Developing Tenth-Grade Students' Problem-Solving Skills in Chemistry through Deductive Learning with the DAPIC Approach

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Article Info	Abstract
	The authentic science classroom requires students to think and solve problems through hands-on activity. This research aims to enhance problem-solving skills in chemistry of grade 10 students through deductive learning with the DAPIC approach, with a passing criterion of 70% or higher of the total score. This research employed action research. The target group consists of 22 students from the model school of Mahasarakham University in the second semester of the academic year 2023. The data collection instruments included nine lesson plans, three sets of essay-type problem-solving tests (each comprising three questions), student interview questionnaires regarding their opinions on learning management, and observational data on problem-solving behavior in chemistry. The research findings indicated that the target group improved their problem-solving skills after learning through deductive learning with the DAPIC approach. In the first cycle, 50% of students (11 out of 22) met the passing criterion of 70%. In the second cycle, 81.82% of students (18 out of 22) passed, and in the third cycle, 95.45% of students (21 out of 22) achieved the passing criterion. It can be concluded that deductive learning with the DAPIC approach can also enhance students' problem-solving in the science classroom.

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INTRODUCTION

In today's rapidly changing world, education is more important than ever we have met (Findler et al., 2019). The current education system aims to prepare students with the feasible knowledge, skills, and abilities to face the complexities of the modern era characterized by rapid technological advancements. In addition, students must be prepared themselves to face the challenges of uncertainty and complexity of the 21st century, which will require adaptability, analytical thinking, and lifelong learning (González-Salamanca et al., 2020; Nurulsari et al., 2023; Peschl et al., 2021). Adapting to a changing world requires understanding the power of technological advancement, economic change, and global interconnectedness (Kurniawati et al., 2023). This understanding can be gained through scientific knowledge, creativity, and other scientific disciplines (Castaneda & Cuellar, 2020; Sawyer & Henriksen, 2024). These disciplines help develop knowledge, skills, thinking methods, practical skills, reasoning, creativity, analytical thinking, and new knowledge acquisition skills (Jaenudin et al., 2020). Science education aims to help students understand basic scientific principles and theories to apply their knowledge and scientific process skills to their lives (Aprilyawati & Umam, 2023; Russell & Martin, 2023).

In general, students need to study various theories according to the needs and control of chemistry (Cooper & Stowe, 2018). Chemistry is a subject about the composition of matter and the

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changes of matter, which is primarily macroscopic (Nakiboğlu, 2024). The leader's properties and concentration can be observed. The complexity of the content, especially regarding problem-solving, is evident as students are required to apply their knowledge, understanding of principles, relevant theories, and computational skills to solve problems (Butler & Leahy, 2021). As mentioned earlier, students with problem-solving skills contribute to developing their thinking methods, including causal thinking, creative thinking, analytical thinking, and critical thinking (Irwanto et al., 2024; Muhammad & Purwanto, 2020). They demonstrate systemic problem-solving capabilities by possessing crucial skills in researching and acquiring knowledge. Therefore, one of the primary goals of learning chemistry is for students to cultivate problem-solving skills. Students embark on this learning journey by grasping fundamental theories and applying them to solve problems in new and diverse situations, facilitated by teachers providing suitable scenarios aligned with the student's potential (Szabo et al., 2020).

From observing the learning behavior during teaching as a student teacher and interviewing teachers in chemistry, it was found that most of the teaching was in the form of lectures. There was no hands-on practice, which caused students to lose concentration during the learning. When the students did the exercises, it was found that they were unable to identify problems and plan to solve them, leading to them being unable to solve the issues (Ronnie & Philip, 2021). In addition, students could not connect knowledge and work systematically. This was observed from the fact that the students could not explain the choice of problem-solving methods by themselves. They mostly waited for the answer from the teacher. Some students knew how to solve problems but could not apply their knowledge to solve them.

Studying different learning management models that promote problem-solving skills, such as project-based learning, inductive learning, inquiry-based learning (Chen & Chang, 2021; Pellegrino & Glaser, 2021; Syawaludin et al., 2022), and problem-solving process, the researcher is particularly interested in the deductive learning approach. Deductive learning is employed to develop problem-solving skills due to its advantages, including time efficiency, as students can directly apply previously learned rules or formulas. This precision helps students memorize rules or formulas accurately, fostering logical thinking and skepticism without readily accepting information without verification or proof (Leng & Leng, 2020; Sinatra & Hofer, 2021).

Additionally, deductive learning is a flexible process in which teachers assist students in achieving predefined learning objectives by providing knowledge and understanding of theories, principles, rules, or summaries relevant to the subject matter. Furthermore, the problem-solving process of DAPIC (Define, Analyze, Plan, Implement) is flexible, allowing for a non-linear approach (Abdulah & Winarti, 2022; Wulandari, 2020). It enables starting at any stage, skipping certain steps, or repeating some, depending on the nature of each problem. This flexibility makes it suitable for assisting learning management, as it enhances students' cognitive abilities, emphasizing thinking, doing, and problem-solving skills.

Consequently, the researcher has applied this problem-solving process to address chemistry-related problem-solving tasks and enhance students' problem-solving skills in chemistry. The study about deductive learning and the DAPIC approach is less reported in science education; there are only a few studies that discuss it, and this study is outside the field of chemistry learning (Chen et al., 2021; Narayanan et al., 2023). The authors try to implement this learning organization to investigate the problem-solving skills of chemistry students. It can be used and implemented in the science classroom.

METHOD

The research utilized an action research methodology carried out throughout three cycles. Each cycle was meticulously planned and executed to ensure a comprehensive understanding of the development of students' problem-solving skills in chemistry. Detailed descriptions of the research methodology, including each cycle's planning, implementation, observation, and reflection phases, were provided to ensure transparency and replicability. This structured approach allowed for continuous assessment and refinement of teaching strategies, ultimately leading to improved student performance.

Target Group

The target group of students was selected from grade 10 students in the second semester of the 2023 academic year at a school in Mahasarakham Province. The researchers selected the target group with scores below 70% on the chemistry problem-solving skills test. Therefore, this research has 22 target students.

Research Instruments

The research instruments for this study included lesson plans, problem-solving skills in chemistry, tests, observation forms, interviews, and student journals. A learning management plan utilizing inductive learning was combined with the problem-solving process DAPIC for the chemistry topic of Stoichiometry 2. The lesson plan consisted of nine sessions, totaling 12 hours.

Table 1. Lesson Plan

Cycle	Lesson plans	Time (hours)
1	1. Concentration	2
	2. Parts per million; ppm	1
	3. Parts per billion; ppb	1
2	4. Molarity (1)	2
	5. Molality (2)	1
	6. Mole fraction	1
3	7. Solution preparation	2
	8. Diluted solution	1
	9. Colligative properties	1
	Total	9

Table 1 illustrates the revised learning plan, modified based on the advisor's recommendations. This updated plan was then submitted to a panel of five experts for a thorough review. The experts assessed the plan for correctness, ensuring it aligned accurately with the established learning indicators. They also evaluated its consistency with the content and the intended learning outcomes. Additionally, the panel examined how well the plan integrated with the proposed learning assessments. After this comprehensive verification process, the plan underwent further revisions based on the experts' feedback. The final learning plan was subsequently implemented in the research study.

The problem-solving skills test in the chemistry subject is in the form of a subjective test consisting of three sets, each comprising three questions per circuit. Each set has a maximum score of 36 points and includes four components: understanding the problem, planning the solution, executing the solution, and summarizing and verifying the answer. Interviews will be conducted to gather students' opinions on learning management and assess their feedback after completing each learning cycle. The researchers collected data regarding the problem-solving skills in the chemistry subject. Specifically, interviews will be conducted with students who did not meet the 70% passing criteria. Observing problem-solving behavior in the chemistry subject will involve monitoring the behavior of students within the target group who face challenges in solving problems in the chemistry course.

Data Collection

This research adopts the action research design (Altrichter et al., 2002) and utilizes the research cycle model PAOR (Plan-Act-Observe-Reflect), divided into three cycles.
1. Plan: The action, analyzing the problem, and assessing the situation in the classroom. The problem is identified through teacher interviews and the researcher's observations. The problem is further confirmed using a problem-solving assessment tool in the chemistry subject.
2. Action: After creating and refining the research tools, the learning management plan is implemented to address problem-solving in the chemistry subject with the target group of students. Cycle 1 uses lesson plans 1, 2 and 3. Cycle 2 uses lesson plans 4, 5 and 6. Cycle 3 uses lesson plans 7, 8 and 9.

3. Observe: Observe the students' learning behaviors based on the behavior observation template for solving problems in the chemistry subject during the practical cycle. Students will complete a problem-solving skills test in chemistry at the end of the cycle. Additionally, interviews will be conducted with students in the target group who did not meet the 70% passing criteria.
4. Reflect: Analyze the various data obtained from the observation step to assess or verify the appropriateness of the activity format that has been created. Identify the problems and obstacles, the progress of the students, and the number of students who still have problems. Use the results to find ways to improve and plan for the next implementation cycle.

Data Analysis

Analysis from the problem-solving skills test in the chemistry subject involves comparing students' answers with the scoring criteria as outlined in Table 2 to evaluate the passing criteria of 70%

Table 2 The Scoring Criteria for Problem-Solving Skills in Chemistry

No	Component	Level		
		2	1	0
1	Understanding the problem	Specify what is provided in the problem statement and accurately identify what the problem is asking to find.	Correctly stating what the problem is asking for, or partially stating what the problem specifies and correctly identifying some of the information the problem is seeking.	No written response
2	Planning the solution	Specify the information or knowledge needed to solve the problem and plan the solution accurately.	Identify the information or knowledge needed for problem-solving and plan the solution correctly in some respects.	No written response
3	Executing the solution	Demonstrates the correct and comprehensive problem-solving methods.	Correctly demonstrates the problem-solving method, with minor calculation errors, or accurately illustrates the problem-solving approach but does not complete it to obtain the final answer.	No written response
4	Summarizing and verifying the answer	Write a summary of the answers and include a demonstration of the correct and complete answer verification process.	There are traces of summarizing answers, and some parts of the verification method are correctly presented.	No written response

RESULT AND DISCUSSION

The results of the analysis of the problem-solving skills in chemistry of the target students before and after the learning activities in each cycle are detailed in Table 3. This table provides a comprehensive overview of how students' abilities evolved through successive cycles of the learning process. Initially, students' problem-solving skills were assessed before introducing the new learning activities, providing a baseline measurement. After each cycle of the learning activities, their skills were reassessed to determine any improvements or changes. The data captured in Table 3 thus illustrate the progression and enhancement of the student's problem-solving skills in chemistry over time, highlighting the effectiveness of the implemented teaching strategies and methodologies.

Table 3 Problem-Solving Skills in Chemistry

| Cycle | Score Component | | | | Total (24) | Pass the 70% criteria |
	1. Understanding the problem	2. Planning the solution	3. Executing the solution	4. Summarizing and verifying the answer		
Before	5.69	3.54	3.18	0.95	13.36	Failed
Cycle 1	5.82	5.18	3.18	1.41	15.59	Failed
Cycle 2	5.64	4.73	4.41	3.59	18.41	Passed
Cycle 3	5.86	5.50	4.32	3.91	19.48	Passed

From Table 2, it is evident that before implementing the learning management strategy using inductive learning combined with the problem-solving process DAPIC, the researcher surveyed a target group of 22 students. The survey results revealed that these students did not meet the 70% criterion for problem-solving skills in chemistry. Recognizing the need for improvement, the researcher designed and implemented a series of learning activities spread across three cycles. These carefully structured activities aimed to enhance the student's problem-solving skills in chemistry. Significant progress was observed throughout these cycles, indicating that the students successfully developed their problem-solving skills in the subject. The detailed analysis and results of these cycles underscore the effectiveness of the inductive learning and DAPIC approach in fostering better problem-solving skills among students in chemistry.

Cycle 1: Out of the target group of 22 students, 11 met the 70% passing criteria, while 11 did not. When considering the total scores for the problem-solving components, the students had an average problem-solving skills score of 15.59 out of the maximum 24 points, equivalent to 64.96%. Simultaneously, when examining each component, it was observed that the scores for understanding the problem, planning the solution, executing the solution, and checking and summarizing the answer were 5.82, 5.18, 3.18, and 1.41, respectively, in descending order. The checking and summarizing component had the lowest average score.

Cycle 2: It was found that among the target group of students, there were 22 students, with 18 students meeting the 70% passing criteria and four not meeting it. When considering the overall score for problem-solving, students had an average total score of 18.41 out of 24, equivalent to 76.70%. Meanwhile, looking at individual components, the average scores for understanding the problem, planning the solution, executing the solution, and checking and summarizing the answer were 5.64, 4.73, 4.41, and 3.59, respectively. This suggests that in the overall picture of Cycle 2, students have started to develop their problem-solving skills in chemistry. Notably, the lowest average score was observed in the checking and summarizing answers component.

Cycle 3: It was found that among the target group of 22 students, 21 did not meet the 70% passing criteria, while one student did. When considering the overall scores for the problem-solving components, the average total score for students' problem-solving skills in chemistry was 19.59 out of a maximum of 24 points, equivalent to 81.63%. Simultaneously, when examining individual components, the average scores for understanding the problem, planning the solution, executing the solution, and checking and summarizing the answer were 5.86, 5.50, 4.32, and 3.91, respectively. Notably, the checking and summarizing component had the lowest average score. However, students in the target group improved their average scores in each practical cycle, as shown in Figure 1.
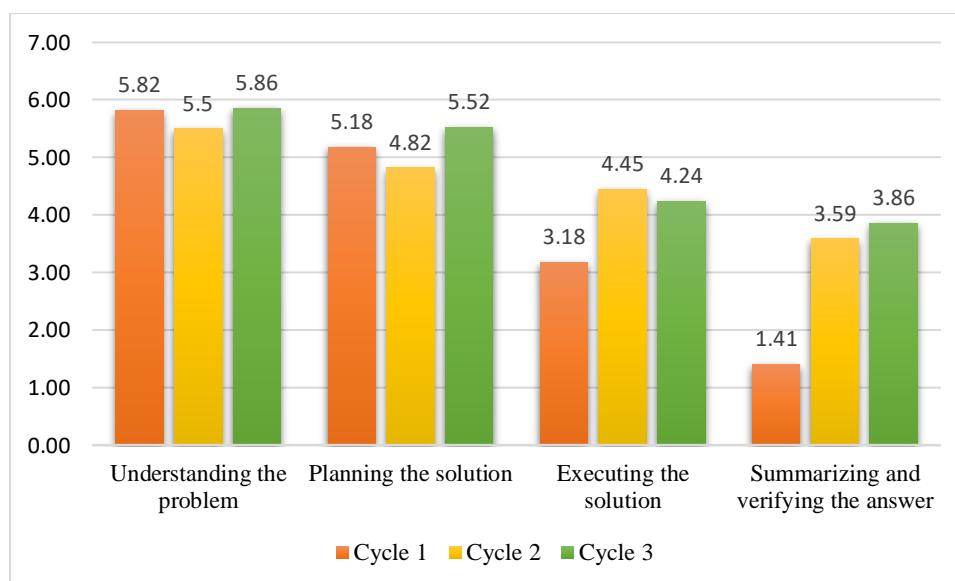
Figure 1. Mean Score of Problem-Solving Skills in Chemistry

Based on the data presented in Figure 1, it is observed that the components related to checking and summarizing answers consistently have the lowest scores across all practical cycles. Specifically, during practical cycle 1, the average score for these components was 1.41, indicating a significant area for improvement. As the cycles progressed, there was a noticeable enhancement in performance, with the average score rising to 3.59 in cycle two and further increasing to 3.86 in cycle 3. Despite this improvement, these scores remain the lowest compared to other components, highlighting a persistent challenge in students' ability to effectively check and summarize their answers. This trend suggests that while there is some progress, additional targeted interventions may be necessary to strengthen these particular skills further.

In cycle 1, the learning activity was observed, revealing that out of the targeted group of 22 students, 11 students met the 70% passing criteria, while 11 did not. The average problem-solving skills score in chemistry was 15.59 out of 24, equivalent to 64.96%. This might be attributed to a learning approach emphasizing individual cognitive development, allowing students to discover knowledge independently, leading to better understanding and retention.

The DAPIC problem-solving process involved defining the problem, assessing relevant information, planning the solution, implementing the plan, and communicating the solution. Students demonstrated improved problem-solving skills, with a top score of 16.69 (83.45%) at the end of the process. Observing individual components, students excelled in understanding problems (97.00%), while planning problem solutions and implementing solutions scored 86.33% and 53.00%, respectively. However, students faced challenges in the verification and conclusion component, scoring 19.00%. This was attributed to difficulties in unit conversion and a lack of precision in writing conclusions. In conclusion, the DAPIC problem-solving approach effectively improved students' problem-solving skills, with notable achievements in understanding problems. Challenges in planning and implementing solutions were identified, suggesting further improvement in the learning process.

In cycle 2, all 22 targeted students were assessed after completing the teaching activity. Eighteen students met the 70% passing criteria, while four did not. The overall problem-solving skills score in chemistry was 18.41 out of 24, representing 76.70%. Upon examination of the post-cycle 2 test, the average scores for understanding the problem, planning problem solutions, implementing solutions, and checking and summarizing answers were 5.64, 4.73, 4.41, and 3.59, respectively. Notably, the understanding and planning components saw a slight decrease in average scores, while the implementing and checking components showed improvement compared to practical cycle 1.

Regarding understanding problems and planning solutions, there was a minor decrease in average scores. Students faced challenges in planning problem solutions, with an average score of 4.73 (78.33%). Students struggled to fully plan problem-solving strategies. The teacher and

students collaborated to review theories for each learning activity, emphasizing the importance of understanding the information provided in the problem.

In implementing solutions, students showed improvement, scoring an average of 4.41 (73.5%). However, this score did not meet the 70% passing criteria. The teacher introduced additional teaching strategies to reinforce calculation skills during sessions without specific teaching interventions. The average score for checking and summarizing answers was 3.59 (59.83%), representing the lowest score. This was partly due to students being unable to obtain correct results from calculations during the checking phase.

Additionally, time management during the test affected the checking and summarizing process. Some students chose to skip this part due to time constraints. The teacher provided examples of effective summary writing and checking techniques to enhance students' understanding (Ansari et al., 2020; Wardani & Kusuma, 2020). In conclusion, the adjustments made in teaching strategies and interventions in practical cycle 2 improved some aspects of students' problem-solving skills. However, challenges remained, especially in planning and implementing problem-solving strategies, indicating the need for further refinement in the teaching process.

In cycle 3, it was observed that out of the 22 targeted students, 21 students met the 70% passing criteria, while one did not. The overall problem-solving skills score in chemistry was 19.59 out of 24, representing 81.63%. When considering individual components, the scores for understanding the problem, planning problem solutions, implementing solutions, and checking and summarizing answers were 5.86, 5.50, 4.32, and 3.91, respectively. The lowest score was found in the checking and summarizing answers component, with an average score of 3.91, representing 64.33%. When comparing the practical of all three cycles, it is evident that students' average scores increased in each cycle. This indicates an improved understanding of problems, the ability to select appropriate formulas or theories for problem-solving planning, and enhanced calculation skills (Ambaryani & Putranta, 2022; Jonassen, 2000). Students were able to obtain better results from their calculations. There was also an improvement in collaborative group activities, with students attempting to solve problems collectively. They demonstrated a shift in behavior by alternating the checking of answers within the group. Additionally, presenting problem-solving approaches allowed peers to provide feedback, earning extra points.

In summary, the continuous improvement in average scores across the three practical cycles suggests that students' problem-solving skills in chemistry have consistently increased. The positive behaviors observed during group activities and the open opportunity for peer feedback have contributed to this enhancement. Therefore, it can be said that deductive learning combined with the DAPIC problem-solving process can develop problem-solving skills in chemistry (Sipayung et al., 2021). After the learning process in the third cycle of implementation, the teaching of problem-solving methods that encourage students to have a problem-solving process, to think analytically from the problem to planning, to implementing problem-solving, and to have a process of summarizing and checking answers to get the correct answer (Duangrawa & Nuangchalerm, 2020). Each step of the learning process following the DAPIC problem-solving process will encourage students to solve problems step by step in detail, resulting in a better understanding of the problem-solving process (Abdulah & Winarti, 2022).

In addition, students practice both the thinking process, problem-solving skills, and calculation skills, and they are encouraged to do activities with their classmates, which will allow them to exchange ideas and work together to solve the problem. Students learn in groups. There is pressure for learners to learn, with more capable students helping those who are less capable in their group to achieve their goals and success. For this reason, students' problem-solving skills in chemistry may be higher than before they received the activity.

CONCLUSION

From this research, it can be concluded that developing problem-solving skills in chemistry to pass the 70% criterion was successful. The research results found that students had an average score of 64.96 in the first round. In the second round, students had an average score of 76.70, and in the third round, students had an average score of 81.15. It can be seen that students' problem-solving skills in chemistry have continuously improved. It can be concluded that deductive learning

with the DAPIC approach can also enhance students' problem-solving in the science classroom. However, this research is still limited to classroom actions, and it is hoped that future research will examine this more widely using a larger sample.

AUTHOR CONTRIBUTIONS

HD data collection. PN data analysis. All authors conducted a study on designing, and drafting an article, and approved the final draft article.

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