTRUMENT	DIMENSIONS	NUMBER OF ITEMS/CRITERIA	SCORE RANGE	INTERPRETATION/FUNCTION
Scientific thinking diagnostic	Analytical skills, criticality, systematicity, hypotheticality, evidence-based reasoning	25 items	25–125	Low: 25–75; medium: 76–100; high: 101–125
Design Thinking in Education questionnaire	Empathy, ideation, prototyping, testing, reflection	20 items	20–100	Low: 20–59; medium: 60–79; high: 80–100
Expert assessment rubric	Originality, justification, and technological competence	3 criteria	3–30	Higher scores indicate stronger project quality

The Design Thinking in Education questionnaire consisted of 20 items rated on a five-point frequency scale ranging from 1 = never to 5 = always. Each dimension consisted of four items, with dimension scores ranging from 4 to 20 and a total engagement score ranging from 20 to 100. The questionnaire showed strong internal consistency, with Cronbach's alpha values of 0.89 at pre-test and 0.91 at post-test. Confirmatory factor analysis supported the five-factor structure of the instrument.

The final projects of the experimental group were evaluated by five independent experts who were blind to the study hypotheses and students' pre-test scores. The expert panel consisted of three faculty members and two practicing designers. Each project was assessed using three criteria: originality, justification, and technological competence. The expert assessment rubric is presented in **Table 4**.

The expert evaluation was used to examine whether students' design project quality was associated with scientific thinking and design thinking engagement. Inter-rater reliability was evaluated using the intraclass correlation coefficient and agreement statistics. The average-measure intraclass correlation coefficient for the total expert score indicated good to excellent reliability.

Table 4. Expert assessment rubric for design projects.

CRITERION	DESCRIPTION	SCORE RANGE
Originality	Novelty of the idea, creative approach, and non-standard solution reasoning	1–10
Justification	Logical reasoning, evidence, coherence, and correspondence to the problem	1–10
Technological competence	Feasibility, quality of execution, realism of implementation, and detailed workmanship	1–10
Integral project score	Sum of originality, justification, and technological competence	3–30

The course was designed to align each stage of design thinking with specific scientific competencies. This alignment was important because the study did not treat design thinking as a separate creative activity, but as a pedagogical process connected to research-based learning. The relationship between design thinking stages, research activities, and scientific competencies is presented in **Table 5**.

Table 5. Alignment between design thinking stages and scientific competencies

DESIGN THINKING STAGE	RESEARCH ACTIVITIES	SCIENTIFIC COMPETENCIES
Empathize	Formulation of preliminary research questions, interviews, observations, and qualitative data collection	Ability to collect primary data, understand context, and apply ethical principles
Define	Analysis and synthesis of collected data, pattern identification, and problem formulation	Analytical skills, systematic thinking, generalization, and hypothesis formulation
Ideate	Generation of alternative solutions based on the formulated problem	Creativity, divergent thinking, and hypothetical reasoning
Prototype	Creation of models to test ideas and assumptions	Evidence-oriented thinking, experimental modeling, and transformation of abstract ideas into concrete forms
Test	Prototype testing, feedback collection, and analysis of results	Criticality, verification, data interpretation, and evidence-based revision

Data were collected in four stages. In the first stage, all participants completed the scientific thinking diagnostic and design thinking engagement questionnaire before the intervention. In the second stage, the experimental group completed the “Design Thinking and Scientific Research” course, while the control group followed the standard curriculum. In the third stage, both groups completed the same instruments after the intervention, and the final design projects of the experimental group were evaluated by independent experts. In the fourth stage, all data were checked, coded, and analyzed statistically.

All statistical analyses were conducted using SPSS Statistics 26. Descriptive statistics were used to calculate means and standard deviations. Paired-samples t-tests were used to examine within-group changes from pre-test to post-test. Independent-samples t-tests were used to compare the experimental and control groups. A 2 × 2 mixed-design ANOVA was used to examine the interaction between group and time. Chi-square tests were used to compare changes in scientific thinking levels. Pearson correlation coefficients were used to examine relationships among scientific thinking, design thinking engagement, and expert assessment scores. The significance level was set at $\alpha = 0.05$, and effect sizes were interpreted using Cohen’s conventions.

The study followed ethical standards for research involving human participants. Institutional approval was obtained before data collection. Participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw at any time without penalty. Informed consent was obtained from all participants. All data were anonymized, and no identifying information was reported.

4. RESULTS AND DISCUSSION

Before examining the effect of the intervention, the dataset was screened for missing values, outliers, normality, and baseline equivalence between the experimental and control groups. The data showed a complete response rate, with no missing values in the pre-test and post-test measurements. No univariate outliers were detected based on standardized scores. The normality assumption was met for all dependent variables, and the homogeneity of variance assumption was also satisfied. These preliminary checks indicated that the dataset was appropriate for parametric statistical analysis. The equivalence of the experimental and control groups before the intervention was examined using independent-samples t-tests, and the results are presented in **Table 6**.

Table 6. Baseline comparison between experimental and control groups.

COMPONENT	EXPERIMENTAL M (SD)	CONTROL M (SD)	T(58)	P
Analytical skills	13.1 (2.7)	13.3 (2.8)	-0.28	0.781
Criticality	12.7 (3.0)	12.9 (2.9)	-0.26	0.795
Systematicity	12.3 (3.2)	12.5 (3.1)	-0.25	0.806
Hypotheticality	11.4 (2.9)	11.6 (2.8)	-0.27	0.787
Evidence-based reasoning	12.0 (2.8)	12.2 (2.9)	-0.27	0.786
Total scientific thinking	61.8 (12.1)	62.5 (11.9)	-0.23	0.819

The baseline comparison showed no statistically significant differences between the experimental and control groups in any component of scientific thinking. The experimental and control groups had similar initial scores in analytical skills, criticality, systematicity, hypotheticality, evidence-based reasoning, and total scientific thinking. This finding indicates that both groups started from a comparable level before the intervention. Therefore, any substantial difference observed at the post-test stage can be more reasonably interpreted in relation to the intervention rather than initial group differences.

After the intervention, the experimental group showed clear improvement in all components of scientific thinking, while the control group showed only minimal changes. The experimental group participated in the "Design Thinking and Scientific Research" course, whereas the control group followed the standard curriculum without design thinking integration. The pre-test and post-test comparison of scientific thinking components for both groups is presented in **Table 7**.

The experimental group experienced statistically significant improvement in all five components of scientific thinking. Analytical skills increased from 13.1 to 18.6, criticality increased from 12.7 to 18.0, systematicity increased from 12.3 to 18.2, hypotheticality increased from 11.4 to 16.9, and evidence-based reasoning increased from 12.0 to 17.8. The total scientific thinking score increased from 61.8 to 90.1, with a mean difference of 28.3 points. The effect sizes for the experimental group were very large, ranging from 1.65 to 2.45. These findings indicate that participation in design-oriented activities was associated with substantial improvement in students' scientific thinking.

In contrast, the control group did not show statistically significant improvement in any component of scientific thinking. The total scientific thinking score in the control group increased only slightly from 62.5 to 63.6, with a small effect size. The same pattern was found

for all five components, where the mean differences ranged only from 0.2 to 0.3 points. This contrast between the experimental and control groups suggests that the improvement observed in the experimental group was not merely the result of ordinary academic maturation or repeated testing. Instead, the results indicate that the structured integration of design thinking into project-based activities played an important role in strengthening students' scientific thinking.

Table 7. Pre-test and post-test comparison of scientific thinking components.

Component	Group	Pre-test M (SD)	Post-test M (SD)	Mean difference	t(29)	Cohen's d	p
Analytical skills	Experimental	13.1 (2.7)	18.6 (2.2)	5.5	9.34	1.78	<0.001
Analytical skills	Control	13.3 (2.8)	13.6 (2.7)	0.3	0.51	0.09	0.613
Criticality	Experimental	12.7 (3.0)	18.0 (2.5)	5.3	8.76	1.65	<0.001
Criticality	Control	12.9 (2.9)	13.1 (2.8)	0.2	0.34	0.06	0.734
Systematicity	Experimental	12.3 (3.2)	18.2 (2.6)	5.9	10.21	1.88	<0.001
Systematicity	Control	12.5 (3.1)	12.7 (3.0)	0.2	0.32	0.06	0.751
Hypotheticality	Experimental	11.4 (2.9)	16.9 (2.7)	5.5	9.05	1.70	<0.001
Hypotheticality	Control	11.6 (2.8)	11.8 (2.9)	0.2	0.31	0.06	0.761
Evidence-based reasoning	Experimental	12.0 (2.8)	17.8 (2.5)	5.8	9.87	1.85	<0.001
Evidence-based reasoning	Control	12.2 (2.9)	12.4 (2.8)	0.2	0.33	0.06	0.742
Total scientific thinking	Experimental	61.8 (12.1)	90.1 (10.4)	28.3	12.67	2.45	<0.001
Total scientific thinking	Control	62.5 (11.9)	63.6 (11.5)	1.1	0.46	0.09	0.647

The greatest improvement in the experimental group was found in total scientific thinking, followed by systematicity and evidence-based reasoning. The increase in systematicity suggests that students became better able to understand relationships among different elements of a problem, organize information, and construct a more holistic view of design situations. This improvement is consistent with the logic of design thinking, in which students analyze information, define problems, and move iteratively from problem understanding to solution development (Razzouk and Shute, 2012; Panke, 2019). The improvement is also consistent with design thinking pedagogy, which emphasizes structured movement from simple activities to more complex forms of problem solving (Wrigley and Straker, 2017). The increase in evidence-based reasoning reflects the emphasis of the course on prototyping, testing, feedback collection, and revision, which are central processes in design-based scientific learning (Ladachart et al., 2022). Through these activities, students were not only

asked to create design products but also to justify their decisions based on data and user responses. These findings support the argument that design thinking can function as more than a creative method. In this study, design thinking operated as a structured inquiry process that encouraged students to move from observation to problem formulation, from idea generation to prototyping, and from testing to evidence-based revision. This process is closely related to scientific thinking because students were required to ask questions, collect information, make assumptions, examine evidence, and refine their conclusions. The results, therefore, strengthen the theoretical position that design thinking can support higher-order thinking when it is implemented through systematic, sustained, and reflective learning activities (Razzouk and Shute, 2012; Panke, 2019; Yu et al., 2024).

The large effect sizes should also be interpreted in relation to the duration and structure of the intervention. The course lasted 120 academic hours and was implemented over one academic period from September 2025 to March 2026. This long-term implementation gave students sufficient time to experience the full cycle of design thinking, including empathy research, problem definition, ideation, prototyping, testing, and reflection. Previous research suggests that design thinking produces stronger educational effects when it is implemented over a sustained period and supported by structured learning activities (Yu et al., 2024). Therefore, the improvement found in the experimental group can be understood as the result of repeated engagement with research-oriented design tasks rather than short-term exposure to isolated creative activities.

The improvement in scientific thinking was also reflected in the distribution of students across low, medium, and high levels. Before the intervention, more than half of the experimental group was classified at the low level of scientific thinking. After the intervention, the number of students at the low level decreased sharply, while the number of students at the high level increased substantially. The distribution of scientific thinking levels before and after the intervention is presented in **Table 8**.

Table 8. Distribution of scientific thinking levels by group.

LEVEL	EXPERIMENTAL	EXPERIMENTAL	CONTROL	CONTROL
	PRE-TEST	POST-TEST	PRE-TEST	POST-TEST
Low	16 (53.3%)	3 (10.0%)	15 (50.0%)	14 (46.7%)
Medium	10 (33.3%)	8 (26.7%)	11 (36.7%)	12 (40.0%)
High	4 (13.3%)	19 (63.3%)	4 (13.3%)	4 (13.3%)

The distribution pattern confirms that the intervention not only increases average scores, but also shifts the overall level of students' scientific thinking. In the experimental group, the proportion of students at the high level increased from 13.3% to 63.3%, while the proportion of students at the low level decreased from 53.3% to 10.0%. In contrast, the control group showed almost no meaningful change, with the high-level category remaining at 13.3% in both the pre-test and post-test. The change in the experimental group was statistically significant, while the change in the control group was not statistically significant.

This shift is important because it shows that the course affected not only students who were already relatively strong, but also students who initially had weaker scientific thinking skills. The movement from low to medium and high levels suggests that repeated engagement with design-oriented inquiry can help students develop more systematic and evidence-based ways of thinking. The structure of the intervention may have contributed to this result

because students were required to collect user data, analyze problems, create prototypes, test assumptions, and reflect on outcomes throughout the course. In other words, the course gave students repeated opportunities to practice the components of scientific thinking in concrete design situations.

The largest change occurred in the high-level category of the experimental group. This result indicates that many students were able to move beyond basic engagement with project tasks and develop stronger capacities for reasoning, analysis, and justification. Such a result is consistent with the idea that design-based activities can support higher-order thinking when students are required to connect creativity with inquiry and evidence. Design thinking can encourage students to move from intuitive decision-making to reasoned decision-making when learning activities require them to justify design choices through data, feedback, and reflection.

The next analysis examined students' engagement in design thinking processes. The experimental group showed substantial improvement in all five dimensions of design thinking engagement: empathy, ideation, prototyping, testing, and reflection. The control group showed only minimal changes. The pre-test and post-test comparison of design thinking engagement is presented in Table 9.

The experimental group experienced significant improvement in all dimensions of design thinking engagement. The total design thinking score increased from 52.0 to 87.1, with a mean difference of 35.1 points and a very large effect size. Reflection showed the largest effect size, followed by prototyping, empathy, testing, and ideation. This pattern suggests that the course not only improved students' ability to generate ideas but also strengthened their ability to evaluate their work, respond to feedback, and understand the needs of users.

The increase in reflection is especially significant because reflection functions as a bridge between design activity and scientific thinking. Through reflective essays, project discussions, testing reports, and feedback analysis, students were required to examine their own assumptions and evaluate the quality of their decisions. Reflection helped students understand why certain ideas worked, why others failed, and how their design decisions could be improved. This process is closely connected to systematicity and criticality because students had to organize their experiences, identify relationships among project components, and evaluate their own reasoning. The role of reflection in this process is consistent with design thinking pedagogy, which emphasizes iteration, structured learning experiences, and movement toward more complex problem solving (Wrigley and Straker, 2017).

The improvement in prototyping and testing also supports the interpretation that students became more engaged in evidence-based design activity. Prototyping required students to transform abstract ideas into concrete forms, while testing required them to evaluate those forms through user feedback. These activities made the learning process more empirical because students had to compare their expectations with actual responses from users. In this way, the design process encouraged students to treat their ideas as hypotheses that needed to be examined and revised rather than as final answers. This interpretation is consistent with design-based learning, where prototyping and testing support the development of scientific concepts through iterative experimentation and feedback (Ladachart *et al.*, 2022).

The increase in empathy shows that students became more attentive to the experiences, needs, and perspectives of users. This finding is pedagogically important because empathy

can help students formulate more meaningful problems and collect more relevant data. Empathy maps can support design-thinking-enhanced innovation because they help students understand user perspectives and connect problem-solving with human experience (Yeung and Ng, 2024). In design education, empathy is not merely an emotional attitude, but a form of contextual inquiry that allows students to understand the conditions in which design problems emerge (Yeung and Ng, 2024). By conducting interviews, observations, empathy maps, and persona development, students practiced collecting qualitative information before proposing solutions. This process helped them connect human-centered design with scientific inquiry (Yeung and Ng, 2024; Razzouk and Shute, 2012).

Table 9. Pre-test and post-test comparison of design thinking engagement.

COMPONENT	GROUP	PRE-TEST M (SD)	POST-TEST M (SD)	MEAN DIFFERENCE	T(29)	COHEN'S D	P
Empathy	Experimental	11.2 (2.8)	18.2 (2.1)	7.0	10.56	1.94	<0.001
Empathy	Control	11.4 (2.7)	11.6 (2.6)	0.2	0.34	0.06	0.734
Ideation	Experimental	12.0 (2.6)	18.6 (2.0)	6.6	9.98	1.83	<0.001
Ideation	Control	11.8 (2.7)	12.0 (2.5)	0.2	0.32	0.06	0.751
Prototyping	Experimental	9.3 (2.4)	16.5 (2.3)	7.2	10.87	1.98	<0.001
Prototyping	Control	9.5 (2.5)	9.7 (2.4)	0.2	0.31	0.06	0.758
Testing	Experimental	8.6 (2.2)	15.9 (2.4)	7.3	10.43	1.92	<0.001
Testing	Control	8.8 (2.3)	9.0 (2.2)	0.2	0.35	0.07	0.727
Reflection	Experimental	10.1 (2.7)	17.4 (2.4)	7.3	10.98	2.01	<0.001
Reflection	Control	10.3 (2.6)	10.5 (2.5)	0.2	0.33	0.06	0.744
Total design thinking	Experimental	52.0 (10.5)	87.1 (9.6)	35.1	12.15	2.34	<0.001
Total design thinking	Control	51.8 (10.3)	52.8 (10.1)	1.0	0.42	0.08	0.677

The control group showed no significant improvement in design thinking engagement. This result is expected because the control group followed the standard curriculum without systematic integration of design thinking activities. Although students in the control group were also enrolled in a design program, they did not complete the structured EDIPT-based course that required empathy research, rapid prototyping, prototype testing, and reflective analysis. The contrast between the two groups suggests that ordinary design instruction alone may not be sufficient to develop design thinking engagement unless design activities are explicitly structured around inquiry, testing, and reflection. The findings on design thinking engagement support the main results on scientific thinking. Students who became more engaged in empathy, ideation, prototyping, testing, and reflection also showed stronger development in scientific thinking. This pattern suggests that the intervention worked not only by adding new content to the curriculum, but by changing the way students approached learning and problem-solving. Design thinking activities gave students a structured process for moving from problem understanding to evidence-based revision, and this process appears to have supported the growth of scientific thinking.

The relationship between design thinking engagement and scientific thinking was further examined through correlation analysis. The analysis focused on the post-test stage because this stage reflected students' outcomes after completing the intervention. The strongest relationships were expected between testing and evidence-based reasoning, and between

reflection and systematicity, because these pairs represent closely aligned design and scientific processes. The correlation results are presented in **Table 10**. The correlation analysis showed a strong positive relationship between total design thinking engagement and total scientific thinking in the experimental group. This result indicates that students who were more actively engaged in design thinking processes also tended to achieve higher scientific thinking scores. The strongest specific relationships were found between testing and evidence-based reasoning, and between reflection and systematicity. These relationships are theoretically meaningful because testing requires students to evaluate assumptions using feedback and data, while reflection requires students to organize experience, identify patterns, and understand the logic of their own learning process. Therefore, the correlation results support the interpretation that design thinking contributed to scientific thinking through repeated cycles of inquiry, testing, and reflective analysis. The strong relationship between testing and evidence-based reasoning suggests that prototype testing was one of the most important mechanisms of the intervention. During the course, students were not only asked to create prototypes, but also to test them with users and analyze the feedback they received. This process required students to compare their initial assumptions with empirical responses. As a result, students learned that design decisions should not be based only on intuition or personal preference, but also on evidence collected from users and project contexts. This finding is consistent with the view that design thinking becomes pedagogically powerful when it includes experimentation, feedback, and revision as central learning activities ([Razzouk and Shute, 2012](#); [Panke, 2019](#)).

Table 10. Correlation among scientific thinking, design thinking engagement, and expert assessment.

RELATIONSHIP	R	P	INTERPRETATION
Total design thinking and total scientific thinking	0.86	<0.001	Strong positive correlation
Reflection and systematicity	0.78	<0.001	Strong positive correlation
Testing and evidence-based reasoning	0.80	<0.001	Strong positive correlation
Expert total score and total scientific thinking	0.77	<0.001	Strong positive correlation
Expert total score and total design thinking	0.74	<0.001	Strong positive correlation
Expert-rated justification and evidence-based reasoning	0.82	<0.001	Strong positive correlation

The strong relationship between reflection and systematicity also helps explain why systematicity showed one of the largest improvements in the experimental group. Reflection required students to examine the sequence of their design process, identify relationships among user needs, problem definitions, ideas, prototypes, and testing results, and evaluate how each stage influenced the next. Through this process, students practiced seeing design problems as systems of interconnected elements rather than isolated tasks. This finding supports the idea that design thinking can strengthen students' ability to understand complex problems when learning activities are structured around iteration and reflective inquiry ([Wrigley and Straker, 2017](#)).

The expert assessment results provided additional evidence for the effectiveness of the intervention. The final design projects of the experimental group were evaluated by five independent experts using three criteria: originality, justification, and technological competence. The expert evaluation results are presented in **Table 11**.

Table 11. Expert evaluation of design projects in the experimental group.

Criterion	M	SD	Maximum score
Originality	8.0	1.3	10
Justification	7.8	1.4	10
Technological competence	7.5	1.4	10
Integral project score	23.3	3.7	30

The expert evaluation showed that the experimental group produced design projects of generally high quality. Originality received the highest mean score, followed by justification and technological competence. This pattern suggests that students were able to generate creative ideas while also providing reasonable justification for their design decisions. Although technological competence received the lowest mean score among the three criteria, the score still indicated a relatively strong level of project execution. This result is understandable because the participants were first-year bachelor's students, so their technical mastery was still developing.

The relationship between expert evaluation and scientific thinking was also important. The expert total score was strongly correlated with total scientific thinking, indicating that students with stronger scientific thinking tended to produce higher-quality design projects. The expert total score was also strongly correlated with total design thinking engagement, suggesting that active participation in design thinking processes was associated with better project outcomes. The strongest expert-related relationship was found between expert-rated justification and evidence-based reasoning. This result shows that students who were better at reasoning with evidence were also better able to justify their design decisions in the eyes of independent experts. These findings indicate that the intervention not only improves students' self-reported thinking skills, but was also reflected in the quality of their design work. This point is important because educational interventions are sometimes criticized when outcomes rely only on questionnaire data. In this study, the questionnaire results were supported by expert evaluation of actual student projects. The convergence between scientific thinking scores, design thinking engagement, and expert assessment strengthens the validity of the findings. It suggests that the course influenced both cognitive development and practical design performance.

The combined results provide evidence that design-oriented activities can promote scientific thinking when they are organized as structured inquiry rather than as isolated creative exercises. The course required students to begin with user research, formulate problems based on collected data, generate alternative ideas, create prototypes, test solutions, and reflect on the results. This sequence helped students experience design as a research-based process. The greatest improvements in systematicity and evidence-based reasoning suggest that the most important contribution of the intervention was not only creativity, but also the development of structured and justified thinking.

The findings also have implications for higher design education. Design programs often emphasize creativity, visual expression, technical skills, and professional production. These elements remain important, but the present findings suggest that they should be accompanied by explicit training in inquiry, evidence, and reflection. Students need opportunities to ask research questions, collect user data, formulate hypotheses, test design alternatives, and justify decisions. This implication is consistent with project-based learning

research, which shows that authentic learning contexts can connect conceptual understanding with practical action and student development (Balleisen *et al.*, 2024; Chang *et al.*, 2024; Paul *et al.*, 2023). When these processes are integrated into design education, students can develop not only better projects but also stronger scientific thinking.

The results are consistent with previous studies showing that design thinking can support student learning, creativity, motivation, and problem solving (Guaman-Quintanilla *et al.*, 2023; Liu and Li, 2023; Liu *et al.*, 2024; Yu *et al.*, 2024). The results are also consistent with studies in STEM and STEAM education showing that design thinking can connect scientific concepts with authentic interdisciplinary activities (Cook and Bush, 2018; Galoyan *et al.*, 2022; Kijima *et al.*, 2021; Öztürk and Korkut, 2023). The present study extends those findings by showing that design thinking can also support specific components of scientific thinking in higher design education. This contribution is important because previous research has often emphasized creativity, innovation, motivation, and problem-solving outcomes, while the present study focused on analytical skills, criticality, systematicity, hypotheticality, and evidence-based reasoning (Guaman-Quintanilla *et al.*, 2023; Liu and Li, 2023; Liu *et al.*, 2024; Yu *et al.*, 2024). The findings also support the use of long-term and structured design thinking interventions. The course was implemented over several months and included repeated practice in empathy research, ideation, prototyping, testing, and reflection. This structure may explain the large effect sizes observed in the experimental group. Short design thinking workshops may raise awareness or stimulate creativity, but sustained interventions are more likely to change students' thinking habits. Therefore, design thinking should be embedded into curriculum design rather than treated only as a temporary activity.

Despite the positive findings, several limitations should be considered. The study used a quasi-experimental design with non-random group assignment, so selection bias cannot be completely eliminated. Although the groups were equivalent at baseline, random assignment would provide stronger causal evidence. The sample was also limited to 60 first-year design students from one Ukrainian university, which may restrict the generalizability of the results. In addition, the study did not include a delayed post-test, so it remains unclear whether the improvement in scientific thinking would be maintained over time.

Future research should examine the effectiveness of design-oriented activities using larger samples, randomized controlled designs, and participants from different disciplines or institutions. Longitudinal studies are also needed to determine whether the development of scientific thinking remains stable after the intervention ends. Qualitative data, such as student reflections, interview transcripts, and classroom observations, could also provide deeper insight into how students experience the transition from creative design activity to scientific inquiry. These future directions would help clarify the mechanisms through which design thinking supports scientific thinking in higher education. The results show that the "Design Thinking and Scientific Research" course produced meaningful improvement in students' scientific thinking, design thinking engagement, and design project quality. The experimental group improved significantly across all measured components, while the control group remained relatively stable. The strong correlations among design thinking engagement, scientific thinking, and expert-rated project quality suggest that the intervention worked through an integrated process of inquiry, experimentation, testing, and reflection. These findings support the use of design-oriented activities as a pedagogical strategy for strengthening scientific thinking among undergraduate design students.

5. CONCLUSION

This study demonstrated that design-oriented activities can effectively promote students' scientific thinking in a modern educational environment. The experimental group, which participated in the "Design Thinking and Scientific Research" course, showed significant improvement in analytical skills, criticality, systematicity, hypotheticality, evidence-based reasoning, and total scientific thinking. In contrast, the control group, which followed the standard curriculum without design thinking integration, showed no significant improvement. These findings indicate that structured design thinking activities can support the development of scientific thinking when students are guided to collect data, define problems, generate ideas, create prototypes, test assumptions, and reflect on outcomes. The strongest improvements were found in systematicity and evidence-based reasoning. This result suggests that the design thinking process helped students understand problems as interconnected systems and justify decisions through data, feedback, and reflection. The increase in design thinking engagement also showed that students became more active in empathy, ideation, prototyping, testing, and reflection. The strong correlations among design thinking engagement, scientific thinking, and expert-rated project quality further indicate that design-oriented activities contributed not only to students' cognitive development but also to the quality of their design work. The study contributes to higher design education by showing that design thinking can function not only as a creative or professional method, but also as a pedagogical approach for developing scientific reasoning. Design students need more than technical and creative skills; they also need the ability to analyze evidence, formulate hypotheses, test ideas, and justify decisions. Therefore, integrating design thinking with scientific research activities can provide a meaningful pathway for strengthening students' academic and professional competencies. Several limitations should be acknowledged. The study used a quasi-experimental design with non-random assignment, so selection bias cannot be completely eliminated. The sample was limited to first-year design students from one university, which may reduce the generalizability of the findings. The study also did not include a delayed post-test, so the long-term stability of the improvement remains unknown. Future studies should involve larger and more diverse samples, randomized research designs, cross-institutional settings, and longitudinal follow-up measurements. Qualitative data such as interviews, reflective journals, and classroom observations may also provide deeper insight into how design-oriented activities support the development of scientific thinking.

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7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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