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# Enhancing Stoichiometry Problem-Solving Skills through 5E Inquiry-Based Learning Combined with the FOPS Strategy

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ABSTRACT

This classroom action research aimed to improve the chemistry problem-solving abilities of Grade 10 students using the 5E Inquiry-Based Learning model combined with the FOPS Strategy, with the goal of achieving a 70 percent success criterion. The target group consisted of 25 Grade 10 students from Sarakhampittayakhom School, Thailand. The research instruments included (1) lesson plans incorporating the 5E Inquiry-Based Learning model and the FOPS Strategy, (2) a chemistry problem-solving ability test, (3) a behavioral observation checklist for assessing problem-solving abilities, and (4) student interviews. Quantitative data were analyzed using statistics such as mean, percentage, and standard deviation, while qualitative data were analyzed using content analysis. The results showed that in the first cycle, 10 students (40.00 percent) achieved the 70 percent criterion. In the second cycle, the number increased to 17 students (68.00 percent). By the third cycle, 23 students (92.00 percent) met the criterion, demonstrating significant improvement in problem-solving abilities.



## I. Introduction

Science is crucial in today's global society and the future, as it is relevant to everyone's daily lives and various professional fields. In Thailand's Basic Education Core Curriculum, there is a strong emphasis on problem-solving, which is considered a key competency for learners. Problem-solving ability is overcoming obstacles and challenges (Ministry of Education, 2012). Moreover, problem-solving fosters diverse thinking approaches and promotes an active disposition, equipping students with essential skills that can be applied throughout their lives (Institute for the Promotion of Teaching Science and Technology, 2008). Chemistry, as a branch of science, integrates various concepts. Both theoretical understanding and practical application are necessary for explaining and solving problems (Gilbert, 2006). The calculation aspect of chemistry focuses on solving chemical problems, requiring knowledge of both theoretical concepts and computational skills, like the mathematical problem-solving process (Smith, 1991). Chemical problems typically involve written statements that cannot be solved immediately, necessitating a structured approach to arrive at a quantitative or numerical answer. This process relies on knowledge, experience, and careful planning to analyze the problem before devising a solution (Osborne & Collins, 2000).

Chemistry, particularly stoichiometry, plays a vital role in computational chemistry problem-solving, requiring students to apply their knowledge of principles, theories, and computational skills (Krulik & Rudnick, 1996). A primary goal of chemistry education is to develop students' ability to solve problems in this area (Dahsah, 2007). At Sarakhampittayakhom School, Grade 10 students had an average score of 54.91% in chemistry, falling short of the 70% benchmark. Initial tests revealed that most students struggled with analyzing and understanding chemistry problems, particularly in identifying and interpreting the provided information.

The main challenge was the lack of critical thinking and understanding of chemical reactions. Many students could not effectively analyze problems or connect the given data to the required solutions, largely due to the absence of clearly defined variables. Their inability to apply classroom knowledge to practical problem-solving further compounded this issue (Hafsah et al., 2014). Additionally, many teachers relied on lecture-based methods to cover material quickly, diminishing student engagement and contributing to weaker problem-solving skills (Barman, 1992). Researchers explored alternative

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teaching methods, such as inquiry-based learning, which encourages independent exploration and problem-solving through structured, question-driven processes (Gokhan & Gulsen, 2014). This method fosters critical thinking and helps students develop a deeper and more permanent understanding of the subject. However, while the 5E inquiry-based learning model supports student-led discovery and problem-solving, its lack of explicit steps for addressing complex problems may limit its effectiveness (Baroody, 1993).

The problem-solving process involves multiple steps and requires a structured approach for effective learning. This study utilized the FOPS strategy, based on Schema-Based Instruction, which emphasizes understanding the problem structure (Rumelhart, 1981). By accurately characterizing the problem and using schematic representations, students can better approach problem resolution (Marshall, 1995). The FOPS strategy consists of four steps: finding the problem type, organizing information through diagrams or symbols, planning by selecting appropriate formulas, and solving the problem using schema-based knowledge. This method encourages meaningful learning and enhances problem-solving abilities (Jitendra & Hoff, 1996; Jitendra et al., 2010; Jitendra & Star, 2011). Addressing earlier challenges, this structured approach aids students in improving comprehension, knowledge acquisition, and active engagement.

This research primarily focused on improving students' chemistry problem-solving abilities by integrating the 5E Inquiry-Based Learning model with the FOPS strategy. The approach encourages teachers to design activities and environments that spark curiosity, pose thought-provoking questions, and foster structured research and analysis. Students are empowered to develop knowledge independently through a systematic, step-by-step discovery process. The researcher expected that this combination of the 5E model and the FOPS strategy would enhance the effectiveness of classroom activities, ultimately leading to better student outcomes in solving chemistry problems.

Despite various approaches to teaching problem-solving in chemistry, many existing methods do not offer a structured and step-by-step framework that supports students in effectively organizing and solving complex problems. While the 5E Inquiry-Based Learning model fosters active learning, it lacks explicit problem-solving steps. On the other hand, the FOPS strategy provides a structured schema-based approach but is rarely combined with inquiry-based models in chemistry education. This reveals a research gap in integrating structured problem-solving strategies into inquiry-based learning environments, particularly in the context of stoichiometry among Grade 10 students in Thailand.

Therefore, this study aims to address the following research question: How does integrating the 5E Inquiry-Based Learning model with the FOPS strategy affect the chemistry problem-solving ability of Grade 10 students in stoichiometry?

## II. Method

### *A. Target Group*

The target group comprised 25 Grade 10 students from Sarakhampittayakhom School in the second semester of 2023. They were assessed with a subjective chemistry problem-solving test of three questions, focusing on students with scores below the 70% benchmark.

### *B. Research Tools*

*1) Lesson Plan:*

The 5E Inquiry-Based Learning model combined with the FOPS strategy was applied to the chemistry content on stoichiometry, with a total of 9 lesson plans over 14 hours. The FOPS strategy was integrated into the Elaboration phase of the 5E learning process, which includes the following steps: 1) Engagement, 2) Exploration, 3) Explanation, and 4) Elaboration, where students apply the principles they have learned to solve problems using the FOPS strategy, and 5) Evaluation, where students assess their progress through tests. The teacher motivates and evaluates students' learning. The lesson plans were rated with an average appropriateness score between 4.68 and 4.75, indicating a high level of effectiveness.

*2) Chemistry Problem-Solving Ability Test*

The stoichiometry test consisted of three subjective exams, each containing nine questions. Each question was designed to assess chemistry problem-solving abilities, focusing on four aspects according to the FOPS strategy: 1) F - Finding the Problem Type, 2) O - Organizing the problem information into a diagram, 3) P - Planning to solve the problem, and 4) S - Solving the problem. The test was evaluated for its item-objective congruence (IOC) index, with the results showing an IOC value of 1.00. Additionally, the scoring rubric for the chemistry problem-solving test was assessed for its appropriateness, yielding an average score of 5.00.

*3) Behavioral Observation Form*

This form was used to observe students' problem-solving abilities during chemistry lessons. The researcher observed the target students' behavior while they engaged in problem-solving activities during the learning sessions. The observation form was assessed for its index of item-objective congruence (IOC), with a result of 1.00.

*4) Student Interview Form*

This interview was conducted to gather student feedback on the 5E Inquiry-Based Learning model combined with the FOPS strategy after each instruction cycle. The interview form was evaluated for its index of item-objective congruence (IOC), with a result of 1.00.

### *C. Data Collection*

This research followed Kemmis and McTaggart's (1988) action research method, comprising four steps: Planning, Action, Observation, and Reflection, conducted over three cycles. In the Planning stage, challenges were identified through a problem-solving test, and lesson plans using the 5E model combined with the FOPS strategy were developed. During the Action phase, the lessons were implemented, covering topics such as chemical equations, conservation laws, reactions, solution concentration, and yield percentage. In the Observation stage, student behavior and problem-solving skills were assessed through reflections, tests, and interviews. Finally, in the Reflection stage, findings were analyzed to assess progress and refine the teaching methods.

### *D. Data Analysis*

The effectiveness of the 5E Inquiry-Based Learning model combined with the FOPS strategy was evaluated through student interviews after each action cycle and reflections from all lesson plans. These data were analyzed and summarized to assess the impact on learning management. Additionally, students' chemistry problem-solving abilities were analyzed using statistical methods, including percentage, mean, and standard deviation, to measure overall skill improvement.

## III. Results and Discussion

The action research results aimed at improving Grade 10 students' chemistry problem-solving ability in stoichiometry, using the 5E Inquiry-Based Learning model combined with the FOPS strategy, showed that students' scores met the 70% benchmark. The target group of 25 students' performance across each action cycle is summarized in Figure 1.

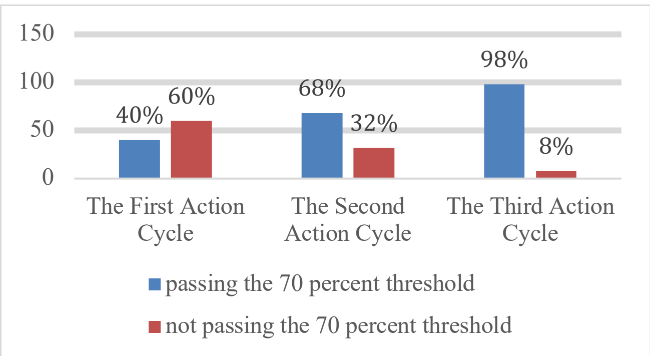


Fig. 1. Number of Students Achieving Problem-Solving Scores Above and Below the 70% Benchmark Across Three Action Research Cycles

Figure 1. Presents the number of students categorized based on the criterion of scoring above or below 70 percent of the full score in the ability to solve chemistry problems for each action research cycle.

Figure 1 shows that the students who participated in the 5E Inquiry-Based Learning model combined with the FOPS strategy achieved a chemistry problem-solving ability score exceeding the 70% benchmark. In the first action cycle, 10 students met the benchmark, accounting for 40.00%. In the second action cycle, 17 students met the benchmark, representing 68.00%. By the third action cycle, 23 students met the benchmark of 92.00%.

In the first action cycle, the researcher implemented three lesson plans using the 5E Inquiry-Based Learning model combined with the FOPS strategy: 1) Chemical Equations, 2) Law of Conservation of Mass and Law of Constant Proportions, and 3) Mass of Substances in Chemical Reactions. Data on the chemistry problem-solving ability of the target group were collected using the chemistry problem-solving ability test.

In the second action cycle, the researcher analyzed issues from the first cycle to improve learning activities. The teacher slowed the instruction pace, allowed more thinking time, and provided repeated explanations when needed. Emphasis was placed on understanding the given information and the connections between variables in formulas. The four steps of the FOPS strategy were reviewed in detail, guiding students through each problem-solving step with examples. The researcher implemented three lesson plans using the 5E model and FOPS strategy: 1) Chemical Reactions Related to Mass, 2) Solution Concentration, and 3) Gas Volume. Chemistry problem-solving data were collected using the FOPS-based test.

In the third action cycle, the researcher reviewed issues from the second cycle to further improve the learning activities. The teacher extended the time for the Planning stage, giving students more time to think and fully understand the content. During problem-solving demonstrations, the teacher provided an overview of the process by explaining how to apply knowledge and formulas in planning solutions. Remedial sessions were also offered to practice solving equations and unit conversions. The researcher implemented three lesson plans using the 5E model and FOPS strategy: 1) Multi-step Chemical Reactions, 2) Limiting Reagents, and 3) Percent Yield. The students' problem-solving ability was assessed based on the four steps of the FOPS strategy, with their scores across all three cycles shown in Table 1.

From Table 1, it can be observed that the chemistry problem-solving ability of students improved across all aspects from the first to the third cycle. In each cycle, the highest average scores were consistently found in the formulating the problem (F) aspect, with mean scores ($\bar{x}$) of 12.96, 14.36, and 15.68, respectively. In contrast, the lowest average scores were observed in the solving the problem (S) aspect, with mean scores ($\bar{x}$of 9.68, 13.72, and 16.52, respectively. These results indicate that students gradually improved in all areas of problem-solving over time.

Table 1. The Average Scores and Standard Deviation of Chemistry Problem-Solving Abilities of 25 Grade 10 Students in Each Experiment Cycle

| Step | F | | O | | P | | S | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cycle | $\bar{x}$ | SD | $\bar{x}$ | SD | $\bar{x}$ | SD | $\bar{x}$ | SD | $\bar{x}$ | SD |
| 1 | 12.96 | 3.08 | 12.16 | 3.02 | 11.48 | 3.54 | 9.68 | 4.12 | 11.57 | 3.44 |
| 2 | 14.36 | 2.06 | 13.68 | 2.56 | 14.4 | 2.87 | 13.72 | 3.45 | 14.04 | 2.74 |
| 3 | 15.68 | 1.84 | 15.68 | 1.95 | 16.28 | 2.05 | 16.52 | 2.12 | 16.04 | 1.99 |

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The researchers summarized the details of the problems encountered during the learning activities and proposed solutions based on the assessment of problem-solving abilities in chemistry, observations of problem-solving behaviors in chemistry, and student interviews in the first practice round as follows:

*A. The First Action Cycle*

1. Most students can define the scope of the problem. They can read the problem and analyze the given tasks. This can be observed from the sample answers provided by the students, as follows:

"I can define the scope of the problem because the questions are not complex." (Student #5, February 14, 2024: Interview)

"I can define the problem scope because I understand the problem statement provided by the teacher." (Student #10, February 14, 2024: Interview)

2. The students cannot define the problem scope because they cannot yet connect what the problem states with what it is or the variables needed. This can be seen from the sample answers provided by the students.

"I do not know why we have to write what the question asks for when it is already stated in the question. Sometimes, I do not write everything the question asks for because I think some of the data is not necessary." (Student #4, February 14, 2024: Interview)

"I cannot define the problem's scope because I understand the problem as stated by the teacher." (Student #13, February 14, 2024: Interview)

3. Students cannot organize the problem data presented using diagrams, pictures, lines, or symbols because they cannot initially demonstrate the process of drawing diagrams. They are unsure and do not know where to start drawing. This can be seen from the sample answers of students as follows:

"I do not know where to start drawing, sir. How should I start from the information provided in the question?" Student #1, February 14, 2024: Interview)

"I do not know which parts of the question I should write, sir, because I do not know which data to use for calculations." (Student #8, February 14, 2,02: Interview)

4. Students cannot plan problem-solving activities due to insufficient time in this phase, resulting in incomplete thinking when applying knowledge, formulas, or fundamental concepts to plan problem-solving strategies. This can be observed from the following example response by students:

"In problems that involve multiple-step solutions, it is challenging, so I would like the teacher to allocate more time." (Student #25, February 14, 2024: Interview)

"Sometimes I am confused about whether I need to convert units in the plan or not, which makes me unsure about starting to follow the plan." (Student #17, February 14, 2024: Interview)

5. Students lack calculation skills and are confused about choosing formulas or unit conversions. This leads to incorrect answers when solving problems. This can be observed from the examples of student responses, as follows:

"I could not write the formula because I did not know which concept to use. It might be because I did not know what the variables given in the problem were for." (Student #23, February 15, 2024: Interview)

"When finding the answer, I made mistakes because I was confused in solving equations and division, especially in converting units for the answer, which I have never answered correctly according to what the problem required." (Student #12, February 15, 2024: Interview)

6. Students are unfamiliar with solving multi-step problems, and the teacher-provided approach, the FOPES method, requires more steps than usual. Normally, students are accustomed to solving problems by identifying what the problem provides, selecting equations or formulas to calculate, and showing the steps to find the answer. This is evident from the sample responses of the students, as follows:

"The content is quite extensive and difficult. I cannot remember the formulas. I wish we could review them every time." (Student #25, February 15, 2024: Interview)

"There are quite a few steps in solving the problems, sometimes confusing, but it is fun because I get to draw pictures." (Student #17, February 15, 2024: Interview)

The researcher thus summarized the problems and guidelines for addressing and developing learning activities in action cycle 1, as shown in Table 2.

Table 2. Problems and Solutions Guidelines in Action Cycle 1

| **Problem in Action Cycle 1** |
|---|
| 1. The students were found to be confused with the steps of problem-solving using the 4-step FOPS strategy. |
| 2. The students were unable to assess the format of the questions and could not identify what the questions were asking for. |
| 3. Students were unable to organize the information of the problem presented using diagrams, pictures, lines, or symbols because they were not yet able to demonstrate the process of drawing diagrams at the basic level. |
| 4. Students were unable to plan problem-solving activities due to insufficient time, leading to incomplete planning and lack of thoroughness in problem-solving strategies. |
| 5. Students also lack computational skills, resulting in incorrect answers when they attempt to solve problems. |
| Solution Guidelines in Action Cycle 1 |
| 1. The teacher should re-explain the 4-step process, providing details about what each step involves. Additionally, students should be encouraged to work through problems together at each step of the problem-solving process. |
| 2. Teachers should explain to students the importance of selecting accurate information, as it can lead to correct answers. |
| 3. Teachers should provide examples of problem-solving demonstrate and explain the planning process using diagrams to show students the overall picture of organizing problem data using diagrams, pictures, lines, or symbols. |
| 4. Teachers should extend the time allocated for planning problem-solving activities to allow students more time to comprehend the content and think through their strategies thoroughly. |
| 5. The teacher provides additional instruction to students to enhance their computational skills in solving equations. |

In the second action cycle, the causes of problems and the outcomes from the first action cycle were analyzed to improve and redesign the learning activities for the second cycle to enhance their quality. The teacher slowed their speech, allocated more time for students to think, and provided repeated explanations when they had questions. The teacher also explained the importance of the given information in the specified scenarios and demonstrated the relationships between variables in the formula, helping students connect the provided data with the desired outcomes. Additionally, the teacher reintroduced the four-step problem-solving strategy (FOPS), explaining each step in detail and outlining the specific tasks students needed to perform at every stage. The teacher guided students through the problem-solving process step-by-step, allowing them to practice each stage together

The researcher summarized the details of the problems that occurred during the learning activities and the approach to problem-solving based on the assessment of the ability to solve chemical problems, observational behavior, and interviews with students in the second action cycle.

1. Students can define the scope of the problem and analyze the problem given by the teacher after reading the instructions. This can be seen from the following examples of student responses.

"...I can define the problem scope because the instructions are complex..." (Student #7, February 21, 2024: Interview)

"...I can define the problem scope because I am confident in the problem statement provided by the teacher..." (Student #20, February 21, 2024: Interview)

2. The students cannot state the problem, as seen from the sample answers provided by the students.

"...I don't know what to write as the task has already been specified in the question. Sometimes, I don't write everything the question asks for because I think that some of the data is unnecessary..." (Student #12, February 21, 2024: Interview)

"...I could not define the problem scope because I was confident in the problem statement provided by the teacher..." (Student #21, February 21, 2024: Interview)

3. Students can organize the problem data presented using diagrams, images, lines, or symbols, as evidenced by the sample responses of students below.

"... I am starting to understand some parts, but I am still not sure how to begin drawing the picture from what the problem provides..." (Student #10, February 21, 2024: Interview)

4. Students cannot organize the problem data into diagrams because they cannot initially illustrate the drawing process. They are uncertain about which picture to start drawing first. This can be seen from the students' responses as follows:

"...Unable to draw diagrams from the data because I do not know how to represent it in a diagram..." (Student #18, February 21, 2024: Interview)

"... Do not know how to start drawing the picture, based on what the question provides..." (Student #21, February 14, 2024: Interview)

5. Students were unable to plan problem-solving due to insufficient time for activities at this stage, resulting in incomplete thinking when applying knowledge, formulas, or fundamental concepts to plan problem-solving. Examples of student responses illustrate this.

"...I cannot write formulas because I do not know which concepts to use..." (Student #18, February 21, 2024: Interview)

"...I do not understand the problem, so I do not know how to plan the solution..." (Student #6, February 21, 2024: Interview)

6. Students still lack calculation skills, confusingly selecting formulas or unit conversions. This results in incorrect answers in problem-solving. This can be observed from the examples of students' responses as follows:

"...When trying to find the answer, I often make mistakes because I get confused with solving equations, and sometimes make errors in division. Especially when converting units, I never get the answer right according to what the question asks for."

"... Cannot solve the problems in time. I wish the teacher would extend the time." (Student #6, February 21, 2024: Interview)

Thus, the researcher summarized the problems and guidelines for addressing and developing learning activities in action cycle 2, as shown in Table 3.

Table 3. Problems and Solutions Guidelines in Action Cycle 2

| **Problem in Action Cycle 2** |
|---|
| 1. The students, it was found that the students were confused with the steps of problem-solving using the 4-step FOPS strategy. |
| 2. The students were unable to assess the format of the questions and could not identify what the questions were asking for. |
| 3. Students were unable to organize the information of the problem presented using diagrams, pictures, lines, or symbols because they were not yet able to demonstrate the process of drawing diagrams at the basic level. |
| 4. Students were unable to plan problem-solving activities due to insufficient time, leading to incomplete planning and lack of thoroughness in problem-solving strategies. |
| 5. Students also lack computational skills, resulting in incorrect answers when they attempt to solve problems. |
| Solution Guidelines in Action Cycle 2 |
| 1. The teacher should explain the 4-step process once again, along with detailing what each step entails for the students. Additionally, they should encourage the students to try solving problems together at each step of the problem-solving process. |
| 2. Teachers should explain to students the importance of selecting accurate information, as it can lead to correct answers. |
| 3. Teachers should provide examples of problem-solving demonstrate and explain the planning process using diagrams to show students the overall picture of organizing problem data using diagrams, pictures, lines, or symbols. |
| 4. Teachers should extend the time allocated for planning problem-solving activities to allow students more time to comprehend the content and think through their strategies thoroughly. |
| 5. The teacher provides additional instruction to students to enhance their computational skills in solving equations. |

In the third action cycle, the causes of problems and the outcomes from the second cycle were analyzed to further improve the design of learning activities in the third cycle, aiming to enhance their quality. The teacher extended the time allocated for the problem-solving planning phase, allowing students more time to think, understand the content thoroughly, and engage with the material. When providing examples of problem-solving, the teacher explained the planning process for applying knowledge and formulas, helping students understand the overall steps involved in problem-solving. Additionally, remedial teaching was provided to strengthen students' calculation skills, particularly in solving equations and unit conversions.

The researcher summarized the details of the problems during the learning activities and the problem-solving strategies based on assessing students' abilities in solving chemistry problems, observations of their problem-solving behaviors, and interviews with students in the third action cycle.

1. Students can define the scope of the problem, read the problem, and analyze the tasks assigned by the teacher. This can be observed from the sample answers provided by the students, as follows.

"...can define the problem scope, sir, because the problems are complex..." (Student #7, February 2,8, 2024: Interview)

"...can define the problem scope, ma'am, because I understand the problem set by the teacher..." (Student #20, February 28, 2024: Interview)

2. Students can organize the data of the problem presented using diagrams, images, lines, or symbols. Examples of student responses follow.

"... I am starting to understand some parts, but I am still not confident about how to begin drawing from what the problem specifies..." (Student #10, February 21, 2024: Interview)

3. Students are starting to be able to plan problem-solving, but there are still some students who cannot do so because the time allocated for the activity is insufficient at this stage. This can be seen from the examples of student responses.

"…Starting to identify better because of improved understanding, but I also wish the teacher would continue to explain more and more for accuracy." (Student #23, February 21, 2024: Interview)

4. The students are getting more familiar with solving multi-step problems, as seen from the examples of their responses.

"The content is quite extensive, but the teacher can make it understandable. I like the teaching techniques that the teacher uses." (Student #12, February 22, 2024: Interview)

"It is a fun and novel way of learning, but the content is quite difficult. I need to understand it better." (Student #23, February 22, 2024: Interview)

The researcher thus summarized the problems and guidelines for addressing and developing learning activities in the action cycle 3, as shown in Table 4

Table 4. Problems and Solutions Guidelines in the Action Cycle 3

| **The problem in the Action Cycle 3** |
|---|
| 1. However, there are still some students who are unable to plan solutions to problems due to insufficient time for activities at this stage.<br>2. Students also lack computational skills, resulting in incorrect answers when they attempt to solve problems. |
| **Solution Guidelines in the Action Cycle 3** |
| The teacher should extend the time for planning problem-solving activities to allow students more time to think and understand the content better. The teacher should explain the process of planning problem-solving when applying formulas to help students understand the overall picture of the problem-solving process.<br>The teacher provides additional instruction to students to enhance their computational skills in solving equations. |

The findings from the research on the 5E Inquiry-Based Learning model combined with the FOPS strategy demonstrate a significant improvement in the chemistry problem-solving abilities of the 25 target students. After completing three action cycles, 23 students scored above the 70% benchmark, while 2 did not. These results indicate that integrating these teaching methods effectively enhances students' abilities to approach and solve chemistry problems.

In the first action cycle, 40% of the students reach the 70% benchmark. This initial phase reveals that students can identify the problem type and articulate it in their own words, which, according to Ijirana (2021), helps understand problem requirements. However, challenges remain, particularly in organizing information into diagrams and executing accurate calculations. Some students struggle to fully implement their problem-solving plans, although they identify relevant formulas, which is consistent with Chi's (2018) assertion that calculation skills are vital for problem-solving success. The need for a combination of analytical, linguistic, and computational skills is evident as students face difficulties integrating these aspects into their problem-solving approach.

In the second action cycle, 68% of students surpass the 70% benchmark. This improvement is attributed to better planning and a clearer understanding of the formulas and principles involved in solving problems. The teacher's detailed explanations and guidance on how to apply formulas help clarify the relationships between variables, allowing students to improve their planning and problem-solving skills. However, confusion persists for some students, particularly in visualizing and organizing problem information into diagrams, which remains challenging (Gokhan & Gulsen, 2014).

By the third action cycle, 92% of students exceed the benchmark. The results show clear progress across all four steps of the FOPS strategy, with students demonstrating better problem-solving abilities, particularly in solving equations and organizing problem information into diagrams. This aligns with Skinner's reinforcement theory, as described by Hergenhahn and Olson (1993), which highlights the effectiveness of positive reinforcement in encouraging active participation and better performance. The improvement in diagram organization, a key element of the FOPS strategy, allows students to visualize and solve problems more effectively. Despite this progress, 8% of students still do not meet the benchmark due to frequent absences, which hinder their ability to grasp the FOPS strategy fully.

Thus, the 5E inquiry-based learning model combined with the FOPS strategy effectively enhances students' chemistry problem-solving abilities. By the end of the third action cycle, 23 out of 25 students achieved scores above the 70% benchmark. This success likely results from the learning activities that emphasize step-by-step problem-solving practice, where students become aware of the given information and use it effectively. For example, students organize the problem data into diagrams and plan their solutions carefully to arrive at accurate answers. This research aligns with Wangtaphan's (2021) study, which examines the development of problem-solving abilities among Grade 11 students using the FOPS strategy. The findings show that students who engage in FOPS-based learning significantly improve their problem-solving skills. Additionally, Rockwell's (2012) research, which focuses on using the FOPS strategy in teaching mathematical problem-solving, similarly finds that students' problem-solving abilities improve after learning with this approach.

It is also important to consider additional factors that might influence students’ problem-solving performance. For instance, gender-related differences in science learning have been reported in various studies, with some suggesting that male and female students may differ in their approaches to abstract reasoning and visualization skills essential in chemistry problem-solving. However, this study did not collect data based on gender, and therefore, such an analysis could not be conducted. Similarly, students' prior knowledge of mathematical concepts and basic chemical principles may significantly affect their ability to apply the FOPS strategy effectively. Students with a stronger foundation may find it easier to follow multi-step strategies and perform calculations, while others may require more intensive support and remediation. Future research is encouraged to explore how variables such as gender and prior academic background interact with the effectiveness of instructional strategies like 5E-FOPS in promoting problem-solving skills.

## IV. Conclusion

The research concludes that combining the 5E inquiry-based learning model with the FOPS strategy effectively enhances students' problem-solving abilities in chemistry. This approach encourages systematic thinking, data analysis, and structured problem-solving, significantly improving all study phases. Students organize information and plan solutions more efficiently, resulting in more accurate problem resolution. Integrating the 5E model and FOPS also enables students to apply their knowledge to real-world problems more effectively, particularly by using diagrams to clarify and solve problems faster. This consistent reinforcement of critical thinking and independent problem-solving strengthens students' analytical skills. This method can be applied to other subjects like physics, mathematics, and science, enhancing students' analytical abilities and critical thinking across various disciplines. It is recommended that students be provided ample time to practice through extended sessions and have the necessary foundational knowledge, such as calculation skills, to support successful problem-solving. Teachers should also adapt the learning process to students' needs to maximize outcomes. The 5E model combined with the FOPS strategy is a powerful tool for developing essential academic and real-world problem-solving skills, applicable across multiple subjects requiring structured, critical thinking.

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