The Effects of Scenario-Based Learning Using Go on Problem-Solving Competency among Undergraduate Students: Integrating Polya's Problem-Solving Framework

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Abstract

This study aimed to (1) develop an instructional approach integrating scenario-based learning and Polya's problem-solving framework through Go-based learning to enhance problem-solving competency among undergraduate students, (2) examine the effectiveness of the instructional approach, (3) compare students' problem-solving competency before and after the implementation, and (4) compare problem-solving competency between the experimental and control groups. A quasi-experimental design with pretest–posttest measures was employed. The participants were undergraduate students from a private higher education institution in Thailand, enrolled in a course on Go and thinking skill development. The experimental group received the instructional approach, while the control group received conventional instruction. The approach was developed based on Polya's four stages of problem solving: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. Data were collected using a problem-solving competency test administered before and after the intervention. The data were analyzed using descriptive and inferential statistics to examine differences within and between groups. The results indicated that students in the experimental group demonstrated higher problem-solving competency after the intervention compared to before the intervention. Furthermore, although the posttest scores of the experimental group were higher than those of the control group, the difference was not statistically significant. These findings suggest that the instructional approach contributed to improvement in problem-solving competency over time, particularly within the experimental group. In conclusion, the integration of scenario-based learning and Polya's framework through Go-based learning can serve as an instructional approach to support the development of problem-solving competency in higher education.

Keywords: game-based learning, Go, problem-solving competency, Polya's problem-solving, scenario-based learning

1. Introduction

1.1 Introduce the Problem

Problem-solving competency has become a critical capability for learners in higher education, particularly in contexts that require decision-making under uncertainty and complexity (Jonassen, 2011; OECD, 2018). However, many instructional approaches continue to prioritize content acquisition over structured engagement with problem-solving processes, limiting learners' opportunities to actively develop such competency (Chernikova et al., 2020; Kirschner et al., 2006). Consequently, students may struggle to systematically analyze situations, generate solutions, and evaluate outcomes when confronted with complex, real-world problems.

To address this limitation, scenario-based learning (SBL) has emerged as an instructional approach that engages learners in authentic, context-rich situations requiring active decision-making and problem solving. In this approach, learners are required to interpret situations, evaluate alternatives, and make decisions under conditions that reflect real-world complexity (Errington, 2011). Empirical evidence suggests that scenario-based and simulation-oriented instructional methods can enhance learners' ability to apply knowledge and develop problem-solving competency, particularly in complex and dynamic learning environments (Chernikova et al., 2020; Sitzmann, 2011).

1.2 Explore Importance of the Problem

Despite the recognized importance of problem-solving competency and the growing use of scenario-based learning, significant challenges remain in designing instructional approaches that systematically develop such competency. While SBL provides authentic contexts for learning, it does not inherently ensure that learners engage in structured problem-solving processes unless explicitly guided.

Among various instructional media, the game of Go has been increasingly recognized as a strategic learning tool that can support the development of problem-solving competency. Go requires players to interpret complex and evolving situations, identify constraints, anticipate consequences, and make decisions under uncertainty. These cognitive demands closely align with key aspects of problem-solving processes, including situation analysis, planning, decision-making, and evaluation. Previous studies have indicated that Go can contribute to the development of strategic thinking and problem-solving abilities by engaging learners in complex reasoning and decision-making activities (Chukusol, 2025; Egri-Nagy, 2011; Finch, 2007; Gürbüzel et al., 2022).

However, existing research has often examined these approaches separately. There remains a need to integrate context-rich instructional strategies, such as SBL, with cognitively demanding learning environments, such as Go, in order to more effectively support the development of problem-solving competency.

1.3 Describe Relevant Scholarship

To provide a theoretical foundation for structuring problem-solving processes within instructional design, Polya's framework (Polya, 1973) remains one of the most influential models. Polya conceptualized problem solving as a systematic process consisting of four stages: understanding the problem, devising a plan, carrying out the plan, and looking back. This framework has been widely adopted in educational contexts to guide learners' thinking processes and support the development of structured problem-solving competency.

In domain-specific contexts, problem-solving processes are often manifested in more concrete and operational forms. In the context of Go, Jeong (2001) proposed a domain-specific process consisting of analyzing the current situation or opponent's move, determining a tactical direction, identifying possible moves, reasoning through sequences of moves, and selecting the most appropriate configuration. These processes reflect how general problem-solving principles are enacted through authentic gameplay, where learners continuously interpret dynamic situations and make strategic decisions.

Recent conceptual and empirical work has further extended this perspective by explicitly aligning general problem-solving frameworks with domain-specific cognitive processes in Go. For example, Jirasophin et al. (2026) proposed an integrated framework that connects Polya's problem-solving stages with Go-based cognitive activities. The framework illustrates how learners engage in iterative cycles of analysis, planning, execution, and reflection through structured gameplay tasks, thereby operationalizing abstract problem-solving processes within concrete learning environments. This integration highlights the potential of Go as a structured cognitive environment for developing problem-solving competency.

Despite these advancements, there remains a lack of empirical research that systematically integrates scenario-based learning, Go-based learning, and structured problem-solving frameworks within a unified instructional design. Existing studies have often examined these components in isolation or focused on general cognitive outcomes without clearly articulating how specific problem-solving processes are enacted and developed through instructional interventions. As a result, the mechanisms through which learners engage in structured problem-solving processes within Go-based learning environments remain insufficiently examined.

1.4 State Hypotheses and Their Correspondence to Research Design

Therefore, this study aims to examine the effects of scenario-based learning using Go, grounded in Polya's problem-solving framework, on the problem-solving competency of undergraduate students. The study was conducted within a general education course, providing an authentic instructional context for implementing the integrated instructional approach.

The study is guided by the following research objectives:

(1) To develop an instructional approach integrating scenario-based learning and Polya's problem-solving framework through Go-based learning to enhance problem-solving competency among undergraduate students.

(2) To examine the effectiveness of the instructional approach on students' problem-solving competency.

(3) To compare the problem-solving competency of students before and after the implementation of the instructional approach.

(4) To compare the problem-solving competency between students in the experimental and control groups.

Based on these objectives, the study proposes the following hypotheses:

H1: Students who participate in the instructional approach will demonstrate significantly higher problem-solving competency after the intervention compared to before the intervention.

H2: Students in the experimental group will demonstrate significantly higher levels of problem-solving competency than those in the control group after the intervention.

The research design employed a research and development (R&D) approach combined with a quasi-experimental design consisting of both one-group pretest–posttest (pilot phase) and experimental–control group comparisons (implementation phase). This design enables the evaluation of both the development and the effectiveness of the instructional approach.

2. Method

2.1 Research Design

This study employed a research and development (R&D) approach to design, develop, and evaluate an instructional approach integrating scenario-based learning, Polya's problem-solving framework, and Go-based learning. The study was conducted in four phases: (1) conceptual development (R1), (2) validation and pilot testing (D1), (3) refinement (R2), and (4) implementation and evaluation (D2).

In Phase D1, a quasi-experimental one-group pretest–posttest design was used to examine the feasibility and initial effectiveness of the instruments and instructional activities. In Phase D2, a quasi-experimental design with experimental and control groups was employed to evaluate the effectiveness of the developed instructional approach.

2.2 Participant (Subject) Characteristics

Participants were undergraduate students from a private higher education institution in Thailand, enrolled in the "Go and Thinking Skill Development" course, a general education elective, during the 2025 academic year. A convenience sampling method was employed based on course enrollment.

In Phase D1 (pilot testing), a tryout sample of 62 students participated to evaluate the clarity and feasibility of the instruments. In Phase D2 (implementation), a total of 98 students participated, comprising 45 students in the experimental group and 53 students in the control group. While some participants had prior experience playing Go, none had previously participated in a structured Go-based training program similar to the one implemented in this study.

This study was approved by the institutional research ethics committee (IRB No. SCPHYLIRB-2568/855). Participation was voluntary, and informed consent was obtained prior to data collection.

2.3 Sampling Procedures

Participants were selected through convenience sampling based on course enrollment. The experimental and control groups were formed based on class enrollment in different course sections. The final sample in the implementation phase consisted of 98 students (experimental group $n = 45$; control group $n = 53$).

The sample size was considered sufficient for examining within-group and between-group differences in problem-solving competency. However, generalization of the findings should be interpreted within the context of the study setting.

2.4 Instruments

The instruments used in this study included instructional plans, a problem-solving test, end-of-unit quizzes, and a self-assessment instrument. All instruments were systematically developed and aligned within a unified instructional and assessment framework based on Knowledge, Skills, and Attitudes (KSA) and Polya's problem-solving processes, consistent with competency-based education principles (OECD, 2018; Williams, 2025).

2.4.1 Instructional Plans

The instructional plans were structured into five sequential units based on foundational Go content and progressively designed to develop learners' problem-solving competency. The units were: (1) introduction to Polya's problem-solving and basic Go concepts; (2) stone connection and opening strategies; (3) fundamental capturing techniques; (4) territory and two-eyes formation with PairGo activities; and (5) endgame and evaluation.

Each unit incorporated scenario-based learning tasks requiring learners to engage in problem understanding, planning, execution, and reflection, thereby operationalizing Polya's problem-solving processes throughout instruction.

The instructional plans were validated by three experts in education and Go instruction using the Index of Item–Objective Congruence (IOC), with values ranging from 0.67 to 1.00.

2.4.2 Problem-solving Test

The problem-solving test was developed as a 20-item multiple-choice instrument, with four response options per item, to assess learners' problem-solving competency within the context of Go-based learning. The test was structured into two complementary components: (1) a general problem-solving scale based on Knowledge, Skills, and Attitudes (KSA), and (2) domain-specific Go-based problem items.

The first component consisted of 15 items (K1–K5, S1–S5, A1–A5), designed to measure learners' general problem-solving competency grounded in Polya's four-step process (1973): understanding the problem, devising a plan, carrying out the plan, and looking back. The Knowledge (K) items assessed conceptual understanding of problem-solving principles, the Skills (S) items assessed the application of these processes in real-life and scenario-based situations, and the Attitudes (A) items assessed learners' dispositions toward systematic and reflective problem-solving. These items were constructed to represent a unified latent construct of general problem-solving competency.

The second component consisted of five Go-based problem items (G1–G5), derived from the five instructional units. These items required learners to apply problem-solving processes within authentic Go situations, emphasizing domain-specific reasoning, strategic decision-making, and pattern recognition.

Content validity of all items was examined using the Index of Item–Objective Congruence (IOC), with values ranging from 0.67 to 1.00. The same test was administered as both pretest and posttest with an interval of more than one month to minimize testing effects.

Internal consistency reliability was examined using the Kuder–Richardson Formula 20 (KR-20; Kuder & Richardson, 1937), calculated based on the pretest data from the tryout sample. The KSA-based component (15 items) demonstrated acceptable reliability (KR-20 = 0.754), indicating satisfactory internal consistency for measuring general problem-solving competency.

In contrast, the Go-based items were treated as performance-based tasks rather than a unidimensional scale. Due to their domain-specific nature and the learners' limited prior experience with Go at the pretest stage, inter-item correlations were low and heterogeneous. Therefore, internal consistency reliability was not emphasized for this component. Instead, these items were used as indicators of domain-specific problem-solving performance and were analyzed separately in terms of learners' ability to apply problem-solving processes in authentic Go contexts. This distinction ensures conceptual clarity between generalizable problem-solving competency and domain-specific performance in Go.

2.4.3 End-of-unit Quizzes

End-of-unit quizzes were developed in alignment with the five instructional units and corresponding KSA-based objectives. Each unit included 10 multiple-choice items, resulting in a total of 50 items across all units.

The quizzes were designed as formative assessments to monitor learners' progress and reinforce their ability to understand concepts, apply strategies, and respond to problem-based scenarios throughout the instructional process.

Content validity was established using the Index of Item-Objective Congruence (IOC), with values ranging from 0.67 to 1.00, indicating acceptable alignment between items and learning objectives.

Given the formative purpose of the quizzes and the heterogeneity of item content across instructional units, internal consistency reliability (e.g., KR-20) was not considered an appropriate indicator for evaluating these assessments. Instead, item-level characteristics, particularly item difficulty, were examined to ensure that the quizzes provided an appropriate range of challenge and effectively supported ongoing learning.

2.4.4 Learning Experience and Self-assessment

The learning experience and self-assessment components were designed to capture learners' perceptions of the instructional approach and their perceived development in problem-solving competency following the training program. The instrument consisted of three parts: (1) learning experience evaluation, (2) rubric-based self-assessment, and (3) reflective open-ended questions.

The learning experience evaluation comprised 18 items measured on a five-point Likert scale (5 = strongly agree to 1 = strongly disagree) across four dimensions: content, learning process, instructor and learning environment, and perceived usefulness. These items examined learners' perceptions of content clarity, the effectiveness of problem-based and Go-based learning activities, engagement in the learning process, and the applicability of the training to real-life contexts.

The rubric-based self-assessment evaluated learners' problem-solving competency based on Polya's framework (Polya, 1973), including four dimensions: understanding the problem, planning, executing, and reviewing. Each dimension was assessed using a four-level performance rubric (4 = very good, 3 = good, 2 = fair, 1 = needs improvement), reflecting the quality of reasoning, strategic planning, execution, and reflective thinking.

The interpretation of Likert-scale scores was conducted using class interval criteria based on the method proposed by Alkharusi (2022), in which composite scores were categorized into qualitative levels using equal interval ranges. For the five-point scale, mean scores were interpreted as follows: 4.24–5.00 = strongly agree, 3.43–4.23 = agree, 2.62–3.42 = moderate, 1.81–2.61 = disagree, and 1.00–1.80 = strongly disagree. For the four-point scale, mean scores were interpreted as follows: 3.26–4.00 = very good, 2.51–3.25 = good, 1.76–2.50 = fair, and 1.00–1.75 = needs improvement.

Furthermore, five open-ended questions were included to elicit reflective responses regarding learners' problem-solving experiences, decision-making processes, application of Polya's steps, and transfer of learning to real-life situations. The qualitative responses were analyzed using content analysis. Responses were first reviewed and coded to identify meaningful units related to problem-solving experiences. Similar codes were then grouped into categories, and broader themes were generated to reflect patterns in decision-making, application of Polya's steps, and transfer of learning to real-life contexts (Creswell & Plano Clark, 2018; Lincoln & Guba, 1985).

Content validity of all components was established using the Index of Item–Objective Congruence (IOC), with values ranging from 0.67 to 1.00. The internal consistency of the learning experience evaluation and the rubric-based self-assessment was examined using Cronbach's alpha based on data from the experimental group, yielding coefficients of .989 and .873, respectively. These values indicate high internal consistency and provide supportive evidence for the reliability of the instruments.

2.5 Instructional Intervention

The instructional approach was structured into five units based on basic-level Go content, including rules, connection, capturing techniques, territory, and endgame evaluation. The intervention was implemented over a 10-week period.

Each unit incorporated scenario-based Go activities designed to engage learners in authentic problem-solving processes, including analyzing board situations, evaluating alternatives, making decisions, and reflecting on outcomes. The instructional activities were explicitly aligned with Polya's problem-solving stages: understanding, planning, executing, and reviewing. For example, learners were presented with specific Go board situations representing problem scenarios, such as defending a weak group or selecting an optimal move in a complex tactical position. In these scenarios, learners were required to analyze the situation, identify possible strategies, justify their decisions, and reflect on the outcomes. These tasks were designed to simulate authentic decision-making contexts and to engage learners in structured problem-solving processes aligned with Polya's framework.

The five instructional units were as follows:

(1) Introduction to Polya's problem-solving and basic Go concepts

(2) Stone connection and opening strategies

(3) Fundamental capturing techniques

(4) Territory and two-eyes formation with PairGo activities

(5) Endgame and evaluation

2.6 Data Analysis

Data were analyzed using descriptive statistics, including mean and standard deviation, to summarize students' problem-solving competency.

Due to the non-normal distribution of the data, non-parametric tests were employed. The Wilcoxon signed-rank test was used to examine differences in problem-solving competency before and after the intervention within groups. The Mann–Whitney U test was used to compare problem-solving competency between the experimental and control groups.

In addition, an analysis of covariance (ANCOVA) was conducted to compare posttest scores between groups while controlling for pretest scores.

Statistical significance was set at the .05 level.

3. Results

3.1 Participant Characteristics

A total of 98 undergraduate students participated in the implementation phase (D2), including 45 students in the experimental group and 53 students in the control group. All participants were enrolled in the "Go and Thinking Skill Development" course, a general education elective at a private higher education institution in Thailand. While some participants had prior experience playing Go, none had previously participated in a structured Go-based training program similar to the one implemented in this study.

Table 1. Participant Characteristics (n = 98)

Variables	Experimental (n = 45) n (%)	Control (n = 53) n (%)	χ^2	p
Gender			0.14	.70
male	28 (62.2)	31 (58.5)		
female	16 (35.6)	22 (41.5)		
undefined	1 (2.2)	-		
Age			-	-
19	-	1 (1.9)		
20	9 (20.0)	13 (24.5)		
21	33 (73.3)	33 (62.3)		
22	3 (6.7)	5 (9.4)		
>22	-	1 (1.9)		
Go experience			1.23	.75
none	14 (31.1)	22 (41.5)		
familiarity with basic rules	12 (26.7)	14 (26.4)		
beginner-level practice	18 (40.0)	16 (30.2)		
competitive experience	1 (2.2)	1 (1.9)		

Note. Percentages may not total 100 due to rounding.

As shown in Table 1, no significant differences were found between the experimental and control groups in terms of gender and prior Go experience ($p > .05$), indicating baseline equivalence and supporting the validity of subsequent comparisons.

3.2 Effects of the Instructional Approach on Problem-Solving Competency

To evaluate the effectiveness of the training program, both within-group and between-group comparisons were conducted. Pretest and posttest scores of the experimental group were analyzed, followed by a comparison of posttest scores between the experimental and control groups.

Table 2. Pretest and Posttest Scores of Problem-Solving Competency in the Experimental Group

Variable	Median (Pre)	Median (Post)	Z	p	Effect size (r)
Problem-solving	13.00	16.00	-4.194	< .001	0.63

As shown in Table 2, a Wilcoxon signed-rank test was conducted to examine differences between pretest and posttest scores in the experimental group. The results indicated a statistically significant improvement in problem-solving competency following the intervention ($Z = -4.194$, $p < .001$).

The median score increased from 13.00 to 16.00, reflecting an overall improvement in performance. Furthermore, the number of participants with increased scores ($n = 33$) exceeded those with decreased scores ($n = 8$), providing additional support for the effectiveness of the problem-based Go instructional approach. The effect size was large ($r = 0.63$), indicating a substantial impact of the intervention.

Table 3. ANCOVA Results Comparing Posttest Scores Between Experimental and Control Groups Controlling for Pretest Scores

Group	N	Adjusted Mean	Std. Error
Experimental	45	15.13	0.34
Control	53	15.15	0.32

Source	df	F	p	Partial Eta Squared
Pretest	1	6.565	.012	.065
Group	1	0.500	.481	.005
Error	95	-	-	-

As shown in Table 3, an ANCOVA was conducted to compare posttest scores between the experimental and control groups while controlling for pretest scores. The adjusted mean scores were comparable between the experimental group ($M = 15.13$) and the control group ($M = 15.15$).

The covariate (pretest) had a statistically significant effect on posttest scores, $F(1, 95) = 6.565$, $p = .012$, $\eta^2 = .065$. However, there was no statistically significant difference between the experimental and control groups, $F(1, 95) = 0.500$, $p = .481$, $\eta^2 = .005$.

Table 4. Comparison of Posttest Scores Between Experimental and Control Groups Using Mann–Whitney U Test

Group	N	Mean Rank	Sum of Ranks
Experimental	45	53.02	2386.00
Control	53	46.51	2465.00
Mann-Whitney U = 1034.00, Z = -1.147, p = .252			

As shown in Table 4, a Mann–Whitney U test was conducted to compare posttest scores between the experimental and control groups. The results indicated that there was no statistically significant difference between the two groups ($U = 1034.00$, $Z = -1.147$, $p = .252$).

Although the experimental group demonstrated a slightly higher mean rank (53.02) compared to the control group (46.51), this difference was not statistically significant. This suggests that, while both groups may have improved, the instructional intervention did not lead to a significantly greater improvement compared to the control condition.

Table 5. Comparison of Gain Scores Between Experimental and Control Groups

Group	N	Mean Rank	Sum of Ranks
Experimental	45	57.60	2592.00
Control	53	42.62	2259.00
Mann-Whitney U = 828.00, Z = -2.615, p = .009			

Note. Gain score = posttest – pretest.

As shown in Table 5, a Mann–Whitney U test was conducted to compare gain scores between the experimental and control groups. The results indicated a statistically significant difference between the two groups ($U = 828.00$, $Z = -2.615$, $p = .009$).

The experimental group demonstrated a higher mean rank (57.60) compared to the control group (42.62), indicating greater improvement in problem-solving competency. This finding indicates greater improvement in problem-solving competency over time in the experimental group.

3.3 End-of-Unit Quiz Performance of the Experimental Group

To examine learners' progress during the intervention, descriptive statistics of quiz scores were analyzed for the experimental group. The results indicated differences in performance across instructional sessions.

Table 6. Descriptive Statistics of End-of-Unit Quizzes Scores in the Experimental Group

Quiz Session	N	Mean	SD
Quiz 1	45	5.27	1.56
Quiz 2	45	4.82	1.50
Quiz 3	45	3.62	1.54
Quiz 4	45	3.76	1.17
Quiz 5	44	3.75	1.40

Note. Quiz scores were used as formative assessments to reflect learners' progress during the instructional process.

As shown in Table 6, quiz scores varied across sessions, with mean scores ranging from 3.62 to 5.27. The results indicate fluctuations in performance across instructional units, which may reflect differences in task difficulty and learning challenges encountered throughout the training process. Overall, the quiz results provide supportive evidence of ongoing engagement and learning during the intervention.

3.4 Learning Experience Evaluation and Self-Assessment

To further examine learners' perceptions of the instructional approach and their perceived development in problem-solving competency, descriptive statistics of the learning experience evaluation and self-assessment were analyzed. The internal consistency of the measurement scales was examined using Cronbach's alpha. The results indicated excellent reliability for the learning experience evaluation scale ($\alpha = .989$, 18 items) and high reliability for the self-assessment in problem-solving scale based on Polya's steps ($\alpha = .873$, 4 items). These findings suggest that the instruments were sufficiently reliable for further analysis. The results are shown in Table 7.

Table 7. Learning Experience Evaluation and Self-Assessment in Problem-Solving

Variables	Mean	SD
Learning experience evaluation	3.97	0.97
Self-assessment in problem-solving competency	3.09	0.58

Note. Learning experience was measured on a 5-point Likert scale. Self-assessment in problem-solving was measured based on Polya's steps using a 4-point Likert scale.

As shown in Table 7, the mean score for learning experience evaluation was 3.97 (SD = 0.97) on a 5-point Likert scale, indicating a generally positive perception of the instructional process.

For self-assessment in problem-solving, the mean score was 3.09 (SD = 0.58) on a 4-point Likert scale, suggesting that learners perceived a relatively high level of problem-solving competency following the intervention. The interpretation of Likert-scale scores was conducted using class interval criteria based on the method proposed by Alkharusi (2022).

Overall, these findings provide supportive evidence that the instructional approach was positively received and may have contributed to the development of learners' problem-solving abilities.

Table 8. Item-level Analysis of Learning Experience Evaluation

Items	Mean	SD
Content		
Q1. Content was clear and easy to understand	3.93	1.053
Q2. Content was appropriate for the learners’ level	3.96	1.043
Q3. Content was sufficient for each session	4.02	1.118
Q4. Learning activities enhanced understanding	4.00	1.022
Q5. Instructional media and materials supported understanding	4.01	1.076
Learning process		
Q6. The five-step learning process enhanced understanding of problems	3.87	1.100
Q7. Hands-on learning improved thinking skills	4.00	1.066
Q8. Competition helped learners recognize their own abilities	4.00	1.022
Q9. Reflection improved self-awareness	3.96	1.127
Q10. Polya’s process supported systematic problem-solving	3.87	1.014
Instructor and learning environment		
Q11. The instructor delivered content clearly	3.98	1.055
Q12. The instructor provided useful feedback	4.07	1.031
Q13. Peers contributed to a positive learning environment	3.98	1.097
Q14. Instruction duration was appropriate	4.02	0.965
Q15. Materials and equipment were adequate	4.00	1.044
Perceived usefulness		
Q16. The instructional approach improved problem-solving ability	3.93	1.116
Q17. The instructional approach should be continued in the future	4.07	1.053
Q18. Learning can be applied to real-life situations	3.78	1.085

Note. Learning experience was measured using a 5-point Likert scale.

As shown in Table 8, all items were rated at the “agree” level, indicating consistently positive perceptions across all dimensions of the instructional approach.

In the content dimension, learners reported high levels of clarity, appropriateness, and adequacy of the content (M = 3.93–4.02), suggesting that the instructional materials were well-aligned with learners’ levels and learning needs. Similarly, items related to learning activities and instructional media received favorable ratings, indicating that both instructional activities and materials effectively supported learners’ understanding.

Within the learning process dimension, hands-on learning (M = 4.00) and competition-based activities (M = 4.00) were among the highest-rated items, highlighting the effectiveness of active and experiential learning strategies. Reflection activities (M = 3.96) were also positively perceived. However, slightly lower mean scores were observed for the five-step learning process (M = 3.87) and the use of Polya’s problem-solving process (M = 3.87), indicating that learners may not have fully internalized structured problem-solving processes, thus requiring additional scaffolding.

In terms of instructor and learning environment, the highest mean score was found for instructor feedback (M = 4.07), followed by appropriate instructional duration (M = 4.02), indicating that instructional support and learning conditions were perceived positively.

For perceived usefulness, learners indicated that the instructional approach should be continued (M = 4.07). While the perceived improvement in problem-solving ability was rated positively (M = 3.93), the lowest mean score across all items was found in the application of learning to real-life situations (M = 3.78), indicating a limitation in the transfer of learning from structured training contexts to real-life situations.

Overall, the item-level findings provide detailed support for the effectiveness of the instructional design, while also highlighting areas for improvement, particularly in strengthening learners’ understanding of structured problem-solving processes and enhancing the transfer of learning to real-life contexts.

Table 9. Self-assessment of Problem-Solving Competency

Dimensions	Mean	SD
Understanding	3.09	0.668
Planning	2.91	0.733
Executing	3.18	0.614
Reviewing	3.20	0.726
Overall	3.09	0.585

Note. Self-assessment was measured using a 4-point Likert scale.

As shown in Table 9, the results of self-assessment in problem-solving competency indicated that learners demonstrated a generally good level across all four dimensions of Polya's framework.

Among the dimensions, the highest mean score was observed in reviewing (M = 3.20, SD = 0.726), followed by executing (M = 3.18, SD = 0.614) and understanding (M = 3.09, SD = 0.668), suggesting that learners were relatively confident in evaluating their performance and carrying out problem-solving processes. In contrast, the lowest mean score was found in planning (M = 2.91, SD = 0.733), indicating that learners may still experience challenges in developing systematic and well-structured problem-solving plans.

Overall, the findings suggest that the instructional approach contributed to the development of learners' problem-solving competency, particularly in execution and reflection, while planning remains an area requiring further support and instructional scaffolding.

3.5 Qualitative Findings from Open-Ended Responses

Additional qualitative data were collected through open-ended questions to further explore learners' experiences and perceived development following the intervention. These questions addressed five aspects: (1) the problem-solving stage most frequently used, (2) decision-making experiences during gameplay, (3) transferable problem-solving insights, (4) perceived self-development, and (5) suggestions for improving the instructional approach.

Thematic analysis revealed four key patterns that complement and help explain the quantitative findings. First, learners reported a clear development in systematic thinking, frequently describing the use of structured processes aligned with Polya's framework. Second, planning emerged as the most frequently mentioned strategy, with learners emphasizing anticipation and forward-thinking. However, this contrasts with its relatively lower quantitative score, suggesting that although learners recognize the importance of planning, they may still face challenges in applying it effectively.

Third, many learners reflected on their own decision-making errors, particularly those related to impulsivity, incomplete analysis, and limited situational awareness. This pattern indicates the development of reflective thinking and corresponds with the higher mean score observed in the reviewing dimension. Fourth, learners reported the ability to transfer problem-solving strategies to real-life contexts, including academic tasks and teamwork. However, consistent with the lower rating in real-life application, this transfer appears to remain at an emerging stage.

In addition, learners suggested improvements such as increased individualized feedback, more diverse problem scenarios, and reduced competitive pressure, highlighting areas for further refinement of the instructional design.

Overall, these qualitative findings provide convergent evidence that triangulates the quantitative results, offering a more comprehensive explanation of how the instructional approach supports the development of problem-solving competency.

4. Discussion

This study aimed to develop and examine the effectiveness of an instructional approach integrating scenario-based learning, Go-based learning, and Polya's problem-solving framework in enhancing undergraduate students' problem-solving competency. The findings provide partial support for the proposed hypotheses.

Specifically, students who participated in the instructional approach demonstrated significantly higher problem-solving competency after the intervention compared to before the intervention. However, no statistically significant difference was found between the experimental and control groups in posttest scores.

In relation to the development of the instructional approach, the results indicate that the integration of scenario-based learning with Go and Polya's framework offers a coherent pedagogical structure that combines experiential engagement with systematic cognitive processes. The use of Go as a strategic learning medium enables learners to engage in authentic problem situations, while Polya's framework provides a structured pathway for reasoning and decision-making (Egri-Nagy, 2011; Polya, 1973). Importantly, the strategic nature of Go requires learners to continuously engage in planning, evaluation, and adaptive decision-making, which are essential components of problem-solving competency. This is consistent with prior research indicating that Go-based learning environments can effectively support the development of higher-order thinking processes, particularly in terms of strategic thinking and self-regulated cognition (Chukusol, 2025; Gürbüzel et al., 2022; Jirasophin et al., 2026; Jirasophin & Tajaroensuk, 2025; Tajaroensuk et al., 2025). This integration supports the view that game-based environments can be aligned with established cognitive frameworks to facilitate higher-order thinking (Sitzmann, 2011).

Regarding effectiveness, the findings from the learning experience evaluation revealed consistently positive perceptions across all dimensions. High ratings in hands-on learning, competition-based activities, and instructor feedback suggest that active learning strategies and supportive instructional environments played a significant role in promoting engagement and understanding. These findings are consistent with research indicating that experiential and problem-based learning environments enhance meaningful learning and cognitive engagement (Hmelo-Silver, 2004; Kolb, 1984).

The comparison between pretest and posttest results demonstrated a significant improvement in students' problem-solving competency following the intervention. This finding supports the effectiveness of the instructional approach in enhancing learners' cognitive performance over time, particularly through repeated engagement in authentic problem-solving situations (Jonassen, 2011).

From a process-oriented perspective, the effectiveness of the instructional approach can be explained through the interaction between experiential engagement and structured cognitive scaffolding. Scenario-based learning provides contextualized problem situations, while Go-based activities require continuous evaluation, adaptation, and strategic decision-making. When combined with Polya's framework, these elements create a recursive problem-solving cycle that encourages learners to engage in iterative thinking, reflection, and refinement. This mechanism may explain the observed improvements in execution and reviewing, as learners repeatedly practice and evaluate their decisions within meaningful contexts.

In addition, although students in the experimental group demonstrated higher mean scores than those in the control group, the difference was not statistically significant. This interpretation is further supported by the ANCOVA results, which indicated no statistically significant difference between groups after controlling for baseline performance.

Taken together, these findings suggest that the instructional approach supports progressive improvement over time, as reflected in gain scores, rather than producing immediate between-group differences in posttest performance. This pattern highlights the potential of integrating game-based and problem-based learning approaches, although such advantages may not be immediately observable in posttest comparisons (Sitzmann, 2011).

Despite these positive outcomes, the item-level analysis and self-assessment results provide important insights into the underlying learning processes. While learners demonstrated strong performance in execution and reflection, the relatively lower scores in planning suggest that learners may not have fully internalized structured problem-solving processes. This finding aligns with prior research indicating that higher-order cognitive skills, particularly planning and strategic thinking, require explicit scaffolding and guided instruction (Hmelo-Silver et al., 2007; Tajaroensuk et al., 2025; Vygotsky, 1978). This convergence between quantitative and qualitative evidence suggests that learners are cognitively aware of planning as a critical component of problem-solving but have not yet fully developed the ability to operationalize it effectively in practice.

Furthermore, although learners perceived improvements in problem-solving ability, the lowest ratings were found in the application of learning to real-life situations. This highlights a limitation in the transfer of learning from structured instructional contexts to authentic real-world problems. Such a gap has been widely reported in studies on problem-based and game-based learning, where transferability remains a critical challenge (Barnett & Ceci, 2002; Perkins & Salomon, 1992). Qualitative responses further indicated that while learners could articulate how problem-solving strategies might be applied in academic and everyday contexts, such transfer appeared to remain at a conceptual or emerging level rather than being consistently enacted in real situations. This suggests that additional instructional support may be required to facilitate deeper and more sustained transfer of learning.

In addition, certain methodological limitations should be considered. The use of self-reported measures may introduce response bias, and the relatively short duration of the intervention may limit the observation of long-term effects. Furthermore, variations in instructional delivery and learner engagement may have influenced the consistency of the intervention implementation.

5. Conclusion

This study developed and examined an instructional approach integrating scenario-based learning, Go-based learning, and Polya's problem-solving framework to enhance undergraduate students' problem-solving competency. The findings suggest that the proposed approach contributed to improvements in students' problem-solving performance, particularly in terms of execution and reflective processes.

More importantly, the results indicate that combining experiential learning environments with structured problem-solving frameworks can support the development of iterative and adaptive thinking processes. These findings highlight the potential of strategically designed game-based learning environments as cognitively grounded tools for enhancing higher-order thinking in higher education.

6. Implications

First, the findings provide practical implications for instructional design. Educators should consider integrating strategic game-based environments such as Go with structured problem-solving frameworks to enhance students' higher-order thinking. The results also highlight the importance of explicit scaffolding, particularly in the planning phase, as learners may not naturally develop systematic problem-solving strategies without guided support. Additionally, incorporating opportunities for real-world application is essential to strengthen the transfer of learning beyond the classroom.

Second, this study extends existing research by providing both empirical and process-level evidence demonstrating how the integration of scenario-based learning, strategic game-based environments, and structured problem-solving frameworks can function as a unified instructional system to support higher-order thinking. Rather than treating game-based learning as a motivational tool, the findings highlight its role as a cognitively grounded learning environment that supports iterative reasoning, reflection, and adaptive decision-making.

Finally, from a broader perspective, the findings of this study may be interpreted in relation to executive functions, as the observed improvements in problem-solving performance reflect enhanced abilities in planning, regulation, and adaptive thinking (Apichartkriangkrai & Prongsantia, 2023; Jirasophin, 2026; Tajaroensuk et al., 2025). Importantly, executive functions are not positioned as direct outcomes but as underlying cognitive processes that emerge through structured and experiential learning conditions. Future research should further investigate this relationship using longitudinal designs and more direct measures of executive functions to better understand the cognitive mechanisms underlying problem-solving development.

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