International Journal of Learning, Teaching and Educational Research
Vol. 23, No. 8, pp. 447-467, August 2024
https://doi.org/10.26803/ijlter.23.8.23
Received Jun 12, 2024; Revised Aug 14, 2024; Accepted Aug 27, 2024

Hybrid Information Technology Learning Based on Project Work to Enhance Students' Design Thinking in Creating Digital Innovations

Lubna Lubna* **and Suhirman Suhirman**
Universitas Islam Negeri Mataram
Mataram, Indonesia

Saiful Prayogi
Universitas Pendidikan Mandalika
Mataram, Indonesia

Abstract. This study explores the effectiveness of a hybrid information technology learning model based on project work in enhancing students' design-thinking skills necessary for creating digital innovations. Traditional teaching methods have shown limitations in fostering essential design-thinking competencies among information technology students, necessitating innovative pedagogical strategies. Utilizing a quasi-experimental design, this research implemented a hybrid learning framework that integrates project-based learning (PjBL) with digital tools to offer a dynamic, student-centered educational environment. Over a two-month period, 80 information technology (IT) students from Mandalika University of Education were selected using purposive sampling and divided into an experimental group, who engaged in the hybrid model, and a control group, which continued with traditional methods. Data were collected using structured questionnaires pre- and post-intervention to assess various design-thinking skills, including creativity, collaboration, and adaptability. The data analysis involved descriptive statistics and analysis of variance (ANOVA) to compare the performance of the two groups. Results indicate significant improvements in the experimental group's design-thinking abilities compared to the control group, emphasizing the hybrid model's potential to effectively bridge the gap between conventional education and the requirements of the digital era. This study contributes to educational research by demonstrating that a well-structured hybrid learning environment can substantially enhance students' abilities to innovate and apply design thinking in real-world digital scenarios, suggesting a need for curricular adjustments that emphasize such integrative approaches in IT education.

* Corresponding author: *Lubna, lubna68@uinmataram.ac.id*

Keywords: hybrid learning; design thinking; project-based learning; digital innovation; IT education

1. Introduction

The demand for skilled human resources to meet needs across all fields of work has positioned IT education as a crucible for fostering innovative talent, especially in creating digital innovations (Huang & Looi, 2021; Northrup et al., 2022). Generating digital innovations is not simple; it stems from how individuals can creatively design innovative works to be produced, or in other words, every innovation originates from design thinking (Smith et al., 2015). Consequently, design thinking has become a critical skill that individuals must acquire in the current era of digital transformation in the context of Industry 4.0. Several developed countries have also emphasized design thinking as a core competency in IT education curricula (Falkner et al., 2019).

Although design thinking is considered a scaffold for innovation, training it within the learning process remains an issue (Lin et al., 2024). Evidence from previous studies shows that traditional teaching methods are insufficient in enhancing students' design-thinking competencies (Li & Zhan, 2022; Prayogi, Ardi, et al., 2023). Specifically, in the context of IT education, studies have demonstrated that traditional expository teaching, which is not oriented toward design thinking, fails to enhance students' design-thinking skills in producing creative IT products (Ardi et al., 2024). A recent descriptive study on 30 IT education students also indicated that their design thinking skills were categorized as poor (Indriaturrahmi et al., 2023). The low design-thinking skills of IT students need attention, and planned and serious efforts must be undertaken starting from building a pedagogical infrastructure that supports students in acquiring adequate design-thinking skills (Indriaturrahmi et al., 2023). If not, it is feared to have systemic impacts on the low ability to innovate, motivation, self-efficacy, creativity, and inventive problem-solving skills (Liu et al., 2023).

Existing research has highlighted a significant discrepancy between the ideal scenario of developing students' design-thinking capabilities for innovation and the current underperformance observed among IT students in this area. This disparity underscores the necessity for research to address how digital pedagogical tools can be optimized to improve IT students' design-thinking skills, thereby enabling them to create digital innovations effectively.

1.1 Problem-solving Approach, Study Objectives and Hypothesis

Given the justification of existing issues, it is imperative to introduce a digital pedagogy within a hybrid framework. The significant advantage of this hybrid approach is its ability to integrate various educational modalities into a cohesive system that promotes both autonomy and inclusiveness in learning environments. Such a system not only caters to diverse learning preferences but also fosters a dynamic educational atmosphere where students are encouraged to engage independently and inclusively. The essence of this approach lies in its direct response to the stagnant development of design-thinking skills among IT students. Traditionally, such skills are not spontaneously nurtured but rather require a structured yet flexible learning environment (Daud et al., 2024; Gwasira et al., 2023; Hernández-Leo et al., 2017). By focusing on a hybrid pedagogical model, this study seeks to bridge the gap between traditional educational methods and the needs of a digital-era student body, thereby enhancing their capability to innovate and think design-centrically.

Hybrid information technology learning based on project work in this study was developed from previous studies (Iskandar et al., 2023; Wahyudi et al., 2023). This model incorporates eight distinct learning phases structured to cultivate students' design-thinking abilities as they develop digital innovations. These phases are graphically represented in Figure 1, illustrating the sequential flow and integration of each learning component.

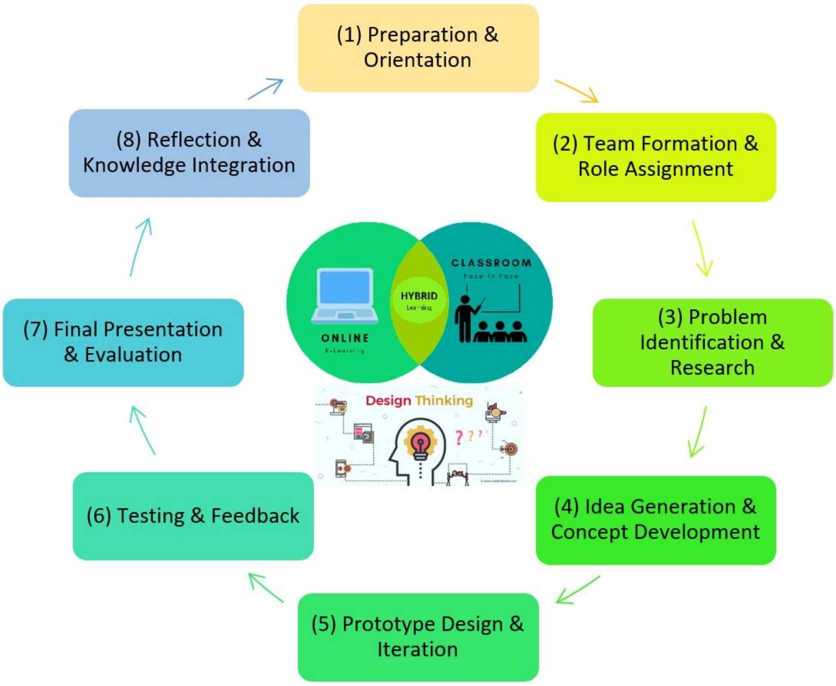

Figure 1: Steps for project work in hybrid IT learning to improve students' design thinking

In practice, the project work steps begin with a preparatory and orientation phase where students are introduced to the hybrid learning framework and the objectives of the project-based learning (PjBL) approach. Students are briefed on the necessary digital tools and resources, emphasizing the role of design thinking in creating digital innovations. As the project progresses, teams are formed, roles are assigned, and the problem identification process begins, leading to extensive research and idea generation. This culminates in the development and iterative refinement of a digital prototype, testing and feedback integration, and a final presentation where the results are evaluated. The learning process concludes with a reflection phase where students integrate the knowledge gained into their broader educational context, ensuring a deep understanding of design thinking in digital innovation.

This intervention emphasizes the role of project-based learning PjBL as a fundamental component of the hybrid system. The amalgamation of investigative processes with design thinking under the umbrella of PjBL can significantly enhance the synergy, thus making the learning experience more effective and pertinent to real-world scenarios (Nichols et al., 2022). Furthermore, recent studies have demonstrated that PjBL is not only complementary to design thinking but also essential as a scaffolding tool in technological education (Chen, 2023). It prepares students by providing the necessary groundwork through practical, project-oriented tasks that develop their design-thinking competencies (Chen, 2023). By implementing a hybrid IT learning strategy centered on project work, the research aims to cultivate a fertile ground for the emergence and enhancement of design thinking skills, ultimately leading to superior digital innovation outputs. This study's goal, therefore, is to not only address the deficiency in design-thinking skills but also to provide a robust educational framework that empowers students to successfully navigate and innovate in the rapidly evolving digital landscape.

Specifically, the aim of this study is to implement hybrid information technology learning based on project work to enhance students' design thinking in creating digital innovations. This study posits the following hypothesis: "Hybrid IT learning, focusing on project work, significantly enhances students' design thinking skills necessary for digital innovation." This hypothesis stems from the premise that integrating project-based learning within a hybrid learning environment will provide a more effective educational framework. This framework is expected to bridge the gap between traditional methods and the evolving requirements of the digital era, ultimately fostering students' abilities to innovate and apply design thinking in real-world digital scenarios.

1.2 State of the Art and Novelty of the Study

Areas related to IT education innovation and design thinking, current literature reflects a paradigm shift from traditional approaches to more progressive approaches. Research in this context emphasizes the importance of design thinking as a main pillar in addressing the dynamics of digital transformation (Bhandari, 2023; Oliveira et al., 2024). Previous research has highlighted that design-thinking skills not only play a key role in creating innovations but also in shaping critical thinking (Ericson, 2022), creativity, and problem-solving abilities necessary to face challenges in the continually evolving technology era (Guaman-Quintanilla et al., 2023; Liu & Li, 2023; Novak & Mulvey, 2021). Other studies highlight the role of design thinking as a powerful tool to facilitate the development of students' creative skills and thinking motivation (Balakrishnan, 2022).

Although there is recognition of the importance of design thinking, empirical studies show that conventional teaching in many IT education programs still fails to effectively develop these skills in students (Indriaturrahmi et al., 2023). This gap creates a substantial problem between educational goals and on-the-ground realities. Moreover, amid the need for human resources excelling in digital innovation, existing literature highlights an urgent need to apply pedagogy that can holistically facilitate students' design-thinking skills, impacting the emergence of innovations (Falkner et al., 2019; Velu, 2022).

This research adds a new dimension to existing literature by proposing an innovative approach in the form of hybrid information technology learning based on projects. The integration of PjBL as a main component within the hybrid learning system establishes a robust foundation for stimulating a learning process that focuses not only on knowledge acquisition but especially on developing students' design-thinking skills. PjBL is closely related to design thinking, as it serves as scaffolding in the IT learning process to achieve students' design-thinking competencies (Chen, 2023). The novelty of this research is reflected through a holistic approach in designing a learning environment that not only incorporates PjBL elements as a creativity driver but also emphasizes the role of information technology as a catalyst for supporting responsive and dynamic learning in the digital age (Pham et al., 2022). Thus, this research has the potential to make a significant contribution to addressing the challenges of designing learning that meets the needs of today's IT students, with the goal of enhancing their design thinking skills in creating digital innovations.

This research has a clear goal: to enhance the design-thinking skills of IT students. By developing a hybrid learning framework, this study strives to bridge the gap between expectations and the reality of students' skills. By introducing project-based learning (PjBL) as a primary driver, this research has the potential to significantly contribute to improving the quality of IT education, with an emphasis on developing essential skills needed to create digital innovations in the current era of digital transformation.

2. Literature Review

2.1 Design Thinking

Design thinking is a mode of thinking employed in design-based activities, which has gained significant attention from both practitioners and academics due to its innovative approach to problem-solving and innovation (Kimbell, 2011; Y. Li et al., 2019; Micheli et al., 2019). Originating from the design field, design thinking involves a variety of aspects that can be described using different terminologies such as traits, attributes, and mindsets (Blizzard et al., 2015; Dosi et al., 2018; Schweitzer et al., 2016). Among these, the term "mindset" is the most commonly used characteristic of design thinking because it encompasses the set of opinions, beliefs, and behaviors that individuals exhibit when engaging in design-based activities (Ladachart et al., 2022).

Design thinking is recognized for its ability to transform how problems are approached and solutions are developed. In the artificial world, design plays an indispensable role in the progress of human society, making design thinking crucial for innovation and advancement (Li & Zhan, 2022). In the field of design, design thinking is associated with the understanding and expertise in design, as highlighted by Cross (2004). It offers a structured methodology that combines creativity with practical application, enabling individuals to tackle complex problems effectively.

As an innovative problem-solving method, design thinking has evolved from a professional concept to a more general framework applicable across various sectors, especially in IT (Dorst, 2011). It is identified as an exciting new paradigm for addressing challenges and fostering innovation in many industries. By integrating design thinking into educational contexts, particularly within IT education, students can develop essential skills that are critical for creating digital innovations and navigating the rapidly evolving technological landscape.

2.2 Project-Based Learning

Project-Based Learning (PjBL) is an educational approach that emphasizes collaborative efforts among students to tackle real-world problems, thereby fostering a deeper understanding of the subject matter (Harjono et al., 2024; Kokotsaki et al., 2016). This method is primarily student-driven, with the central objective being the completion of a project where students actively engage in acquiring knowledge and applying it to solve practical challenges (Biazus & Mahtari, 2022). The PjBL framework involves several key steps, including information gathering, project planning, and producing tangible outcomes (Babalola & Keku, 2024). It is grounded in constructivist principles, which emphasize context-specific learning, active learner engagement, and goal achievement through social interactions and knowledge sharing (Rohmatika et al., 2024).

The implementation of PjBL aims to develop students' problem-solving skills, innovative thinking, and collaborative abilities through independent inquiry and group work (Lubna et al., 2023). By providing authentic learning experiences that extend beyond the classroom, PjBL allows students to plan, execute, and evaluate projects that have real-world applications. This approach helps students to tackle complex issues directly related to real-life situations, thereby enhancing their critical thinking and creativity (Idris et al., 2024). Moreover, PjBL has been shown to improve students' understanding of technology and learning content when applied in actual classroom settings (Ekawati & Prastyo, 2022).

The benefits of PjBL are manifold, including the acquisition of new skills and knowledge, promotion of student collaboration, enhancement of student responsibility, and guidance through the design process to achieve desired outcomes (Dewi et al., 2021). PjBL is particularly relevant to design thinking, as it provides the necessary scaffolding in the IT learning process to develop students' design-thinking competencies (Chen, 2023). This research introduces a holistic approach to creating a learning environment that not only integrates PjBL elements to drive creativity but also emphasizes the role of information technology in supporting responsive and dynamic learning in the digital age (Pham et al., 2022).

2.3 Information Technology Education in Hybrid Learning

Hybrid learning, which combines traditional face-to-face instruction with online tools, has become increasingly prominent in higher education (Prayogi, Ahzan, et al., 2023; Wahyudi et al., 2023). This model is particularly relevant in the context of IT education, and STEM generally, where the integration of digital technologies is essential (Aliyu et al., 2023; Fransisca & Saputri, 2023). Hybrid learning enhances teacher-student relationships and boosts learning motivation through a blend of face-to-face interactions and information and communication technologies (Aristika et al., 2021). This dual approach facilitates a more engaging and dynamic learning environment, enabling students to benefit from the advantages of both traditional and digital learning methodologies.

Hybrid learning is recognized as an integrative approach that promotes contextual, transformative, collaborative, and situated learning, addressing the growing complexities of IT education (Jamison et al., 2014). By combining synchronous and asynchronous teaching methods, hybrid learning provides flexibility and accessibility, allowing students to engage with course materials and activities at their own pace while still benefiting from real-time interactions (Bilad, 2023). This method ensures that students receive a comprehensive education that prepares them for the demands of the modern digital world, fostering a more resilient and adaptable education system.

Educators and technology providers must consider the perspectives of both learners and educators to create effective hybrid educational environments (Mayer, 2023). Optimizing technology use in classrooms enhances the competence and effectiveness of the hybrid learning model. This approach supports the development of essential skills in IT, enabling students to navigate and succeed in the rapidly evolving technological landscape. By integrating project-based learning within a hybrid framework, this research aims to demonstrate how such an educational model can significantly enhance students' design-thinking skills, bridging the gap between traditional education methods and the needs of digital-era students.

3. Methodology

3.1 Research Design

This study employed a quasi-experimental design using a quantitative approach to investigate the efficacy of hybrid information technology learning based on project work in enhancing students' design-thinking skills. Specifically, a pretest-post-test control group design was used to compare outcomes between two groups: an experimental group that engaged in Hybrid Learning Based on project work and a control group that received traditional instructional methods. This design was chosen because it allows for the evaluation of the effect of the hybrid learning intervention by comparing the pre-intervention and post-intervention performance of both groups. The learning intervention, focused on IT education material conducive to creating digital innovations, included topics such as developing mobile applications, designing user interfaces, and creating digital marketing strategies, and was administered over a period of two months.

The suitability of the pretest-post-test control group design in this research lies in its ability to demonstrate causal relationships by measuring changes in design thinking before and after the intervention. This design is particularly useful in educational research as it helps in assessing the learning outcomes attributable to specific educational strategies, in this case, the hybrid project-based approach versus traditional methods. By using this design, the study aims to provide robust evidence on the effectiveness of the innovative educational model in enhancing the design-thinking capabilities necessary for creating digital innovations.

3.2 Participants

A total of 80 IT students from Mandalika University of Education, Indonesia, participated in this study. The students were divided into two groups: an experimental group consisting of 40 students and a control group of 40 students. Participants were selected using a purposive sampling technique, which involved choosing students who were currently enrolled in courses relevant to IT and had demonstrated initial interest in digital innovation projects. This sampling method was chosen to ensure that the participants had a foundational understanding of IT concepts and a genuine interest in the subject matter, which are critical for the effectiveness of the project-based learning approach.

The age range of the participants was 18 to 19 years, with an equitable gender distribution among male and female students. The study adhered to ethical standards set by the Mandalika University of Education Research Ethical Council, focusing particularly on the ethics of conducting research involving human participants. These ethical considerations were integral to ensuring the dignity, rights, and welfare of the participants throughout the research process.

3.3 Research Procedures

The research began with a preparatory phase where objectives and methodologies were clarified, and materials were developed. Experienced IT instructors, who were well-versed in classroom routines and familiar with the intervention methods, were involved in teaching both the experimental and control groups. Following this, the two-month intervention period commenced, during which the experimental group engaged with the hybrid learning model based on project work, while the control group continued with traditional teaching methods. Data were systematically collected at two points: at the beginning of the intervention (pretest) and after the two-month period (post-test), to assess the impact of the learning models on students' design-thinking skills.

After data collection, the next phases involved data analysis and the preparation of findings for presentation. The analysis aimed to elucidate the differences in design-thinking development between the two groups, thereby assessing the effectiveness of the hybrid learning model. The results were then compiled and presented in a manner that highlighted the key outcomes and educational implications of the study.

3.4 Research Instrument

The instrument used to assess students' design thinking skills in this study was a structured questionnaire designed based on the theoretical framework (Ladachart et al., 2022). This structured questionnaire was a closed-ended type, meaning that it comprised items with predefined response options that specifically measured six key indicators of design thinking: comfort with uncertainty and risks, focus on human-centeredness, mindfulness regarding the process and its impact on others, collaboration with diverse perspectives, orientation toward learning through making and testing, and confidence and optimism in utilizing creativity (Ladachart et al., 2022). Each item was formulated to capture the extent of students' engagement with and competency in these aspects, ensuring a comprehensive assessment of their design-thinking capabilities.

Prior to its deployment, the questionnaire underwent a rigorous validation process to confirm its psychometric properties, including its reliability and validity. To establish reliability, a pilot test was conducted with a sample of 30 students similar to the study's target population. The data collected from the pilot test was analyzed using Cronbach's alpha to measure internal consistency (Cronbach & Meehl, 1955; Taber, 2018). The Cronbach's alpha coefficient for the questionnaire was calculated at 0.87, indicating high internal consistency and reliability of the instrument. For the validation process, the content validity was assessed by a panel of five experts in IT education and design thinking. They evaluated each item for relevance, clarity, and comprehensiveness. The Content Validity Index (CVI) for the entire instrument was calculated, yielding a score of 0.92, which demonstrates excellent validity. Additionally, exploratory factor analysis (EFA) was conducted to confirm the construct validity of the questionnaire. The EFA results showed that all items loaded significantly on their respective factors, further supporting the validity of the instrument. This validation ensured that the instrument was both credible and capable of producing meaningful and actionable insights into students' design-thinking skills.

3.5 Analysis

Data collected from the questionnaire were analyzed using both descriptive and inferential statistical methods to interpret the effects of the hybrid learning intervention on design-thinking skills. Descriptive statistics provided a preliminary overview, detailing mean scores and standard deviations for each design thinking indicator in both pretest and post-test assessments. This analysis helped to depict the initial and concluding stages of students' abilities in the context of the educational intervention, offering a straightforward illustration of the learning outcomes.

Before conducting data analysis, rigorous statistical validation processes were repeated to ensure the reliability and validity of the instrument for the new group of participants. This involved recalculating Cronbach's alpha for internal consistency and performing EFA to confirm construct validity with the current study sample. Additionally, data cleaning processes were implemented to identify and address any inconsistencies or outliers in the dataset, ensuring the accuracy and integrity of the data.

For inferential statistics, a parametric ANOVA was utilized to determine the statistical significance of the differences observed between the experimental and control groups' post-test scores. To validate the use of parametric ANOVA, the data were tested for normality using the Shapiro-Wilk test, which confirmed that the data were normally distributed. The ANOVA was particularly suitable for this study as it allowed for comparisons between the pretest and post-test scenarios for both groups. By setting a significance level at 0.05, the ANOVA helped confirm whether the observed changes in design-thinking skills were attributable to the hybrid learning intervention rather than mere chance. This method provided a robust statistical framework to support the evaluation of the effectiveness of the educational strategies implemented, highlighting the impact of hybrid project-based learning on enhancing students' design-thinking capabilities.

4. Findings

A detailed analysis of the impact of hybrid information technology learning on students' design-thinking capabilities as demonstrated through a series of structured assessments and statistical tests. Tables 1 and 2 provide a comparison of design-thinking scores between control and experimental groups before and after the intervention, respectively. Table 3 further quantifies these enhancements by showing the average scores across all indicators. The robustness of the results is supported by the statistical analysis (ANOVA) in Table 4. Finally, Table 5 details the post hoc comparisons.

Table 1: Results of student design thinking data analysis in the pretest

Design-thinking indicator	Group	Valid	Mean	SE	SD	Coeff. of var.
1. Comfort with uncertainty and risks	Control	40	2.213	0.086	0.547	0.247
	Experimental	40	2.446	0.101	0.637	0.260
2. Focus on human-centeredness	Control	40	2.987	0.118	0.745	0.249
	Experimental	40	2.958	0.156	0.986	0.333
3. Mindfulness regarding the process	Control	40	2.583	0.099	0.624	0.241
	Experimental	40	2.605	0.140	0.888	0.341
4. Collaboration with diverse perspectives	Control	40	2.796	0.111	0.704	0.252
	Experimental	40	3.136	0.175	1.108	0.353
5. Orientation toward learning through making and testing	Control	40	2.894	0.122	0.773	0.267
	Experimental	40	2.615	0.146	0.923	0.353
6. Confidence and optimism in utilizing creativity	Control	40	2.790	0.136	0.860	0.308
	Experimental	40	2.659	0.154	0.973	0.366

Table 2: Results of student design thinking data analysis in the post-test

Design-thinking indicator	Group	Valid	Mean	SE	SD	Coeff. of var.
1. Comfort with uncertainty and risks	Control	40	2.204	0.092	0.583	0.265
	Experimental	40	3.592	0.148	0.937	0.261
2. Focus on human-centeredness	Control	40	2.987	0.118	0.745	0.249
	Experimental	40	4.103	0.115	0.727	0.177
3. Mindfulness regarding the process	Control	40	3.209	0.126	0.794	0.247
	Experimental	40	4.034	0.125	0.791	0.196
4. Collaboration with diverse perspectives	Control	40	3.050	0.111	0.704	0.231
	Experimental	40	4.401	0.092	0.582	0.132
5. Orientation toward learning through making and testing	Control	40	2.994	0.134	0.850	0.284
	Experimental	40	4.311	0.128	0.806	0.187

Design-thinking indicator	Group	Valid	Mean	SE	SD	Coeff. of var.
6. Confidence and optimism in utilizing creativity	Control	40	3.296	0.119	0.752	0.228
	Experimental	40	4.173	0.109	0.692	0.166

The results from Table 1 provide a detailed baseline comparison of design-thinking competencies between the control and experimental groups before the intervention. The control group generally had lower mean scores across most design-thinking indicators, including comfort with uncertainty and risks, collaboration with diverse perspectives, and confidence and optimism in utilizing creativity. The experimental group showed slightly higher initial scores, particularly in collaboration with diverse perspectives, suggesting a somewhat better foundation in engaging with various viewpoints. However, both groups started with similar challenges in areas such as mindfulness regarding the process and human-centered focus, highlighting areas needing improvement through the hybrid learning approach.

Table 2 illustrates the post-intervention impact on students' design-thinking skills. Remarkable improvements were observed in the experimental group across all design-thinking indicators, with significant increases in scores, particularly in comfort with uncertainty and risks, and collaboration with diverse perspectives, where they scored significantly higher than the control group. The control group, still subjected to traditional teaching methods, showed marginal improvements, emphasizing the effectiveness of the hybrid project-based learning approach in enhancing critical design-thinking competencies necessary for innovation in the digital era.

Table 3: Average score of students' design-thinking skills in the pretest-post-test for each group

Average score of design thinking	Group	Valid	Mean	SE	SD	Coeff. of var.
Pretes	Control	40	2.710	0.063	0.398	0.147
	Experimental	40	2.736	0.084	0.531	0.194
Post-test	Control	40	2.956	0.073	0.460	0.156
	Experimental	40	4.143	0.084	0.530	0.128

Table 3 synthesizes the overall changes from pretest to post-test for both groups. It clearly demonstrates the superiority of the hybrid learning approach, with the experimental group achieving a mean score increase to 4.143 in the post-test compared to their pretest scores. This contrasted with the control group, which only slightly improved to a mean of 2.956. This data suggests that hybrid learning significantly accelerates the development of design-thinking skills compared to traditional methods. These results are clarified in the descriptive plot of students' design-thinking skills, as shown in Figure 2.

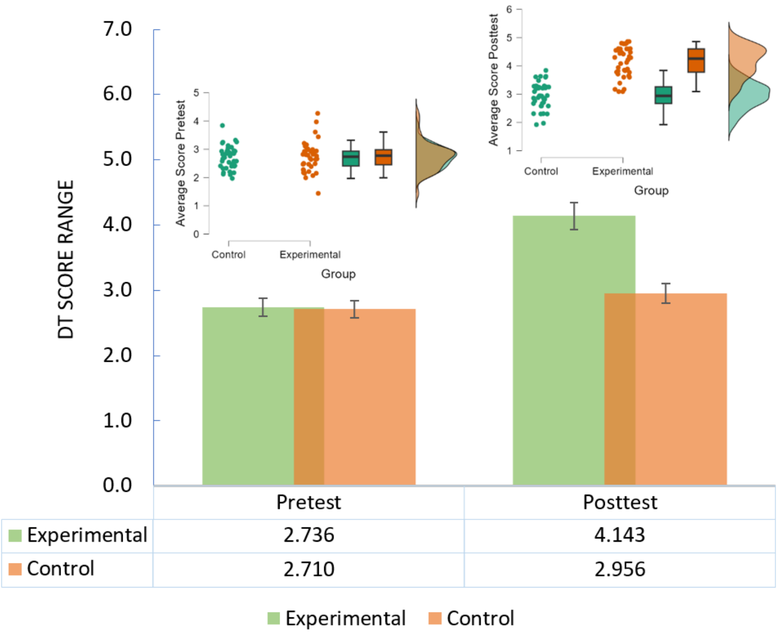

Figure 2: Descriptive plot of students' design-thinking skills

Figure 2 presents a visual representation of the change in design-thinking skills between the control and experimental groups before and after the intervention. The bar graph component shows the average design-thinking scores, where the experimental group demonstrates a significant increase from a pretest mean of 2.736 to a post-test mean of 4.143, while the control group shows a smaller increase from 2.710 to 2.956. The error bars indicate the variability within each group's scores, and it is observable that the experimental group's post-test scores have a tighter confidence interval, suggesting more consistent results post-intervention. The scatter plots above the bars provide a distribution of individual scores, with each point representing a student. For the experimental group, there's a clear upward shift in the post-test, with most points clustering at the higher end of the design-thinking score range, showing that the majority of students improved substantially. In contrast, the control group's scatter points are more concentrated at the lower end, indicating little change. The small inset violin plots give a deeper insight into the density and distribution of scores. They show that post-intervention, the experimental group's scores are not only higher but also more densely packed toward the upper end of the scale, emphasizing the effectiveness of the hybrid learning approach. The control group's plot shows a less pronounced change with a broader spread of scores, reflecting less overall improvement in design-thinking skills.

The robustness of the students' design-thinking outcomes following the educational intervention is confirmed by the statistical analysis presented in Table 4 and Table 5.

Table 4: The results of ANOVA

Cases	Sum of Squares	df	Mean Square	F	p	η²
Within Subjects Effects						
RM Factor	27.324	1	27.324	199.662	< .001	0.297
RM Factor ✻ Group	13.456	1	13.456	98.326	< .001	0.146
Residuals	10.674	78	0.137			
Between Subjects Effects						
Group	14.726	1	14.726	44.674	< .001	0.160
Residuals	25.711	78	0.330			

Note: RM Factor = repeat measure factor (pretest – post-test)

Table 5: The results of post hoc comparisons - Group ∗ RM Factor 1 (pretest – post-test)

Variables		Mean Diff.	SE	t	Cohen's d	p_{tukey}
Cont. - pretest	Exp. - pretest	-0.027	0.108	-0.248	-0.055	0.995
	Cont. - post-test	-0.246	0.083	-2.980	-0.510	0.020
	Exp. - post-test	-1.433	0.108	-13.272	-2.968	< .001
Exp. – pretest	Cont. - post-test	-0.220	0.108	-2.035	-0.455	0.180
	Exp. - post-test	-1.407	0.083	-17.003	-2.912	< .001
Cont. - post-test	Exp. - post-test	-1.187	0.108	-10.989	-2.457	< .001

Table 4 displays the ANOVA results, which reveal significant differences in design-thinking scores between the control and experimental groups from pretest to post-test. The Within Subjects Effects show a substantial Repeat Measure (RM) factor with an F value of 199.662 and a p-value of less than 0.001, demonstrating the strong effect of the intervention over time across all participants. The interaction effect (RM Factor ✻ Group) also indicates significant changes with an F value of 98.326 and a p-value of less than 0.001, emphasizing the distinct impact of the hybrid learning approach on the experimental group compared to the control. The Between Subjects Effects further highlight that the group factor alone (comparing control versus experimental) significantly influences the outcomes, with an F value of 44.674 and a p-value of less than 0.001. The effect sizes (η^2) for both within-subject and between-subject effects are substantial, suggesting that the hybrid learning model significantly impacts enhancing design-thinking skills.

Table 5 provides detailed post hoc comparisons, shedding light on the changes in design-thinking skills between the pretest and post-test for both control and experimental groups. The mean differences underscore significant improvements in the experimental group post-intervention, with a highly significant t-value of -13.272 for the experimental post-test compared to the experimental pretest, and a Cohen's d indicating a large effect size. The comparisons between groups at each time point illustrate that while both groups show improvements, the gains in the experimental group are notably more substantial than those of the control group, as evidenced by a p-value of less than 0.001 in the experimental group's post-test improvements.

These statistical findings robustly support the study's hypothesis that hybrid IT learning, focusing on project work, significantly enhances students' design-thinking skills necessary for digital innovation. The significant F-values and low p-values indicate that the differences observed are statistically significant and attributable to the hybrid learning intervention rather than chance. This evidence strongly suggests that incorporating a project-based learning framework within hybrid IT education can effectively foster essential design-thinking competencies, thus bridging the gap between traditional educational methods and the needs of digital-era students.

5. Discussion

The integration of hybrid information technology learning through project work has been shown to significantly enhance students' design-thinking capabilities. This approach, as evidenced by the improvements seen in the experimental group compared to the control group, highlights the effectiveness of project-based hybrid learning models. Traditional lecture-based methods are often less successful in fostering the competencies necessary for innovation in the digital era (Dym et al., 2005). The success of hybrid learning systems has been noted in various studies, emphasizing the importance of information technology integration and the ability of teachers to effectively utilize technology in education (Zakaria et al., 2022). With the rapid advancement of IT, the fusion of technology and teaching methods has become a focal point in educational research (Wu & Liu, 2019). Research also indicates the need for a balanced approach between pedagogy and technology in designing and delivering hybrid courses, emphasizing the complexity of this task (Linder, 2017). Furthermore, studies have delved into the indirect impact of design-thinking practices on innovation performance, highlighting the role of knowledge management and dynamic capability theory in understanding how design thinking contributes to innovation (Kurtmollaiev et al., 2018; Robbins & Fu, 2022).

Capabilities rooted in individual mindsets that promote creativity and learning, are essential for leveraging design thinking effectively (Magistretti et al., 2021). The application of design thinking in problem-solving processes has been shown to significantly enhance dynamic capabilities, aligning with the notion that design thinking contributes to innovation and capability development (Roth et al., 2023). The challenges and benefits of hybrid learning models, particularly in the context of the COVID-19 pandemic, have been explored, highlighting the increasing popularity of hybrid learning in higher education (Prihadi et al., 2021). Design thinking has been recognized for its contributions to project management in various fields, showcasing its versatility and effectiveness in complex projects (Mahmoud-Jouini et al., 2016).

Previous studies highlight that the dynamic environment fosters design-thinking attributes such as comfort with uncertainty, focus on human-centeredness, mindfulness in the process, collaboration with diverse perspectives, learning through making and testing, and confidence in utilizing creativity (Ladachart et al., 2022). The integration of a hybrid model in IT courses, combining online resources with hands-on project work, has been recognized as highly advantageous for students in applying theoretical knowledge practically to enhance their design-thinking skills. Research has shown that this approach not only allows students to bridge the gap between theory and practice but also fosters thinking abilities (Marco et al., 2017; Tanujaya et al., 2017). By incorporating project-based learning and design thinking into the curriculum, students are provided with a platform to collaborate and develop thinking skills in a structured manner (Tanujaya et al., 2017). This model has been found to positively impact students' attitudes toward learning and their intention to use hybrid learning methods (Shahnila Syed et al., 2023).

The empirical evidence from the study strongly supports the hypothesis that hybrid IT learning, particularly through project work, significantly enhances students' design-thinking skills crucial for digital innovation. By incorporating a project-based learning framework within hybrid IT education, essential design-thinking competencies can be effectively nurtured, bridging the gap between traditional educational methods and the evolving needs of digital-era students. The conclusion aligns with the findings who explored the outcomes of Hybrid-PjBL on learning motivation and creative thinking skills, using a quasi-experimental design (Rahardjanto et al., 2019). The study's methodology and focus on creativity and learning outcomes resonate with the idea that project-based learning within a hybrid setting can enhance students' creative thinking abilities. Moreover, the research by on integrated project-based and STEM-based e-learning tools to improve students' creative thinking and self-regulation skills further supports the notion that project-based approaches can significantly enhance thinking skills (Hasibuan et al., 2022). In essence, the amalgamation of project-based learning with hybrid IT education has been shown to be a potent strategy for fostering design-thinking skills essential for digital innovation.

6. Conclusion

The findings of this study underscore the profound impact that hybrid IT learning based on project work has on enhancing students' design-thinking skills. By integrating project-based learning within a hybrid educational framework, the study demonstrated significant improvements in various indicators of design thinking, including collaboration, creativity, and comfort with uncertainty. These enhancements are crucial for students who aspire to excel in the rapidly evolving digital landscape. The empirical data showed that students engaged in the hybrid model not only improved their ability to innovate but also developed a deeper understanding and application of design-thinking principles. This shift from traditional educational methodologies to a more interactive and practical hybrid approach highlights the necessity of adopting dynamic educational strategies that align with contemporary digital demands.

Moreover, the success of the hybrid model in fostering these competencies reiterates the importance of adapting educational practices to better prepare students for the challenges of modern technological environments. The integration of hands-on project work encourages a deeper engagement with the material, fostering an environment where students can experiment and learn from real-world scenarios. As digital innovation continues to drive the future, the ability of educational institutions to equip students with robust design-thinking skills will be paramount. This study, therefore, provides a compelling blueprint for how hybrid learning models can be effectively utilized to meet these educational goals and prepare students for successful careers in digital innovation. It is recommended that future research explore the long-term impacts of hybrid learning models on students' career trajectories and the sustainability of design-thinking skills in professional settings.

7. Implications and Recommendation

The findings of this study have both theoretical and practical implications. Theoretically, this research contributes to the body of knowledge by demonstrating the effectiveness of hybrid IT learning models, specifically those based on project work, in enhancing design-thinking skills. This supports the notion that integrating project-based learning within a hybrid educational framework can significantly improve students' creative and critical thinking abilities, which are essential for innovation in the digital era. Practically, the study provides a robust educational framework that can be adopted by educators and policymakers to improve IT education. By implementing this hybrid learning approach, institutions can better prepare students for the demands of modern technological environments, fostering a generation of innovative thinkers capable of tackling real-world problems.

Based on the study's findings, several recommendations can be made for educational policymakers and authorities. Firstly, it is essential to integrate hybrid learning models that combine project-based learning with traditional instructional methods in IT curricula. This approach has proven effective in enhancing students' design-thinking skills, which are crucial for innovation. Secondly, teacher training programs should be updated to include strategies for effectively implementing hybrid learning environments, ensuring that educators are equipped to facilitate this integrative approach. Lastly, educational institutions should invest in the necessary technological infrastructure to support hybrid learning, enabling students to engage in both online and face-to-face learning activities seamlessly.

8. Limitations

This study acknowledges several limitations that should be considered in future research. Firstly, the sample size of 80 students, while sufficient for this study, may not be representative of the broader student population, and larger sample sizes could provide more generalizable results. Secondly, the study design was quasi-experimental, which, although robust, does not control for all potential confounding variables. Future studies could employ randomized controlled trials to strengthen the findings. Lastly, the data collection tools used, primarily structured questionnaires, while validated, may not capture all dimensions of design thinking comprehensively. Incorporating a mixed-methods approach, including qualitative interviews and observational studies, could provide deeper insights into students' design-thinking processes.

9. References

Aliyu, H., Ebikabowei, M., & Kola, A. J. (2023). Problem-based learning in remote learning scenario utilizing climate change virtual reality video in mobile application to train critical thinking. *International Journal of Essential Competencies in Education*, *2*(2), 144–159. https://doi.org/10.36312/ijece.v2i2.1612

Ardi, R. F. P., Bilad, M. R., Mustofa, H. A., & Maulachela, A. B. (2024). Analysis of Students' design thinking in creating 3D creative works utilizing mobile technology within the framework of local wisdom. *International Journal of Ethnoscience and Technology in Education*, *1*(1), 15–27. https://doi.org/10.33394/ijete.v1i1.10879

Aristika, A., Darhim, ., Juandi, D., & Kusnandi, . (2021). The effectiveness of hybrid learning in improving of teacher-student relationship in terms of learning motivation. *Emerging Science Journal*, *5*(4), 443–456. https://doi.org/10.28991/esj-2021-01288

Babalola, E. O., & Keku, E. (2024). Ethno-STEM integrated project-based learning to improve students' creative thinking skills. *International Journal of Ethnoscience and Technology in Education*, *1*(2), 116–130. https://doi.org/10.33394/ijete.v1i2.11308

Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: A study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education*, *32*(3), 1799–1812. https://doi.org/10.1007/s10798-021-09652-y

Bhandari, A. (2023). Design thinking: from bibliometric analysis to content analysis, current research trends, and future research directions. *Journal of the Knowledge Economy*, *14*(3), 3097–3152. https://doi.org/10.1007/s13132-022-00920-3

Biazus, M. de O., & Mahtari, S. (2022). The impact of project-based learning (PjBL) model on secondary students' creative thinking skills. *International Journal of Essential Competencies in Education*, *1*(1), 38–48. https://doi.org/10.36312/ijece.v1i1.752

Bilad, M. R. (2023). Enhancing engineering electromagnetics education: A comparative analysis of synchronous and asynchronous learning environments. *International Journal of Essential Competencies in Education*, *2*(1), 66–74. https://doi.org/10.36312/ijece.v2i1.1369

Blizzard, J., Klotz, L., Potvin, G., Hazari, Z., Cribbs, J., & Godwin, A. (2015). Using survey questions to identify and learn more about those who exhibit design thinking traits. *Design Studies*, *38*, 92–110. https://doi.org/10.1016/j.destud.2015.02.002

Chen, P.-H. (2023). Integrating sustainable development goals into project-based learning and design thinking for the instructional design of a virtual reality course. *2023 IEEE 5th Eurasia Conference on Biomedical Engineering, Healthcare and Sustainability*, 78. https://doi.org/10.3390/engproc2023055078

Cronbach, L. J., & Meehl, P. E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, *52*(4), Article 4. https://doi.org/10.1037/h0040957

Cross, N. (2004). Expertise in design: An overview. *Design Studies*, *25*(5), 427–441. https://doi.org/10.1016/j.destud.2004.06.002

Daud, K. A. M., Khidzir, N. Z., Hidayat, I. K., & Ismail, M. E. (2024). Empowering Art and design education via a flexible curriculum. *KnE Social Sciences*. https://doi.org/10.18502/kss.v9i15.16176

Dewi, S. J., Setiti, S., & Hasanah, M. (2021). Project based learning models in advancing learning results of handicraft entrepreneurs with object inspiration of local culture. *2nd International Conference on Social Sciences Education (ICSSE 2020),* Banjarmasin, Indonesia. https://doi.org/10.2991/assehr.k.210222.029

Dorst, K. (2011). The core of 'design thinking' and its application. *Design Studies*, *32*(6), 521–532. https://doi.org/10.1016/j.destud.2011.07.006

Dosi, C., Rosati, F., & Vignoli, M. (2018). *Measuring design thinking mindset*. 1991–2002. https://doi.org/10.21278/idc.2018.0493

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103–120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Ekawati, E. Y., & Prastyo, A. (2022). Optimization of TPACK-based project learning in micro-teaching courses in physics education study programs during the pandemic. *Journal of Physics: Conference Series*, *2392*(1), 012035. https://doi.org/10.1088/1742-6596/2392/1/012035

Ericson, J. D. (2022). Mapping the relationship between critical thinking and design thinking. *Journal of the Knowledge Economy*, *13*(1), 406–429. https://doi.org/10.1007/s13132-021-00733-w

Falkner, K., Sentance, S., Vivian, R., Barksdale, S., Busuttil, L., Cole, E., Liebe, C., Maiorana, F., McGill, M. M., & Quille, K. (2019). An international comparison of k-12 computer science education intended and enacted curricula. *Proceedings of the 19th Koli Calling International Conference on Computing Education Research*, 1–10. https://doi.org/10.1145/3364510.3364517

Guaman-Quintanilla, S., Everaert, P., Chiluiza, K., & Valcke, M. (2023). Impact of design thinking in higher education: A multi-actor perspective on problem solving and creativity. *International Journal of Technology and Design Education*, *33*(1), 217–240. https://doi.org/10.1007/s10798-021-09724-z

Gwasira, A., Stack, A., & Poulsen, S. (2023). Learning design principles that cultivate future-oriented students. *ASCILITE Publications*. https://doi.org/10.14742/apubs.2023.616

Harjono, A., Gunawan, Busyairi, A., & Prayogi, S. (2024). Implementation of project-based learning to enhance the creativity of prospective physics teachers in generating learning media viewed from cognitive styles. *International Journal of Education and Practice*, *12*(2), 253–267. https://doi.org/10.18488/61.v12i2.3676

Hasibuan, M. P., Sari, R. P., Syahputra, R. A., & Nahadi, N. (2022). Application of integrated project-based and STEM-based e-learning tools to improve students' creative thinking and self-regulation skills. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 51–56. https://doi.org/10.29303/jppipa.v8i1.1050

Hernández-Leo, D., Agostinho, S., Beardsley, M., Bennett, S., & Lockyer, L. (2017). *Helping teachers to think about their design problem: A pilot study to stimulate design thinking*. 5681–5690. https://doi.org/10.21125/edulearn.2017.2291

Huang, W., & Looi, C.-K. (2021). A critical review of literature on "unplugged" pedagogies in K-12 computer science and computational thinking education. *Computer Science Education*, *31*(1), 83–111. https://doi.org/10.1080/08993408.2020.1789411

Idris, N. I. F., Purnamawati, & Djawad, Y. A. (2024). Development of project based learning model in object oriented programming (OOP) learning in polytechnic. *Asian Journal of Education and Social Studies*, *50*(3), 1–12. https://doi.org/10.9734/ajess/2024/v50i31275

Indriaturrahmi, I., Prayogi, S., Asy'ari, M., & Samsuri, T. (2023). Analysis of Students' design thinking in information technology innovation. *Lensa: Jurnal Kependidikan Fisika*, *11*(2), 89–96. https://doi.org/10.33394/j-lkf.v11i2.10493

Iskandar, H., Triono, S., Yulanto, D., Koto, I., & Lisyanto, L. (2023). Hybrid project-based learning process for students. *Proceedings of the 4th Annual Conference of Engineering and Implementation on Vocational Education, ACEIVE 2022, 20 October 2022, Medan, North Sumatra, Indonesia*. https://doi.org/10.4108/eai.20-10-2022.2328885

Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education*, *103*(2), 253–273. https://doi.org/10.1002/jee.20041

Kimbell, L. (2011). Rethinking design thinking: Part I. *Design and Culture*, *3*(3), 285–306. https://doi.org/10.2752/175470811X13071166525216

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kurtmollaiev, S., Fjuk, A., Pedersen, P. E., Clatworthy, S., & Kvale, K. (2018). Organizational transformation through service design: The institutional logics perspective. *Journal of Service Research*, *21*(1), 59–74. https://doi.org/10.1177/1094670517738371

Ladachart, L., Cholsin, J., Kwanpet, S., Teerapanpong, R., Dessi, A., Phuangsuwan, L., & Phothong, W. (2022). Ninth-grade students' perceptions on the design-thinking mindset in the context of reverse engineering. *International Journal of Technology and Design Education*, *32*(5), 2445–2465. https://doi.org/10.1007/s10798-021-09701-6

Li, T., & Zhan, Z. (2022). A systematic review on design thinking integrated learning in K-12 education. *Applied Sciences*, *12*(16), 8077. https://doi.org/10.3390/app12168077

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2019). Design and design thinking in STEM education. *Journal for STEM Education Research*, *2*(2), 93–104. https://doi.org/10.1007/s41979-019-00020-z

Lin, L., Dong, Y., Chen, X., Shadiev, R., Ma, Y., & Zhang, H. (2024). Exploring the impact of design thinking in information technology education: An empirical investigation. *Thinking Skills and Creativity*, *51*, 101450. https://doi.org/10.1016/j.tsc.2023.101450

Linder, K. E. (2017). Fundamentals of hybrid teaching and learning. *New Directions for Teaching and Learning*, *2017*(149), 11–18. https://doi.org/10.1002/tl.20222

Liu, S., & Li, C. (2023). Promoting design thinking and creativity by making: A quasi-experiment in the information technology course. *Thinking Skills and Creativity*, *49*, 101335. https://doi.org/10.1016/j.tsc.2023.101335

Liu, X., Gu, J., & Xu, J. (2023). The impact of the design thinking model on pre-service teachers' creativity self-efficacy, inventive problem-solving skills, and technology-related motivation. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-023-09809-x

Lubna, Suhirman, & Prayogi, S. (2023). Evaluation of STEM students' critical thinking in terms of cognitive style through problem-based distance learning. *Journal of Education and E-Learning Research*, *10*(3), 557–568. https://doi.org/10.20448/jeelr.v10i3.4972

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

Mahmoud-Jouini, S. B., Midler, C., & Silberzahn, P. (2016). Contributions of design thinking to project management in an innovation context. *Project Management Journal*, *47*(2), 144–156. https://doi.org/10.1002/pmj.21577

Marco, L. D., Venot, A., & Gillois, P. (2017). Does the acceptance of hybrid learning affect learning approaches in France? *Journal of Educational Evaluation for Health Professions*, *14*, 24. https://doi.org/10.3352/jeehp.2017.14.24

Mayer, S. (2023). Understanding the challenges and opportunities of hybrid education with location asynchrony. P*aper presented at Hawaii International Conference on System Sciences.* https://doi.org/10.24251/HICSS.2023.013
Micheli, P., Wilner, S. J. S., Bhatti, S. H., Mura, M., & Beverland, M. B. (2019). Doing design thinking: Conceptual review, synthesis, and research agenda: Doing design thinking. *Journal of Product Innovation Management*, *36*(2), 124–148. https://doi.org/10.1111/jpim.12466
Monica Fransisca, & Permata Saputri, R. (2023). Digital technology's implementation in hybrid learning at higher educational level. *Indonesian Journal of Computer Science*, *12*(3). https://doi.org/10.33022/ijcs.v12i3.3213
Nichols, K., Musofer, R., Fynes-Clinton, L., & Blundell, R. (2022). Design thinking and inquiry behaviours are co-constituted in a community of inquiry middle years' science classroom context: Empirical evidence for design thinking and pragmatist inquiry interconnections. *International Journal of Technology and Design Education*, *32*(5), 2527–2551. https://doi.org/10.1007/s10798-021-09711-4
Northrup, A. K., Burrows Borowczak, A. C., & Slater, T. F. (2022). K-12 teachers' perceptions and experiences in starting to teach computer science. *Education Sciences*, *12*(11), 742. https://doi.org/10.3390/educsci12110742
Novak, E., & Mulvey, B. K. (2021). Enhancing design thinking in instructional technology students. *Journal of Computer Assisted Learning*, *37*(1), 80–90. https://doi.org/10.1111/jcal.12470
Oliveira, M., Zancul, E., & Salerno, M. S. (2024). Capability building for digital transformation through design thinking. *Technological Forecasting and Social Change*, *198*, 122947. https://doi.org/10.1016/j.techfore.2023.122947
Pham, C. T. A., Magistretti, S., & Dell'Era, C. (2022). The role of design thinking in Big Data innovations. *Innovation*, *24*(2), 290–314. https://doi.org/10.1080/14479338.2021.1894942
Prayogi, S., Ahzan, S., Indriaturrahmi, Rokhmat, J., & Verawati, N. N. S. P. (2023). Dynamic blend of ethnoscience and inquiry in a digital learning platform (e-learning) for empowering future science educators' critical thinking. *Journal of Education and E-Learning Research*, *10*(4), 819–828. https://doi.org/10.20448/jeelr.v10i4.5233
Prayogi, S., Ardi, R. F. P., Yazidi, R. E., Tseng, K.-C., & Mustofa, H. A. (2023). The Analysis of students' design thinking in inquiry-based learning in routine university science courses. *International Journal of Essential Competencies in Education*, *2*(1), Article 1. https://doi.org/10.36312/ijece.v2i1.1338
Prihadi, S., Sajidan, S., Siswandari, S., & Sugiyanto, S. (2021). The challenges of application of the hybrid learning model in geography learning during the Covid-19 pandemic. *GeoEco*, *8*(1), 1. https://doi.org/10.20961/ge.v8i1.52205
Rahardjanto, A., Husamah, H., & Fauzi, A. (2019). Hybrid-PjBL: Learning outcomes, creative thinking skills, and learning motivation of preservice teachers. *International Journal of Instruction*, *12*(2), 179–192. https://doi.org/10.29333/iji.2019.12212a
Robbins, P., & Fu, N. (2022). Blind faith or hard evidence? Exploring the indirect performance impact of design thinking practices in R&D. *R&D Management*, *52*(4), 704–719. https://doi.org/10.1111/radm.12515
Rohmatika, R., Yuliani, H., & Annovasho, J. (2024). Meta-analysis: The impact of PjBL on students' creative thinking skills in physics education. *Lensa: Jurnal Kependidikan Fisika*, *12*(1), 116–134. https://doi.org/10.33394/j-lkf.v12i1.11793
Roth, K., Rau, C., & Neyer, A. (2023). Design thinking and dynamic managerial capabilities: A quasi-experimental field study in the aviation industry. *R&D Management*, *53*(5), 801–818. https://doi.org/10.1111/radm.12600

Schweitzer, J., Groeger, L., & Sobel, L. (2016). The design thinking mindset: An assessment of what we know and what we see in practice. *Journal of Design, Business & Society*, *2*(1), 71–94. https://doi.org/10.1386/dbs.2.1.71_1

Shahnila Syed, Munazza Gul, & Alisher, S. (2023). Comparing the influence of critical thinking on the academic performance of two secondary education boards in Pakistan. *International Journal of Social Science & Entrepreneurship*, *3*(1), 205–231. https://doi.org/10.58661/ijsse.v3i1.95

Smith, R. C., Iversen, O. S., & Hjorth, M. (2015). Design thinking for digital fabrication in education. *International Journal of Child-Computer Interaction*, *5*, 20–28. https://doi.org/10.1016/j.ijcci.2015.10.002

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tanujaya, B., Mumu, J., & Margono, G. (2017). The relationship between higher order thinking skills and academic performance of student in mathematics instruction. *International Education Studies*, *10*(11), 78. https://doi.org/10.5539/ies.v10n11p78

Velu, S. R. (2022). Design thinking approach for increasing innovative action in universities: ICT's mediating effect. *Sustainability*, *15*(1), 24. https://doi.org/10.3390/su15010024

Wahyudi, W., Putu Verawati, N. N. S., Islahudin, I., & Agustina, S. (2023). Hybrid Ethno-project based learning integrated with virtual assistive technology to enhance students' critical thinking in fundamental physics course. *TEM Journal*, 2006–2012. https://doi.org/10.18421/TEM124-11

Wu, B., & Liu, Y. (2019). Autonomous learning ability cultivation based on hybrid teaching model of descriptive geometry and mechanical drawing. *Proceedings of the 2019 International Conference on Advanced Education and Social Science Research (ICAESSR 2019)*. Dalian, P.R. China. https://doi.org/10.2991/icaessr-19.2019.36

Zakaria, W., Turmudi, T., & Pentang, J. T. (2022). Information and Communication technology in elementary schools: A comparison between hybrid and face-to-face learning systems. *Profesi Pendidikan Dasar*, *9*(1), 46–54. https://doi.org/10.23917/ppd.v9i1.17534