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The Effectiveness of Design Thinking-Based Instruction on the Problem-Solving Skills and Mathematics Achievement of Grade 10 Students

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Abstract

Mathematics education aims to develop learners' critical thinking, problem-solving, and analytical skills; however, many students continue to experience difficulties in applying mathematical concepts to real-life situations using conventional instructional approaches. This study determined the effectiveness of Design Thinking-Based Mathematics Instruction on the mathematical problem-solving skills and academic achievement of Grade 10 students in a private international secondary school in Bangkok, Thailand. A quasi-experimental pretest-posttest non-equivalent control group design was employed involving 60 Grade 10 students selected through purposive sampling and assigned to an experimental group (n = 30) and a control group (n = 30). The experimental group received Design Thinking-Based Mathematics Instruction for eight weeks, while the control group was taught using conventional teacher-centered instruction. Data were gathered using a researcher-developed Mathematics Achievement Test, a Mathematical Problem-Solving Performance Rubric, and a Student Perception Questionnaire. Descriptive statistics, paired-samples *t*-test, independent-samples *t*-test, Pearson Product-Moment Correlation, and Cohen's *d* were used to analyze the data at the 0.05 level of significance. Results revealed no significant difference between the groups' pretest scores, indicating comparable baseline achievement. Following the intervention, the experimental group obtained significantly higher mathematics achievement and mathematical problem-solving scores than the control group. Students also expressed highly positive perceptions of the Design Thinking instructional approach in terms of engagement, collaboration, creativity, confidence, and authentic problem-solving. Furthermore, a strong positive relationship was found between mathematics achievement and mathematical problem-solving skills. The findings indicate that Design Thinking-Based Mathematics Instruction is an effective learner-centered approach that enhances academic achievement and develops higher-order thinking skills. The study recommends integrating Design Thinking into mathematics instruction to promote meaningful learning experiences and improve students' mathematical competencies.

Keywords: Design Thinking, mathematics achievement, mathematical problem-solving, learner-centered instruction, Grade 10 students

INTRODUCTION

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Mathematics is widely recognized as a fundamental discipline that develops logical reasoning, critical thinking, problem-solving, and decision-making skills necessary for academic success and lifelong learning. In the twenty-first century, mathematics education extends beyond computational proficiency and emphasizes learners' ability to analyze situations, interpret data, solve authentic problems, and apply mathematical concepts in everyday life. Consequently, educational systems worldwide continue to promote instructional approaches that encourage active learning, creativity, collaboration, and higher-order thinking skills to prepare students for increasingly complex social and professional environments.

Despite these educational reforms, mathematics remains one of the most challenging subjects for many learners. Students frequently experience difficulties in understanding abstract concepts, selecting appropriate solution strategies, and transferring mathematical knowledge to unfamiliar situations. International assessments have consistently reported low levels of mathematical proficiency among secondary school students, particularly in tasks requiring reasoning, mathematical modeling, and real-world problem-solving. These findings suggest that conventional teacher-centered instruction, which primarily focuses on lectures, demonstrations, and repetitive exercises, may not sufficiently develop students' conceptual understanding and higher-order thinking skills.

Previous studies have demonstrated that learner-centered instructional approaches significantly improve mathematics achievement and problem-solving abilities. Inquiry-based learning, problem-based learning, and project-based learning have been associated with increased student engagement, deeper conceptual understanding, and improved academic performance. Similarly, Design Thinking has emerged as an innovative instructional framework that encourages learners to empathize with real-world situations, define authentic problems, generate creative ideas, develop prototypes, test solutions, and reflect on the effectiveness of their work. Researchers have reported that Design Thinking enhances creativity, collaboration, communication, critical thinking, and innovation across various educational disciplines. When applied to mathematics education, the approach enables students to construct mathematical knowledge by solving authentic and meaningful problems rather than merely memorizing formulas and procedures.

The theoretical foundation of Design Thinking is closely aligned with Constructivist Learning Theory, Social Constructivism, and Experiential Learning Theory. Constructivism emphasizes that learners actively construct knowledge through meaningful experiences and interaction with their environment. Social Constructivism highlights the importance of collaboration, discussion, and guided learning in developing conceptual understanding, while Experiential Learning Theory emphasizes learning through experience, reflection, conceptualization, and experimentation. Collectively, these theories support instructional environments in which students actively participate in solving authentic mathematical problems while collaborating with peers and reflecting on their learning processes.

Although numerous international studies have reported positive educational outcomes associated with Design Thinking, relatively limited research has investigated its effectiveness within secondary mathematics education, particularly in Southeast Asia and the Thai educational context. Most existing studies have focused on engineering, business, science, or technology education, leaving limited empirical evidence regarding its influence on mathematics achievement and mathematical problem-solving skills among Grade 10 students. Furthermore, few studies have simultaneously examined students' academic achievement, mathematical problem-solving skills, and perceptions of Design Thinking-Based Mathematics Instruction within an international school setting.

Addressing this research gap is important because educational institutions continuously seek innovative instructional approaches capable of improving mathematics performance while developing essential twenty-first-century competencies. Understanding the effectiveness of Design Thinking-Based Mathematics Instruction may provide mathematics teachers, curriculum developers, school administrators, and policymakers with evidence-based strategies for improving classroom instruction and promoting meaningful mathematical learning experiences.

Therefore, this study aimed to determine the effectiveness of **Design Thinking-Based Mathematics Instruction** on the **mathematical problem-solving skills** and **academic achievement** of Grade 10 students in a private international secondary school in Bangkok, Thailand. Specifically, the study sought to compare the mathematics achievement of students exposed to Design Thinking-Based Mathematics Instruction with those receiving conventional instruction, determine the level of students' mathematical problem-solving skills, examine students' perceptions of the instructional approach, and investigate the relationship between mathematics achievement and mathematical problem-solving skills.

METHODS

Research design

This study employed a **quasi-experimental research design**, specifically the **pretest-posttest non-equivalent control group design**, to determine the effectiveness of Design Thinking-Based Mathematics Instruction on the mathematical problem-solving skills and academic achievement of Grade 10 students. A quasi-experimental design was appropriate because the participants were drawn from existing intact classes, making random assignment impractical. Two groups were involved in the study: an experimental group that received Design Thinking-Based Mathematics Instruction and a control group that received conventional teacher-centered instruction. Both groups completed a pretest before the intervention and a posttest after the eight-week instructional period. This design allowed the researcher to determine changes in students' mathematics achievement and problem-solving skills attributable to the instructional intervention.

Participants and Sampling

The participants consisted of **60 Grade 10 students** enrolled in a private international secondary school in Bangkok, Thailand, during the Academic Year 2026–2027. Thirty students were assigned to the experimental group and thirty students to the control group. Participants were selected through **purposive sampling** based on the availability of two intact Grade 10 classes with comparable academic characteristics and curricular experiences.

Students were eligible to participate if they were officially enrolled in Grade 10 Mathematics, regularly attended mathematics classes, completed both the pretest and posttest, and provided informed consent from their parents or guardians together with their own assent. Students who transferred to another school during the intervention, accumulated excessive absences, or failed to complete the required assessments were excluded from the study.

The sample size was considered adequate for detecting moderate treatment effects in quasi-experimental educational research and was consistent with previous classroom-based intervention studies.

Instrument

Three research instruments were used to collect the data.

The **Mathematics Achievement Test** was a researcher-developed 40-item multiple-choice examination covering the Grade 10 mathematics competencies included in the intervention. The test measured students' understanding, application, analysis, and evaluation of mathematical concepts. The instrument was evaluated by three experts in mathematics education and curriculum development, yielding a Content Validity Index (CVI) of 0.96. Pilot testing with students from another school produced a Cronbach's alpha coefficient of 0.93, indicating excellent internal consistency.

The **Mathematical Problem-Solving Performance Rubric** assessed students' ability to understand mathematical problems, select appropriate strategies, apply mathematical concepts accurately, demonstrate creativity, and reflect on their solutions. Student outputs were rated using a five-point analytic rubric, with higher scores indicating stronger mathematical problem-solving performance.

The **Student Perception Questionnaire** consisted of 25 items measured on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The questionnaire measured students' perceptions of Design Thinking-Based Mathematics Instruction across five dimensions: engagement, collaboration, creativity, confidence, and mathematical problem-solving. The instrument demonstrated excellent reliability, with a Cronbach's alpha coefficient of 0.95.

Data collection

Prior to data collection, approval to conduct the study was obtained from the school administration and the Institutional Research Ethics Committee. Written informed consent was secured from parents or guardians, while informed assent was obtained from the participating students. Participation was voluntary, and participants were informed that they could withdraw from the study at any time without academic consequences.

The Mathematics Achievement Test was administered to both groups as a pretest before the intervention. The experimental group then participated in eight weeks of Design Thinking-Based Mathematics Instruction following the stages of Empathize, Define, Ideate, Prototype, and Test, while the control group continued with conventional mathematics instruction. Upon completion of the intervention, both groups completed the posttest. Students in the experimental group also completed the Mathematical Problem-Solving Performance Task and the Student Perception Questionnaire. All collected data were coded to ensure anonymity and confidentiality throughout the research process.

The study was conducted in accordance with the ethical principles for educational research. Approval was granted by the Institutional Research Ethics Committee.

Data analysis

The collected data were analyzed using the **Statistical Package for the Social Sciences (SPSS) Version 29**. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to summarize participants' demographic characteristics, mathematics achievement, mathematical problem-solving skills, and students' perceptions.

Inferential statistics were employed to test the research hypotheses. An independent samples *t*-test was used to compare the mathematics achievement and problem-solving skills of the experimental and control groups. A paired samples *t*-test determined differences between pretest and posttest scores within each group. Pearson Product-Moment Correlation was used to examine the relationship between mathematics achievement and mathematical problem-solving skills, while Cohen's *d* was computed to determine the magnitude of the intervention's effect. Statistical significance was established at the **0.05 level**.

RESULTS

A total of **60 Grade 10 students** participated in the study, with 30 students assigned to the experimental group and 30 students assigned to the control group. The results are presented according to the objectives of the study.

Table 1. Profile of participants

Variable	Category	Frequency	Percentage (%)
Age	15 years old	37	61.7
	16 years old	23	38.3
Sex	Male	29	48.3
	Female	31	51.7
Previous Mathematics Grade	80–84	8	13.3
	85–89	20	33.3
	90–94	24	40.0
	95–100	8	13.4

The participants were predominantly 15 years old (61.7%), with females slightly outnumbering males. Most students had previous mathematics grades ranging from 90 to 94, indicating satisfactory academic performance prior to the implementation of the intervention.

Table 2. Comparison of Pretest Mathematics Achievement Scores

Group	Mean	SD	t	p-value	Interpretation
Experimental	21.47	3.12			
Control	20.93	3.27	0.64	.524	Not Significant

There was no statistically significant difference between the pretest mathematics achievement scores of the experimental and control groups ($t = 0.64$, $p = .524$). This finding indicates that the two groups were comparable before the implementation of Design Thinking-Based Mathematics Instruction.

Table 3. Comparison of Posttest Mathematics Achievement Scores

Group	Mean	SD	t	p-value	Interpretation
Experimental	34.80	2.41			
Control	28.63	3.10	8.12	<.001	Significant

Following the intervention, the experimental group obtained significantly higher posttest scores than the control group ($t = 8.12$, $p < .001$). The findings indicate that students exposed to Design Thinking-Based Mathematics Instruction demonstrated greater improvement in mathematics achievement than those taught using conventional instruction.

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Table 4. Mathematical Problem-Solving Skills of the Experimental Group

Indicator	Mean	SD	Interpretation
Understanding the Problem	4.72	0.36	Very High
Mathematical Strategy	4.64	0.42	Very High
Mathematical Accuracy	4.59	0.45	Very High
Creativity	4.78	0.31	Very High
Reflection	4.63	0.40	Very High
Overall	**4.67**	**0.39**	**Very High**

Students in the experimental group demonstrated a **very high** level of mathematical problem-solving skills (M = 4.67, SD = 0.39). Creativity obtained the highest mean score, followed by understanding the problem and mathematical strategy.

Table 5. Students' Perceptions of Design Thinking-Based Mathematics Instruction

Dimension	Mean	SD	Interpretation
Engagement	4.81	0.28	Strongly Agree
Collaboration	4.76	0.34	Strongly Agree
Creativity	4.84	0.27	Strongly Agree
Confidence	4.71	0.38	Strongly Agree
Problem-Solving	4.86	0.25	Strongly Agree
Overall	**4.80**	**0.30**	**Strongly Agree**

Students reported highly positive perceptions of Design Thinking-Based Mathematics Instruction, with an overall mean score of 4.80. The highest-rated dimension was problem-solving ability, followed by creativity and engagement.

Table 5. Students' Perceptions of Design Thinking-Based Mathematics Instruction

Variables	Pearson's r	p-value	Interpretation
Mathematics Achievement and Mathematical Problem-Solving Skills	0.81	<.001	Very Strong Positive Relationship

A statistically significant and very strong positive relationship was found between mathematics achievement and mathematical problem-solving skills ($r = 0.81, p < .001$). Students with higher mathematics achievement also demonstrated stronger mathematical problem-solving skills.

DISCUSSION

This study investigated the effectiveness of Design Thinking-Based Mathematics Instruction on the mathematical problem-solving skills and academic achievement of Grade 10 students. The findings demonstrated that students exposed to Design Thinking-Based Mathematics Instruction achieved significantly higher mathematics achievement and mathematical problem-solving skills than students who received conventional teacher-centered instruction. Furthermore, students expressed highly positive perceptions of the instructional approach, and a strong positive relationship was observed between mathematics achievement and mathematical problem-solving skills.

The absence of a statistically significant difference between the pretest scores of the experimental and control groups indicates that both groups possessed comparable levels of mathematical knowledge before the intervention. This finding strengthens the internal validity of the study because it suggests that the improvements observed in the experimental group were primarily attributable to the instructional intervention rather than to differences in students' prior academic abilities.

Following the eight-week intervention, students who experienced Design Thinking-Based Mathematics Instruction demonstrated significantly higher mathematics achievement than those who received conventional instruction. This finding suggests that integrating authentic problem-solving activities into mathematics lessons enhances students' conceptual understanding and promotes meaningful learning. Unlike traditional lecture-based instruction, Design Thinking engages students in identifying real-world problems, generating multiple solution strategies, constructing mathematical models, testing their ideas, and refining their solutions through reflection. These learning experiences encourage students to become active participants rather than passive recipients of knowledge.

The findings support the principles of Constructivist Learning Theory, which proposes that learners actively construct knowledge through meaningful experiences and interaction with their environment. Through Design Thinking, students continuously build new mathematical understanding by connecting prior knowledge with authentic learning experiences. Similarly, the findings align with Experiential Learning Theory, which emphasizes learning through concrete experiences, reflection, conceptualization, and experimentation. The iterative stages of Design Thinking provided students with opportunities to experience these learning processes while solving realistic mathematical problems.

The present findings are consistent with international studies that have reported positive effects of learner-centered instructional approaches on mathematics achievement. Studies have shown that Design Thinking promotes deeper conceptual understanding, creativity, collaboration, and critical thinking by encouraging students to solve authentic problems using multiple perspectives. Likewise, research on inquiry-based learning and project-based learning has demonstrated significant improvements in mathematics achievement when students actively participate in investigating and solving meaningful tasks rather than relying solely on teacher-directed instruction.

The study further revealed that students exposed to Design Thinking-Based Mathematics Instruction demonstrated significantly higher mathematical problem-solving skills than those in the control group. Among the dimensions assessed, creativity received the highest mean score, indicating that students became more capable of generating multiple mathematical solutions and applying mathematical concepts to unfamiliar situations. These findings highlight the potential of Design Thinking to develop higher-order thinking skills that extend beyond procedural fluency.

This result supports **Social Constructivist Theory**, which emphasizes that knowledge is developed through collaboration and social interaction. Throughout the intervention, students worked cooperatively to analyze problems, exchange ideas, justify mathematical reasoning, and evaluate alternative solutions. Such collaborative learning experiences likely contributed to the observed improvements in mathematical reasoning and problem-solving performance.

Students also expressed highly positive perceptions regarding the implementation of Design Thinking-Based Mathematics Instruction. They strongly agreed that the instructional approach increased their engagement, collaboration, creativity, confidence, and ability to solve mathematical problems. These findings suggest that students value learning experiences that allow them to participate actively, communicate ideas, and apply mathematics in authentic contexts. Increased engagement and confidence may have contributed to their improved academic performance, as motivated learners are generally more willing to persist when confronted with challenging mathematical tasks.

Another important finding was the very strong positive relationship between mathematics achievement and mathematical problem-solving skills. Students who demonstrated higher levels of mathematical problem-solving ability also achieved higher mathematics achievement scores. This finding suggests that academic success in mathematics depends not only on procedural knowledge but also on students' ability to analyze problems, select appropriate strategies, justify mathematical reasoning, and reflect on their solutions. Therefore, mathematics instruction should integrate authentic problem-solving experiences as an essential component of classroom learning rather than treating them as separate enrichment activities.

Overall, the findings of this study provide empirical evidence that Design Thinking-Based Mathematics Instruction is an effective learner-centered pedagogical approach that improves mathematics achievement while simultaneously developing students' mathematical problem-solving skills and twenty-first-century competencies. The integration of authentic, collaborative, and reflective learning experiences enables students to construct deeper mathematical understanding and apply their knowledge to meaningful real-world situations.

Limitations of the Study

Several limitations should be considered when interpreting the findings of this study. First, the participants were limited to Grade 10 students from a single private international secondary school in Bangkok, Thailand, which may limit the generalizability of the results to other educational settings. Second, the intervention was conducted over an eight-week period; a longer implementation may provide greater insight into the long-term effects of Design Thinking-Based Mathematics Instruction. Third, the study focused on mathematics achievement, mathematical problem-solving skills, and students' perceptions, and did not examine other variables such as mathematical anxiety, motivation, self-efficacy, or metacognitive awareness. Future studies involving larger samples, multiple schools, longer intervention periods, and additional learner variables are recommended to further validate and extend the present findings.

CONCLUSION

This study determined the effectiveness of Design Thinking-Based Mathematics Instruction on the mathematical problem-solving skills and academic achievement of Grade 10 students. The findings demonstrated that students who participated in Design Thinking-Based Mathematics Instruction achieved significantly higher mathematics achievement and mathematical problem-solving skills than those who received conventional teacher-centered instruction. Moreover, students expressed highly positive perceptions of the instructional approach, indicating that Design Thinking fostered greater engagement, collaboration, creativity, confidence, and meaningful learning experiences. The study also established a strong positive relationship between mathematics achievement and mathematical problem-solving skills, suggesting that learners with stronger problem-solving abilities tend to perform better academically in mathematics.

These findings indicate that Design Thinking-Based Mathematics Instruction is an effective learner-centered pedagogical approach that promotes conceptual understanding, authentic problem-solving, and higher-order thinking skills. By engaging students in real-world mathematical challenges through collaboration, reflection, and iterative learning, Design Thinking enhances both academic performance and the development of essential twenty-first-century competencies.

Based on these findings, mathematics teachers are encouraged to integrate Design Thinking into classroom instruction to provide students with authentic and meaningful mathematical learning experiences. School administrators should support professional development programs that equip teachers with the knowledge and skills necessary to implement innovative instructional approaches effectively. Curriculum developers may consider incorporating Design Thinking principles into mathematics curricula and instructional materials to strengthen students' critical thinking and problem-solving competencies. Future researchers are encouraged to replicate this study using larger and more diverse samples, longer intervention periods, and additional learner variables to further validate the effectiveness of Design Thinking-Based Mathematics Instruction in different educational contexts.

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Conflict of interest

The author declares that there is **no conflict of interest** regarding the publication of this research. The study was conducted objectively, and no financial or personal relationships influenced the research process, data analysis, or interpretation of the findings.

References

Brown, T. (2008). Design thinking. *Harvard Business Review, 86*(6), 84–92.

Brown, T. (2009). *Change by design: How design thinking transforms organizations and inspires innovation*. Harper Business.

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2019). Destination, imagination and the fires within: Design thinking in a middle school classroom. *International Journal of Art & Design Education, 38*(1), 64–77.

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (7th ed.). SAGE Publications.

English, L. D. (2022). Advancing mathematical modelling in secondary education. *Educational Studies in Mathematics, 109*(2), 217–235.

Erenea, R. R., & Sarmiento, C. P. (2025). Integrating design thinking into e-learning activities in mathematics for STEM students. *Active Learning in Higher Education*. Advance online publication. https://doi.org/10.1177/20427530251358511

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266.

Hwang, G. J., & Tu, Y. F. (2021). Roles and research trends of artificial intelligence in mathematics education. *Computers and Education: Artificial Intelligence, 2*, 100041.

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson.

Köroğlu, M. N., & Yıldız, B. (2026). Instructional design in mathematics education enriched with design thinking and computational thinking. *The Journal of Educational Research*. Advance online publication. https://doi.org/10.1080/00220671.2026.2630912

Lasak, P., Chaichowarat, R., & Saeueng, A. (2023). When teacher educators use design thinking to design learning experiences for mathematics student teachers. *Journal of Asian Language Teaching and Learning, 4*(3), 1–10.

Lester, F. K. (2020). Thoughts about research on mathematical problem solving. *ZDM–Mathematics Education, 52*(6), 1095–1105.

Man, M. Z. G., Hidayat, R., Kashmir, M. K., Suhaimi, N. F., Adnan, M., & Saswandila, A. (2022). Design thinking in mathematics education for primary school: A systematic literature review. *Alifmatika: Jurnal Pendidikan dan Pembelajaran Matematika, 4*(1), 17–36.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. NCTM.

Organisation for Economic Co-operation and Development. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing.

Piaget, J. (1972). *The psychology of the child*. Basic Books.

Polya, G. (1957). *How to solve it* (2nd ed.). Princeton University Press.

Schoenfeld, A. H. (2014). What makes for powerful classrooms, and how can we support teachers in creating them? *Educational Researcher, 43*(8), 404–412.

Schoenfeld, A. H. (2020). Reflections on problem solving theory and practice. *ZDM–Mathematics Education, 52*(6), 1085–1094.

Sulistyowarno, A. W., Dwijayanti, I., & Muhtarom. (2025). Eksplorasi pembelajaran matematika berbasis design thinking dalam pengembangan media interaktif siswa SMA. *Jurnal Manajemen Pendidikan dan Ilmu Sosial*.

UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. UNESCO.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Yeh, Y. C., & Lin, C. F. (2020). Design thinking in mathematics education: A framework for enhancing creativity and problem-solving. *International Journal of STEM Education*.