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Using Problem-Solving Learning to Improve Students' Learning Outcomes in Chemistry in Grade 8: A Case Study of Symbol Lessons, Formulas, and Chemical Reactions

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Abstract

Teaching methods are crucial in the teaching and learning process, helping students solve problems in both lesson content and real-life situations to achieve their learning outcomes. This study aimed to evaluate students' learning outcomes and understand their perceptions after implementing a problem-solving learning method. The study was conducted for ten weeks at Chea Sim Samaki High School in Phnom Penh, Cambodia, and included 42 participants from two classes. This research used a quantitative method through quasi-experimental research design with data collected through pre-tests, post-tests, and Likert-scale questionnaires. The data were analyzed using SPSS. The results showed that students taught using the problem-solving method ($M = 36.19$, $SD = 6.18$) outperformed those taught using traditional methods ($M = 26.76$, $SD = 6.80$), with a statistically significant p-value of 0.000 ($p < 0.05$). Students reported enhanced understanding of concepts, improved critical thinking, and better collaboration skills. They valued this approach for encouraging them to focus on understanding problems rather than memorizing solutions, fostering positive attitudes toward learning. These results suggest that the problem-solving learning method not only enhances students' learning outcomes but also strengthens their ability to retain knowledge and develop teamwork skills.

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Keywords

Chemistry, Problem-solving Learning, Learning outcome, Perception, Symbol lesson

1. Introduction

1.1 Background of Study

The education sector in Cambodia plays an important role in the development of human resources, promoting social and economic growth, which is the catalyst for the improvement of education to respond to new social and economic developments (Ministry of Education, Youth and Sport [MoEYS], 2013). The main goal of the Socio-Economic Development Plan is to prepare Cambodian people to become full citizens with knowledge, skills, and behavioral and physical education, which is an important educational strategy to achieve the goal of national development. Thus, improving the education sector is a guarantee of improving the quality of education, which is a common trend in many countries in the world.

Capacity development on right teaching methods and scientific teaching and planning are at the core of improving the quality and efficiency of education (National Institute of Education [NIE], 2018). According to the Deputy Prime Minister, the Minister of Economy and Finance who said at the opening ceremony of a conference to review education, youth

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and sport for the academic year 2020-2021, "Teachers are the heart of the rehabilitation and development of the education sector" because teachers play an important role in education, especially lifelong learning, and research to find new things to improve the quality of education. In addition, teachers will continue to be key individuals in leading school activities and constantly developing creative and effective mentors for students (Oun, 2022).

Chemistry is one of the science subjects such as physics, biology, and earth science, which studies in detail the composition, form, function, and activity of a chemical reaction in matter. In addition, chemistry is the foundation of various scientific disciplines such as biology, physics, techniques in the laboratory of medicine, geology and earth science, food science, and engineering (Domenici, 2022). It is considered the most difficult and complex subject for secondary school students (Gafoor & Vevaremmal, 2014).

According to the Department of Education Policy (2021), some of the challenges in the current education sector are related to the fact that students are slow to learn science subjects due to their activities, attitudes, behaviors, abilities, passions, and efforts. To address these challenges, teachers must use effective teaching methods that promote academic results and align with the Education Ministry's curriculum standards. Student-centered approaches are essential in this content area, as they help students participate in activities and improve their learning outcomes (Hang Chuon, 2021).

Abdu-Raheem (2012) showed that the main challenge in education is that students' participation in activities and learning outcomes in the learning process is diminished for two reasons: the use of teaching methods in science subjects and the fact that students are lazy, inactive, and unable to identify and solve problems that arise on their own. The policy plan on capacity development in the education sector in 2020-2024 revealed that most teachers were not able to access modern teaching methods due to a lack of training, limited resources, and inadequate support (MoEYS, 2020).

As a result, students' academic performance in science subjects was low, with a lack of knowledge in science and practical science-related activities (Muchwe & Aru, 2014). To assist in solving these problems, education in public and private institutions is required to transfer teacher knowledge to students with new pedagogy strategies and modern teaching methods in the teaching process. Akpoghol et al. (2013) defined problem-solving approaches as a way for students to learn to find solutions to problems and challenges in the rules and to be able to solve their problems successfully. Implementing problem-solving approaches can help students to think, analyze, and evaluate learning content and activities, especially to expand students' knowledge allowing them to solve problems in the future.

1.2 Research Problem

According to MoEYS (2018), the education sector in Cambodia was facing a significant challenge in terms of student proficiency. The PISA-D test results showed that only 5% of 15-year-old students had a basic level of proficiency in science, which was lower than the global capacity requirements (MoEYS, 2018). The report also revealed that approximately 90% of undergraduate students in Cambodia were below Level 2, which was much higher than the member countries participating in PISA-D, ASEAN, and OECD (Pritchett & Viarengo, 2021). Based on these results, there is a need to focus on strengthening the ability of students from primary and secondary levels to apply knowledge and skills in real-life contexts. Furthermore, Su et al. (2022) found that students became slow learners in science subjects due to two main reasons. Firstly, teachers lacked modern teaching methods and knowledge content. Teachers often teach through traditional teaching methods (Boumová, 2008). Secondly, students themselves did not like science subjects because it was difficult to study such subjects (Palmer et al., 2017).

Based on a five-week pedagogical practicum at Chea Sim Samaki High School in Phnom Penh, Cambodia, which involved meetings, class observations, and examination of students learning outcomes, it was revealed that problems with classroom management appeared particularly during group work, as some students refused to participate or needed extra help. Additionally, teachers found it challenging to adjust to a facilitative role in tasks, group work, and peer learning, which frequently conflicted with students' expectations of traditional teaching. Furthermore, student comprehension and engagement were below expectations, highlighting the necessity of improving student-centered approaches in this context.

Students were found to be unable to think critically and were not able to solve problems by answering questions, calculating exercises, and completing worksheets. Traditional teaching methods often emphasize rote memorization and passive learning, which do not adequately prepare students to handle complex problems or think deeply about the material they are studying. Therefore, many students struggle with critical thinking and problem-solving skills (Choi et al., 2014). By implementing problem-solving learning, teachers can create a more student-centered learning environment that encourages active engagement, critical thinking, and active learning. This method requires students to identify problems, gather relevant information, establish possible solutions, and evaluate their effectiveness (Hmelo-Silver, 2004).

1.3 Objectives of the Study

This study has two objectives:

1. To evaluate students' learning outcomes through the implementation of problem-solving teaching methods.
2. To understand students' perceptions after implementation of problem-solving teaching methods.

1.4 Research Questions

The study is guided by the following research questions:

1. How does the implementation of problem-solving teaching methods in the teaching and learning process change students' learning outcomes?
2. What are the students’ perceptions about the implementation of problem-solving teaching methods?

2. Review of Relevant Literature

2.1 Definition of Problem-Solving Learning

The National Institute of Education (2018) has defined problem-solving learning as a student-centered approach used step-by-step to help students find solutions to problems and challenges in content through quizzes and repeatedly based on other approaches for them to succeed.

2.2 Implementation of Problem-Solving Learning

In the implementation of problem-solving learning, teachers need to instruct students to implement problem-solving strategies (NIE, 2018). The implementation of problem-solving learning involves four crucial steps that both teachers and students must follow with precision to effectively solve problems (Hung, 2011). The first step is problem identification, where the problem is defined and comprehended with clarity. The second step involves selecting related information, which calls for gathering all pertinent information to gain a better grasp of the problem. The third step entails implementing a plan, where teachers pose questions or assign exercises to the students to facilitate the discovery of solutions. Finally, the fourth step, evaluation, involves reviewing the answers and results and reflecting on the problem-solving process (Aswir & Misbah, 2018).

In the process of using problem-solving techniques in the classroom, instructors can achieve this by giving students tasks or questions that require them to use their problem-solving abilities. Teachers can ask students to recognize hypotheses and understand what has to be done to solve the problem (Snyder & Snyder, 2008). Additionally, students can then start debating options and putting problem-solving techniques into practice, and students' ability to solve problems is aided by regular problem-solving observation and discussion (Ashmore et al., 1979). Similar studies by Kaplan et al. (2016) suggested that students' beliefs and perceptions of problem-solving practices in learning and daily life were influenced by their knowledge, experience, context, and education. Students' perceptions of the application of problem-solving approaches also impacted their attitudes, feelings, and attitudes toward problem-solving in learning (Heppner et al., 2004).

2.3 Challenges in the Problem-Solving Process

Furthermore, according to Tambychik et al. (2010), to apply the problem-solving process, students need to understand the problem, gather the necessary data, identify possible solutions, and evaluate the solutions. Students should spend plenty of time researching, engaging in activities, and crafting ideas relevant to the task while teaching and learning through problem-solving methods (Serin et al., 2010).

Researchers asserted that implementing a problem-solving approach demands a lot of work, including practice exercises and answering questions (Ali, 2019). However, students often make mistakes during the review phase, which is the fourth stage, due to the lack of a thorough examination, accurate assessment, and reflection (Sukoriyanto et al., 2016). These mistakes can result from various factors such as teaching methods, action planning, lack of textbooks and materials, and inadequate mathematical skills related to calculating and writing equations (Ogunleye, 2009).

2.4 Overcoming Challenges with Problem-Solving Learning

To overcome these challenges, teachers can use various teaching methods, such as developing prior knowledge and thinking skills, reasoning skills, and problem-solving skills, to help students build their ability and teamwork skills (Nnorom, 2021). Additionally, Aisya et al. (2017) suggested that teachers can assist students in finding research information by using reading activities from various sources, documents, and books. Problem-solving methods aid students in succeeding when solving problems for the first time and during the review phase (Mataka et al., 2014). Elias (1991) posited that problem-solving approaches provide several benefits in the teaching and learning process, such as increasing comprehension of problems and problem-solving skills, encouraging students to explore all means effectively and successfully, being courageous and resilient in the face of problems, and developing positive emotions, particularly in group discussions.

2.5 Benefits of Problem-Solving Learning

Implementing problem-solving approaches stimulates activities and drives student learning outcomes (Jitendra et al., 2019). It aided in increasing problem-solving skills or tasks that include aspects of problem identification, problem-solving, choosing the best solution, and allowing students to play an active role in building their knowledge, enabling them to develop their thinking skills (Dewey, 2010).

2.6 Research Gap

Despite extensive research on the use of problem-solving learning in various educational contexts, there is a significant gap in empirical studies assessing its effectiveness in enhancing chemistry education outcomes in Cambodia. Previous studies have demonstrated the positive impact of problem-solving teaching strategies on students' attitudes toward science (Ahmad et al., 2010), problem-solving and reasoning abilities (Malik & Iqbal, 2011), and academic performance in chemistry (Omoniyi et al., 2018) and social studies (Abdu-Raheem, 2012). However, no research has specifically investigated the use of problem-solving learning to improve chemistry education for Grade 8 students in Cambodia. Therefore, this study aims to address this gap by examining the effectiveness of problem-solving approaches in enhancing the learning outcomes of Grade 8 chemistry students in Cambodia.

3. Methodology

3.1 Research Setting

A quasi-experimental analysis for this quantitative study was conducted at Chea Sim Samaki High School in Phnom Penh, Cambodia. The area of the study was carried out at a pedagogical practicum site in Phnom Penh, specifically at the participating high School. This initiative, requested by the Phnom Penh Education Teacher College, aimed to facilitate the training of future educators. The researchers chose this high school because it was the practicum school that allowed the research team to conduct the study easily. It made the research process and data collection easier and more efficient.

3.2 Sample and Sampling Method

The population for this study included 76 students from two classes, 53 of them were male and 23 were female. The sampling methodology used the Yamane formula. Yamane's equation was utilized to get the required sample size. The significance of this equation is that it affords the study the necessary sampling freedom for a known population.

$$n = \frac{N}{1+N(e)^2}$$

where

n = Sample size

N = population under study

e = margin error (0.09)

1 = constant

Based on this formula, the sample size for the experiment and control groups were calculated as follows:

In the experimental group, there were 33 students on the list, but only 25 were punctual students. These students were considered the population. Thus, we have the sample for the experimental group n = $\frac{25}{1+25(0.09)^2}$ = 20.79 ≈ 21. In the control group, there were 43 students on the list, but only 26 were punctual students and were considered the population. Thus, we have the sample for the control group n = $\frac{26}{1+26(0.09)^2}$ = 21.47 ≈ 21. Therefore, the sample size for this study was 42 respondents.

3.3 Research Instruments

Test: The pre-test took place in the first week before applying the problem-solving method, and the post-test was completed in the fifth week after the lesson content, symbols, chemical formulas, and chemical reactions in chemistry were taught. The test was developed by the research with a clear analysis of the standard test and focused on Bloom's taxonomy (Adams, 2015). This standard test was reviewed and revised by three potential chemistry lecturers in Phnom Penh Teacher Education College. It consisted of two parts. The first is a multiple-choice question format with four different multiple-choice answers, including eight questions, level of wisdom, easy level and intermediate level of memory, level of understanding, and level of practice. Another part was a comprehensive question consisting of two comprehensible and analytical questions related to lessons, symbols, chemical formulas, and chemical reactions.

Questionnaire: A tool designed to measure participants' attitudes, knowledge, interests, and perceptions of a particular issue by including questions (Baburajan et al., 2020). The questionnaire was adapted from Mandina and Dube (2018). It consisted of 24 elements (20 positives and 4 negatives) representing three parts: Part 1 is students' perceptions of problem-solving approaches; Part 2 is the development of problem-solving skills; and Part 3 is behavioral reflections. The average price index measures four levels: Strongly disagree = 1.00–1.75, Disagree = 1.76-2.50, Agree = 2.51-3.25, and Strongly agree = 3.26-4.00. A valuation is the result of an average price index using a notation. The cut-off point value is 2.5, which is the deductible value of the index. The average score of the cut-off point is 2.5, which means for the decision of acceptance, the point between 2.5 and above is accepted while the point below 2.5 is rejected. The reliability test using the Cronbach alpha result is 0.752.

3.4 Data Collection

The data collection method was selected based on Mandina and Dube (2018); this study employed problem-solving methods in teaching and learning chemistry. Data collection was conducted for five weeks, from January 25, 2023, to February 22, 2023. A pre-test was offered in the first week prior to introducing problem-solving methods, while a post-test in the fifth week aimed to assess students' learning outcomes after the teaching session. According to Aswir and Misbah (2018), descriptive and inferential statistics were used to analyze the pre-test and post-test results, examining mean, standard deviation, percentage, maximum, and minimum values. An independent sample t-test was then applied to determine the significance of changes. Data on participants' attitudes, knowledge, interests, and perceptions were gathered using a four-level Likert scale questionnaire (Baburajan et al., 2020). Average scores were classified as follows: 3.26–4.00 (very high), 2.51–3.25 (high), 1.76–2.50 (low), and 1.00–1.75 (very low), indicating levels of agreement (Akan, 2015). Reliability testing using Cronbach's alpha yielded a coefficient of 0.752, indicating acceptable reliability.

3.5 Data Analysis

Data analysis combined descriptive and inferential statistics to evaluate learning outcomes and students' perceptions. Descriptive measures, such as mean, standard deviation, and score ranges, summarized pre-test and post-test results, while an independent sample t-test assessed the significance of observed changes. Students' attitudes, knowledge, interests, and perceptions were measured using a four-level Likert scale questionnaire (Baburajan et al., 2020), with scores classified into very low to very high levels (Akan, 2015). Reliability testing using Cronbach's alpha yielded a coefficient of 0.752, indicating acceptable reliability.

3.6 Ethical Considerations

This research was conducted with permission from the Phnom Penh Teacher Education College's management team, and all participants and stakeholders consented to participate. All data and information obtained were kept confidential to protect the participants' identity. The test design was developed specifically for this study, incorporating standard tests and Bloom's taxonomy levels of understanding, under the supervision of chemistry lecturers at the Phnom Penh Teacher Education College.

4. Results

4.1 Results of Pre- and Post-Test

The present study aims to investigate the impact of problem-solving teaching methods on students' learning outcomes. The study comprised two groups of students: the experimental group, which received problem-solving learning (PSL), and the control group, which received traditional teaching (TM).

Table 1 shows the results of the pre-test of the experiment group and control group to check and examine prior knowledge of students before applying problem-solving in the chemistry class. The results indicated that the prior knowledge of the students among the two groups was not significantly different ($p > 0.05$).

Table 1. Comparison of students' knowledge of answering questions.

	Control Group (TM)		Experiment Group (PSL)		
	M	SD	M	SD	*p*-value
Students' knowledge of answering questions	20.24	5.35	23.81	6.50	0.059

Table 2 shows the results of the post-test of the two groups after applying the method to the teaching and learning process in the chemistry class. The results revealed that students participating in problem-solving learning scored higher than those in the control group who did not receive problem-solving learning ($t = 4.702$, $p < 0.05$). The mean score of knowledge of test questions for the experiment group (M = 36.16, SD = 6.18) was higher than the control group (M = 26.76, SD = 6.80). Based on this result, there was *effectiveness of problem-solving teaching methods in enhancing students' performance in the class.*

Table 2. *S*tudents' knowledge of answering questions.

	Control Group(TM)		Experiment Group(PSL)		
	M	SD	M	SD	*p*-value
Students' knowledge of answering questions	2.10	2.64	8.86	4.96	0.000

Table 3 shows that the post-test score of the experimental group was significantly higher than that of the control group, demonstrating the effectiveness of problem-solving teaching methods in enhancing students' performance.

Table 3 also provides some data measures based on research objectives, such as the minimum score of the experiment group which is 25 and that of the control group which is 20. This means that after applying the problem-solving method, students received a higher minimum score than using the traditional teaching method.

The maximum score of the experimental group was 50 and the control group was 35, meaning that the experimental group that were taught with the problem-solving instruction scored higher than the control group that learned through the traditional teaching.

The results of the average score and the standard deviation of both classes were that the experiment group (M = 36.19, SD = 6.18) performed better than the control group (M = 26.76, SD = 6.80). These results show that after teaching the second lesson which focused on the symbols of chemical formulas and chemical reactions, the experimental group scored better than the traditional instruction group.

In addition, both the problem-solving and traditional teaching groups had a p value smaller than 0.05, meaning that they are effective (significant), but problem-solving teaching methods were more effective in making the student score increase in the first instance.

Table 3. The effectiveness of the implementation of problem-solving teaching and learning methods.

	Control Group (TM) (n = 21)				Experiment Group (PSL) (n = 21)				*p*-value
	M	SD	Min	Max	M	SD	Min	Max	
Pre-test	7.24	6.93	0	20	7.90	6.88	0	25	0.756
Post-test	26.76	6.80	12	35	36.19	6.18	23	50	0.000

4.2 Results of Students' Perceptions about Problem-Solving Learning

One of the objectives of this study was to explore students' perceptions of problem-solving teaching methods. A total of 21 participants were assigned to the experiment group. The participants were asked to complete a survey consisting of three sections, and their responses were recorded and analyzed. The results of the study are presented as follows:

Part 1: Understanding problem-solving teaching methods in chemistry. The participants were asked to respond to six statements related to problem-solving teaching methods in chemistry. Integrating theoretical knowledge and practical applications is crucial for effectively addressing problems within chemistry lessons. By presenting main concepts, study objectives, and relevant examples and exercises aligned with the lesson content, students can engage in problem-solving, grasp theoretical principles, and participate in activities that foster active thinking. This approach stimulates memory retention, reinforces understanding, and develops the rules and skills necessary for mastering chemistry.

The average score for this section was 2.76, with a standard deviation of 0.61, indicating some variability around the mean score. The range of scores, from 1.39 to 3.62, highlights the variation in perceptions among respondents. While the average score suggests a moderate level of agreement, some participants rated their confidence and problem-solving skills quite low, while others rated them significantly higher. Including the range, mean, and standard deviation provides a more comprehensive understanding of the diverse experiences that students had with problem-solving strategies in chemistry.

The results suggest that the participants had a positive perception of problem-solving teaching methods in chemistry. The problem-solving learning are easily able to build on their prior knowledge with new knowledge in groups to solve problems under the existing realities in the student environment. Problem-solving learning enhances their understanding of the subject matter; their understanding of problem-solving is impacted by practical experiences rather than just theoretical knowledge, which limits their ability to apply problem-solving skills in real-world contexts.

Part 2: Development of problem-solving skills. The participants were asked to respond to seven statements related to the development of problem-solving skills. The average score for this section was 3.7, with a standard deviation of 0.44. The results show that students could identify problems and seek solutions in problem-solving in chemistry lessons. This high mean indicates that the problem-solving method promotes critical thinking abilities, as they are required to analyze problems, evaluate information, and develop solutions. The ability to delve into lesson content empowers students to seek out information pertinent to overcoming the challenges they encounter. This active participation deepens their understanding of the material and cultivates a heightened interest in learning.

Part 3: Reflection on behavioral development. The participants were asked to respond to five statements related to their behavioral development. The average score for this section was 2.82, with a standard deviation of 0.49. The results suggest that the participants were actively engaged in the learning process and were not intimidated by the problem-solving exercises. The results of the study indicate that students learning attitudes are very positive because they are happy and satisfied, which appears through several attitudes and activities, such as a deep need for learning, active participation in the classroom, a lot of courage in presentations and sharing with the entire class.

The results showed that applying problem-solving learning can make learning enjoyable and increase students' independence and active roles. Many students realized that problem-solving could help them develop critical thinking skills. They understood that analyzing problems, evaluating options, and making decisions were valuable skills that would benefit them in their learning and personal lives. In addition, it could increase their interest in science subjects and impacted their approach to problem-solving and positive attitudes.

Table 4. Students' perceptions of problem-solving learning.

N	Description	Experiment Group (n = 21)			
		$\bar{x}$	Liker Scale	SD	Decision
	Part 1: Understanding problem-solving teaching methods in Chemistry				
1	I like to learn problem-solving strategies in Chemistry.	3.62	Strongly Agree	0.50	Accepted
2	I can identify the problem in the lesson content by themselves.	3.58	Strongly Agree	0.67	Accepted
3	I can solve the problem in the lesson content by themselves	3.43	Strongly Agree	0.61	Accepted
4	I cannot determine the problem in the content.	3.14	Agree	0.72	Accepted
5	Learning through problem solving spend a lot of time	1.39	Strongly Disagree	0.50	Accepted
6	I cannot solve the problem encountered in the content of the lesson	1.42	Strongly Disagree	0.67	Accepted
	Total Average Score	**2.76**	**Agree**	**0.61**	**Accepted**
	Part 2: Development of problem-solving skills				
1	I have read the problem many times and selected the main ideas.	3.77	Strongly Agree	0.44	Accepted
2	I write the variables that are asked and the hypotheses.	3.82	Strongly Agree	0.34	Accepted
3	I always think the terms are appropriate for the problem.	3.7	Strongly Agree	0.41	Accepted
4	I think of characteristics such as theory, content and formulas.	3.86	Strongly Agree	0.36	Accepted
5	I seek solutions by finding problems that have occurred before.	3.34	Strongly Agree	0.58	Accepted
6	I started to take action on the chosen solution.	3.81	Strongly Agree	0.39	Accepted
7	I always check the answers or result.	3.66	Strongly Agree	0.47	Accepted
8	I have the skills to solve problems in the lesson Symbols Chemical formulas and chemical reactions	3.62	Strongly Agree	0.51	Accepted
	Total Average Score	**3.7**	**Strongly Agree**	**0.44**	**Accepted**
	Part 3: Reflection on behavioral development				
1	I focus on solving problems	3.72	Strongly Agree	0.46	Accepted
2	I actively participate in answering questions.	3.81	Strongly Agree	0.41	Accepted
3	I actively participate in the calculation of the exercise.	3.67	Strongly Agree	0.49	Accepted
4	I feel scared when solving each exercise.	1.43	Strongly Disagree	0.52	Accepted
5	I feel scared when answering question.	1.47	Strongly Disagree	0.58	Accepted
	Total Average Score	**2.82**	**Agree**	**0.49**	**Accepted**

5. Discussion

5.1 Analysis of Test Results

The results of this study showed both control and experiment groups of students correctly answered easy-level and multiple-choice test questions, which were available in the textbook of the Ministry of Education, Youth and Sport textbook. The results were analyzed using independent sample tests with a significance level of 0.05, using the average score and standard deviation as statistical values. It is assumed that both groups had a clear understanding of the purpose of the questions and remembered the lesson content well.

The results of the final test showed that the average score of the experiment team was 36.19 and that of the control team was 26.76. The standard deviation is 6.18 to 6.80, which indicates a significant difference in the mean score. The results of the t-test analysis show that the p 0.000 ($p < 0.05$), which is significant. The implementation of effective problem-solving teaching methods showed increased knowledge of science and basic knowledge, the development of self-study skills, research studies, thinking ability, the ability to analyze, motivation for participation in multiple learning activities, the ability to solve problems in the content of the lesson by answering questions, calculating exercises, and so on. These results are in line with the findings of Ifeanyi-Uche and Ejabukwa (2013) which found that there was a difference between the students' mean scores at the end of the experimental group, which used a problem-solving approach, and those of the control group that was taught traditionally. Based on these results, problem-solving approaches help students identify and think about problems, find solutions, and focus on successful learning outcomes (Noelin, 2021).

The results are also similar to Boris (2020) who found that students' learning outcomes increased the mean scores of students' completion tests in the experiment group, so students who learned by the method of problem-solving practice were better than those who learned by traditional teaching methods. Problem-solving teaching and learning could stimulate problem-solving, understanding of scientific concepts, active participation, group discussion, and problem-solving (Dye et al., 2019). Aswir and Misbah (2018) showed significant differences in student practice in problem-solving and traditional teaching. Problem-solving methods helped to increase students' knowledge and ability in the learning process to solve problems. This study fully supports the implementation of problem-solving approaches in chemistry. It is similar to Shehu's (2015) study that showed that students who practice problem-solving methods had a higher-grade point average than those who were taught using traditional methods. It is assumed that the use of problem-solving methods improved students' learning outcomes more than traditional methods in chemistry. At the same time, the implementation of problem-solving teaching methods has helped to increase students' learning outcomes. It was concluded that problem-solving methods are more effective for boosting learning outcomes and improving students' problem-solving than traditional teaching. Many students value structured approaches to problem-solving that include clear instructions. They feel that such structures help them navigate complex problems more effectively and build confidence in applying their knowledge. They can also discuss how problem-solving methods align with constructivist principles, emphasizing active learning and knowledge construction through experience. Similar studies by Boris (2020) and Dye et al. (2019) found similar results regarding how problem-solving could help improve students' learning outcomes.

As shown in Table 2, it is observed that the p value is equal to 0.059 ($p > 0.05$) in an analysis involving two groups of students and their responses to a set of questions with varying levels of difficulty, which suggests that the observed difference is not statistically significant. According to Nakhleh (1993), students often rely on memorization rather than analytical thinking. Additionally, the lack of time for review may contribute to poor academic results (Harskamp & Suhre, 2007).

5.2 Analysis of the Questionnaire Results

The results of the analysis in the questionnaire showed that in the first part, which showed the perception of the teaching method, the total mean score was 2.76 and the standard deviation was 0.61, meaning that the students agreed that the value of the average score was greater. A cut-point value of 2.5 is acceptable. Next, in the second part, which shows the development of problem-solving skills, the grade point average is 3.70 and the standard deviation is 0.44, with students fully agreeing that greater than the cut-off point of 2.5 is acceptable. Based on the results, the researchers were able to analyze the above data to determine that the students' perceptions of the implementation of problem-solving methods in teaching were positive and that the students were interested in learning. They could synthesize knowledge or use previous experience from the problems, start identifying problems, brainstorm, find the information needed in problem-solving, participate in class activities and small group discussions, and develop problem-solving skills. They develop confidence and cultivate responsibilities for any obstacles and problems that occur. At the same time, they know how to share and exchange ideas with each other. Similar studies by Kaplan et al. (2016) suggested that students' beliefs and perceptions of problem-solving practices in learning and daily life were influenced by their knowledge, experience, context, and education. Students' perceptions of the application of problem-solving approaches also impacted their attitudes, feelings, and beliefs about problem-solving in learning (Heppner et al., 2004).

Furthermore, according to Tambychik et al. (2010), to apply the problem-solving process, students need to understand the problem, gather the necessary data, identify possible solutions, and evaluate the solutions. They need to spend plenty of time researching, engaging in activities, and crafting ideas relevant to the task while teaching and learning through problem-solving methods (Serin et al., 2010).

The present study's results agree with Ntibi and Neji's (2018) findings, which reflect students' positive perceptions of the practical approach to problem-solving instruction, such as active participation in classroom activities, participation in group discussions, interest in studying chemistry, and developing problem-solving skills in the context of chemistry lessons. This study is supported by various studies that show the development of problem-solving skills and chemistry learning in students who have developed significantly in the teaching and learning process, as well as influencing the development of positive attitudes in the process (Wahyudiati et al., 2020). Problem-solving approaches help students develop academic satisfaction, develop basic knowledge, and be motivated to learn personal study skills, including problem-solving skills (Yavuz et al., 2017). The findings of this research indicate that students' perceptions of problem-solving methods significantly impact the development of problem-solving skills, which are essential lifelong learning abilities. These perceptions strongly influence their attitudes, skill, will, and commitment to engaging in the problem-solving process at the secondary education level (Montague et al., 2016). Students were also found to have more positive attitudes, share ideas, exchange ideas during discussions, enjoy learning, and support each other (Selcuk et al., 2008).

6. Conclusion

The present study confirmed that the problem-solving teaching method significantly improves students' learning outcomes in chemistry compared to traditional methods. This approach not only motivates students to succeed but also enhances their overall learning experience. Engaging in problem-solving helps students develop essential skills, such as the ability to independently solve problems through reading, research, inquiry, and observation, both in and out of the classroom. Additionally, problem-solving methods foster participation in class activities, promote critical thinking, enhance long-term memory retention, and clarify lesson content. Students express a positive perception of their knowledge of the lesson content and the teaching methods employed, particularly involving problem-solving skills. To further enhance the benefits of these strategies, educators are encouraged to adopt problem-solving activities in their lesson plans, adjust techniques to accommodate different learning styles, and foster collaboration among students. Providing support and guidance can ensure that students feel empowered to seek help when needed. By creating a flexible learning approach, educators can make lessons more accessible and engaging for all students. Ultimately, allowing students to take charge of their learning while receiving the necessary support that fosters a positive and motivating educational experience.

7. Recommendations

According to the results of this study, there are many good points in learning, but there are still some shortcomings and the need for improvements in the process of conducting teaching methods. The study has shown that problem-solving teaching methods can increase learning outcomes and stimulate students' interest in chemistry. Hence, we recommended that teachers should shift from traditional teaching methods to problem-solving teaching methods to improve learning outcomes. Moreover, teachers should increase their knowledge of specialized subjects and teaching methods.

We also have some recommendations for future researchers. As a recommendation, future researchers should develop other research tools, such as semi-structured interviews, and checklists to observe students' learning in the class. Therefore, we recommend that researchers should expand the scope of their research by increasing the number of participants. We also recommend that they combine problem-solving approaches with other schools in other disciplines, such as science and social sciences, at different levels to learn the effectiveness of teaching methods in the teaching and learning process.

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