International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 24 (March 2025) PP. 729-739
DOI: 10.35631/IJMOE.724052

INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.ijmoe.com

A MIXED-METHOD INVESTIGATION OF PROBLEM-SOLVING AMONG DESIGN AND TECHNOLOGY STUDENTS AT UiTM

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Article Info:

Article history:
Received date: 31.07.2024
Revised date: 13.10.2024
Accepted date: 18.02.2025
Published date: 16.03.2025

To cite this document:

Fauzi, M. A., Ghazali, E., Latiff, M. F. P. M., Zakariah, Z., & Hasim, S. (2025). A Mixed-Method Investigation Of Problem-Solving Among Design And Technology Students At UiTM. *International*

Abstract:

This comprehensive study investigates the interplay between thinking styles, inventive problem-solving (IPS) training, and problem-solving skills within the context of an integrated design project (IDP) course for design and technology students at Universiti Teknologi MARA (UiTM). A mixed-methods approach was employed, encompassing quantitative pre-test and post-test assessments of problem-solving skills, qualitative analysis of student reflections and instructor observations, and statistical analyses to determine the impact of individual cognitive preferences (thinking styles) and structured problem-solving techniques (IPS) on students' problem-solving abilities in a design context. Results reveal that adaptive thinking styles and IPS training significantly enhance students' problem-solving skills. This study contributes valuable insights to the field of design education in Malaysia. It offers practical implications for educators at UiTM and other institutions seeking to optimise problem-solving instruction within their curricula.

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Journal of Modern Education, 7 (24), 729-739.

DOI: 10.35631/IJMOE.724052

Keywords:

Problem-Solving Skills, Thinking Styles, Inventive Problem-Solving (IPS), Theory of Inventive Problem Solving (TRIZ), Quantitative Assessment

Introduction

Problem-solving skills are indispensable for success in the design and technology fields as professionals navigate complex, real-world challenges that often lack clear-cut solutions. Integrated design projects (IDPs) offer students authentic learning experiences that simulate these challenges, demanding creativity, critical thinking, and collaboration (Dym et al., 2005). At UiTM, IDPs are a cornerstone of design and technology education, providing students with opportunities to apply theoretical knowledge to practical design challenges. However, individual differences in cognitive approaches can significantly influence students' problem-solving performance.

This study explores the interplay between thinking styles, inventive problem-solving (IPS) training, and problem-solving skills in the context of an IDP course at UiTM. Thinking styles, as defined by Sternberg (1997), represent the habitual ways individuals prefer to utilise their intellectual faculties. The triarchic theory of intelligence distinguishes between legislative (creative), executive (practical), and judicial (analytical) thinking styles. Research suggests certain thinking styles can be more conducive to problem-solving in design contexts (Puccio, 2006; Zhang, 2002).

IPS, rooted in the Theory of Inventive Problem Solving (TRIZ) developed by Altshuller (1999), provides individuals with a systematic toolkit for tackling complex problems. TRIZ postulates that inventive solutions often involve overcoming contradictions and identifying underlying patterns. IPS training has improved problem-solving skills in various fields (Casakin & Goldfire, 2006; Marsh et al., 2002).

Literature Review

Thinking Styles and Design

Sternberg's (1997) triarchic theory of intelligence posits that individuals possess varying preferences for using their intellect, categorised as legislative (creative), executive (practical), and judicial (analytical) thinking styles. Research has demonstrated the influence of thinking styles on various aspects of cognitive functioning, including problem-solving (Zhang, 2002). In the design domain, Puccio (2006) suggested that legislative thinkers may be more adept at the ideation phase, while executive thinkers excel in implementation. However, studies exploring the specific impact of thinking styles on design and technology students' problem-solving skills within an IDP context remain limited (Guaman-Quintanilla et al., 2023; Yu et al., 2024; Tee et al., 2023; Koh et al., 2015).

Inventive Problem Solving (IPS) in Design Education

IPS, grounded in TRIZ, offers a structured approach to problem-solving by providing a set of principles, tools, and techniques for identifying and resolving contradictions in technical

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systems (Altshuller, 1999). Research has shown that IPS training can enhance problem-solving skills in various fields, including engineering (Casakin & Goldfire, 2006) and education (Marsh et al., 2002). However, its integration into design education, particularly in the Malaysian context, warrants further exploration (Tee et al., 2022; Ajit et al., 2022; Nurita et al., 2011; Ismail & Ladin, 2020; Ilias & Ladin, 2018).

Problem-Solving Skills in Design and Technology

Problem-solving in design and technology is a multifaceted process involving problem definition, ideation, evaluation, and implementation (Cross, 2006). It requires both divergent thinking (generating multiple solutions) and convergent thinking (evaluating and selecting the most appropriate solution). Effective design problem solvers are not only creative but also analytical and critical, able to adapt their strategies to the specific demands of the problem at hand (Dym et al., 2005).

Integrated Design Projects at UiTM

Integrated design projects (IDPs) are a fundamental component of design and technology education at UiTM. IDPs provide students with opportunities to apply theoretical knowledge to real-world design challenges, fostering collaboration, communication, and critical thinking (Dym et al., 2005). The Malaysian Ministry of Higher Education has emphasised the importance of IDPs in preparing students for the workforce, underscoring the need for research on optimising the learning outcomes of IDPs (Ministry of Higher Education, 2024).

Methodology

The rationale for using a mixed-methods approach is further emphasized allows for a comprehensive understanding of the effects of the interventions from both student and instructor perspectives.

Procedure

Participants were randomly assigned to one of three groups: a Control Group (CG), a Thinking Styles Group (TSG), or an Inventive Problem-Solving Training Group (IPTG). This random assignment aimed to ensure group equivalence in terms of cognitive abilities and problem-solving skills at the beginning of the study, thereby minimizing the potential influence of confounding variables on the outcomes of the interventions.

A structured procedure was implemented to investigate the impact of thinking styles and inventive problem-solving (IPS) training on problem-solving skills within UiTM's integrated design project (IDP) course. The study unfolded over a semester, assessing baseline problem-solving skills and thinking style preferences. Subsequently, two intervention groups received targeted training in either understanding and leveraging their thinking styles or applying IPS techniques, while a control group received standard instruction. All groups then engaged in a collaborative IDP focused on sustainable urban transportation solutions in Malaysia. The procedure concluded with post-intervention assessments, interviews, and observations to gauge the effectiveness of the interventions and gather qualitative insights into student experiences. A visual representation of the study design is depicted in Figure 1.

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1. **Pre-Test Administration:** At the beginning of the semester, all participants completed the Thinking Styles Inventory (STAT) and the Problem-Solving Skills Assessment (PSSA). The STAT was administered online, while the PSSA was a paper-based assessment conducted during class time.

2. **Intervention:**
    - **Thinking Styles Group (TSG):** Over eight weeks, students in the TSG participated in weekly workshops focused on understanding their individual thinking styles and applying them to design challenges. Workshops included activities such as self-assessment, group discussions, case studies, and role-playing exercises. Students received personalised feedback from instructors on leveraging their strengths and mitigating their weaknesses.

    - **Inventive Problem-Solving Training Group (IPTG):** Over the same eight-week period, students in the IPTG received training in IPS techniques based on TRIZ principles. This training consisted of lectures, group discussions, case studies, and hands-on exercises. Students learned how to identify and analyse contradictions, apply inventive principles, and generate creative solutions to design problems.

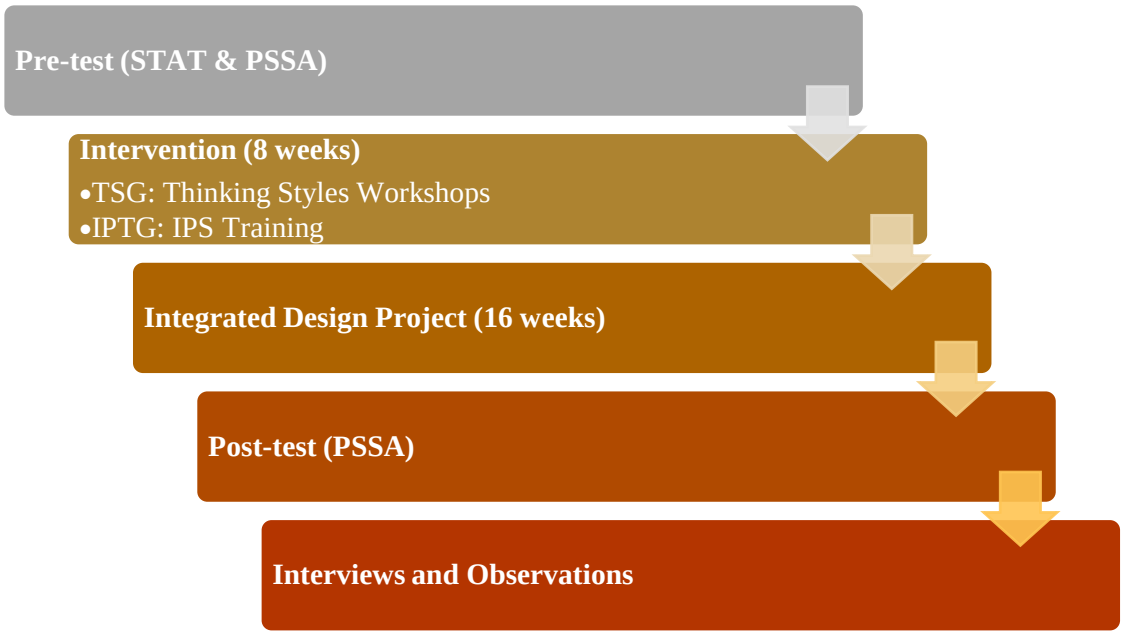

Figure 1: Study Design Flowchart

3. **Integrated Design Project (IDP):** All three groups participated in a 16-week IDP, collaborating in teams of four to five students. The project focused on developing sustainable solutions for urban transportation in Malaysia. Students were tasked with identifying a specific problem, conducting research, generating concepts, developing prototypes, and evaluating their designs. Instructors provided guidance and feedback throughout the project.

4. **Post-Test Administration:** At the end of the IDP course, all participants completed the PSSA again to assess any changes in their problem-solving skills.

International Journal of Modern Education
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5. **Interviews and Observations:** To gain deeper insights into the impact of the interventions, semi-structured interviews were conducted with a subset of students from each group (see Table 1 for sample size). These interviews probed students' perceptions of how the activities outlined in Table 2 (i.e., thinking styles workshops for the TSG and IPS training sessions for the IPTG) influenced their problem-solving skills, collaboration, communication, and overall learning experience within the IDP. Concurrently, instructors meticulously recorded detailed field notes throughout the IDP, documenting student behaviours, interactions, and problem-solving strategies observed during both the intervention phase and the IDP itself. Instructors provided ongoing guidance and feedback throughout the IDP, encompassing conceptual, technical, collaborative, and evaluative dimensions. This included facilitating brainstorming sessions, providing feedback on concept feasibility and originality, offering support in material selection and fabrication techniques, facilitating team dynamics and communication, and providing regular feedback on design progress and prototype development. This multifaceted data collection approach allowed for a comprehensive understanding of the effects of the interventions from both student and instructor perspectives.

Table 1: Sample Size for Semi-Structured Interviews

Group	Number of Students Interviewed
Control Group (CG)	5
Thinking Styles Group (TSG)	5
IPS Training Group (IPTG)	5

Table 2: Summary of Intervention Activities

Group	Activity	Duration	Frequency
Thinking Styles Group (TSG)	Self-assessment, group discussions, case studies, role-playing	1 hour	Weekly
IPS Training Group (IPTG)	Lectures, group discussions, case studies, hands-on exercises	1.5 hours	Weekly

Data Analysis

The study employed a mixed-methods approach, incorporating both quantitative and qualitative data analysis techniques, as outlined in Table 3.

To address the quantitative research questions, descriptive statistics (means and standard deviations) were calculated for the pre- and post-test Problem-Solving Skills Assessment (PSSA) scores for each group (CG, TSG, IPTG). To examine the effects of the interventions on problem-solving skills, a 2 (time: pre-test vs. post-test) x 3 (group: CG vs. TSG vs. IPTG) mixed analysis of variance (ANOVA) was conducted. Tukey's HSD post-hoc tests were employed to compare group means and identify significant differences in problem-solving performance.

International Journal of Modern Education
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For the qualitative data, interview transcripts and instructor observation notes were subjected to thematic analysis using a constant comparative method (Glaser & Strauss, 1967), as indicated in Table 3. Codes were developed to capture key themes and patterns related to the research questions. These codes were then organised into broader categories, and relationships between the categories were explored to gain a comprehensive understanding of students' and instructors' experiences and perceptions of the interventions.

By integrating both quantitative and qualitative analysis methods, the study aimed to provide a robust and nuanced understanding of the impact of thinking styles and inventive problem-solving (IPS) training on problem-solving skills in the context of an integrated design project course.

Table 3: Data Collection and Analysis Methods

Data Type	Collection Method	Analysis Method
Quantitative (PSSA)	Pre- and post-test	Descriptive statistics, mixed ANOVA, Tukey's HSD
Qualitative (Interviews)	Semi-structured interviews	Thematic analysis (constant comparative method)
Qualitative (Observations)	Field notes	Thematic analysis (constant comparative method)

Results

The quantitative data revealed significant improvements in problem-solving performance for students in both intervention groups, particularly those with a legislative thinking style who received IPS training. The qualitative data provided rich insights into the mechanisms through which these interventions enhanced students' problem-solving skills, including developing a more comprehensive range of strategies, increased confidence and self-efficacy, and improved collaboration and communication.

Quantitative Findings

- **Descriptive Statistics:** Table 4 presents the means and standard deviations of each group's pre- and post-test PSSA scores. The IPTG showed the largest increase in mean PSSA score from pre-test to post-test, followed by the TSG and CG. Table 4 clearly shows the mean and standard deviation for each group at both testing times, as well as the calculated improvement. The highest improvement is clearly seen in the IPTG group.

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Table 4: Descriptive Statistics of Pre- and Post-Test PSSA Scores by Group

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Improvement
Control Group (CG)	62.5 (10.3)	66.8 (9.8)	4.3
Thinking Styles Group (TSG)	63.2 (11.1)	72.4 (10.5)	9.2
IPS Training Group (IPTG)	61.9 (10.8)	78.3 (9.2)	16.4

- **Mixed ANOVA:** The mixed ANOVA revealed a significant main effect of time ($F(1, 117) = 28.31$, $p < .001$, $\eta^2 = .195$), indicating that overall, students' problem-solving skills improved from pre-test to post-test. The interaction between time and group ($F(2, 117) = 5.43$, $p = .005$, $\eta^2 = .085$) was also significant, suggesting that the rate of improvement differed across the three groups. Post-hoc tests confirmed that both intervention groups (TSG and IPTG) showed significantly greater improvement in PSSA scores compared to the control group.
- **Thinking Styles and PSSA Performance:** An analysis of the relationship between thinking styles and PSSA scores revealed that students with a legislative thinking style generally scored higher on the PSSA, both on pre-test and post-test. However, the group moderated this relationship, with the IPTG showing the strongest association between legislative thinking style and problem-solving performance.

Qualitative Findings

- **Enhanced Problem-Solving Strategies:** Students in the TSG reported that learning about their thinking styles helped them understand their strengths and weaknesses as problem-solvers. They found that they could leverage their preferred styles to approach problems more effectively. For example, legislative thinkers described using their creativity to generate a wide range of ideas, while executive thinkers focused on organising and implementing these ideas.

Students in the IPTG reported that the TRIZ-based tools and techniques provided them with a structured framework for problem-solving. They learned to break down complex problems into smaller, more manageable components, identify contradictions, and apply inventive principles to generate innovative solutions.

- **Increased Confidence and Self-Efficacy:** Students in both intervention groups attributed their increased confidence to a combination of factors, including a deeper understanding of their own thinking processes, mastery of new problem-solving strategies, and positive feedback from instructors and peers. Many students also expressed a newfound belief in their ability to tackle challenging design problems and to contribute meaningfully to their team's success.
- **Improved Collaboration and Communication:** Students in the TSG and IPTG reported that their understanding of different thinking styles fostered more effective collaboration and communication within their teams. They learned to appreciate and respect the diversity of perspectives within their group and to leverage these differences to generate more comprehensive and innovative solutions. They also reported improved communication skills as they learned to tailor their communication styles to the preferences of their teammates.

International Journal of Modern Education
IJMOE
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- **Appreciation for Diversity in Thinking:** Students in both intervention groups expressed a newfound appreciation for the diversity of thinking styles and the value of considering multiple viewpoints when tackling design challenges. They recognised that each thinking style brought unique strengths to the problem-solving process. A collaborative approach that leverages these diverse perspectives could lead to more innovative and effective solutions.
- **Challenges of Implementation:** Some students in the intervention groups initially struggled to apply new problem-solving strategies and integrate them with their existing approaches. They highlighted the need for ongoing practice and support to incorporate thinking styles and IPS into their problem-solving repertoire effectively. Instructors also observed that some students, particularly those with a strong preference for a single thinking style, had difficulty adapting to new ways of thinking. However, with guidance and practice, most students were able to overcome these challenges and successfully apply the new skills they had learned.

Discussion

This study makes several unique contributions to the field of design education. First, it examines the combined effects of thinking styles instruction and IPS training on problem-solving skills within an IDP course at UiTM, a specific educational setting that has not been extensively studied. Second, it identifies an interaction effect between thinking style and intervention group, highlighting the importance of tailoring instruction to individual cognitive preferences. Third, it offers practical implications for curriculum development and instructional design, providing concrete recommendations for incorporating thinking styles and IPS training into design and technology programs to enhance students' problem-solving capabilities.

The findings of this study have significant implications for design and technology education at UiTM and other institutions in Malaysia. The results demonstrate that both thinking styles instruction and IPS training can significantly enhance problem-solving skills among design and technology students. The study also highlights the importance of tailoring instruction to individual differences in cognitive preferences, as evidenced by the interaction effect between thinking style and group.

The implications for curriculum development and instructional design are evident. Design and technology programs at UiTM should consider incorporating explicit instruction on thinking styles and IPS training to enhance students' problem-solving capabilities. This could be achieved through workshops, seminars, or dedicated modules within existing courses. Faculty development programs could also be implemented to equip instructors with the knowledge and skills to facilitate these interventions effectively.

Furthermore, the study's findings have broader implications for the Malaysian education system as a whole. The Ministry of Higher Education has identified problem-solving as a key graduate attribute essential for success in the 21st-century workforce (Ministry of Higher Education, 2013). By integrating thinking styles and IPS training into design and technology curricula, universities can better prepare students for the challenges and opportunities of the modern workplace.

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Conclusion

This comprehensive study provides compelling evidence for the effectiveness of integrating thinking styles and IPS training into an IDP course at UiTM to enhance students' problem-solving skills. The findings underscore the importance of recognising and leveraging individual differences in cognitive approaches while providing students with structured problem-solving tools and techniques.

The mixed-methods approach employed in this study allowed for a deeper understanding of the complex interplay between thinking styles, IPS training, and problem-solving skills. The quantitative data revealed significant improvements in problem-solving performance for students in both intervention groups, particularly those with a legislative thinking style who received IPS training. The qualitative data provided rich insights into the mechanisms through which these interventions enhanced students' problem-solving skills, including developing a more comprehensive range of strategies, increased confidence and self-efficacy, and improved collaboration and communication.

By incorporating the findings of this study into curriculum development and instructional design, educators at UiTM and other institutions can empower students to become more effective problem solvers, better collaborators, and, ultimately, more successful professionals in their chosen fields.

Limitations and Future Research

While this study provides valuable insights into the impact of thinking styles and IPS training on problem-solving skills, it has limitations. The sample was limited to UiTM undergraduate design and technology students, and the findings may not be generalisable to other populations or contexts. Additionally, the study focused on short-term outcomes, and future research could investigate the long-term impact of these interventions on students' problem-solving skills and career trajectories. Further research is also needed to explore the effectiveness of these interventions in different design disciplines and cultural contexts.

Future studies could also investigate the interaction between thinking styles and IPS training, examining how different thinking styles and problem-solving approaches influence problem-solving performance. Additionally, research could investigate the role of individual differences in learning styles and motivation in moderating the effectiveness of these interventions.

Finally, future research could explore the potential of integrating thinking styles and IPS training into other curriculum areas, such as engineering, business, and education. By understanding how these interventions can be adapted and implemented across diverse disciplines, educators can unlock the full potential of thinking styles and IPS to enhance problem-solving skills and prepare students for the challenges of the 21st-century workplace.

Acknowledgement

We gratefully acknowledge Civil Engineering Studies, College of Engineering, Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang, Permatang Pauh Campu for its steadfast support and enriching academic environment, the dedicated students and college whose understandings fueled this investigation into problem-solving in design and technology, and the editorial team of the *International Journal of Modern Education (IJMOE)* for their

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 24 (March 2025) PP. 729-739
DOI: 10.35631/IJMOE.724052
invaluable guidance, along with our colleagues, families, and friends for their solid encouragement as we melded traditional wisdom with innovative strategies.

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EISSN: 2637-0905
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Volume 7 Issue 24 (March 2025) PP. 729-739
DOI: 10.35631/IJMOE.724052

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