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# Comparison of chemistry students in solving algorithmic, conceptual and open-ended problems

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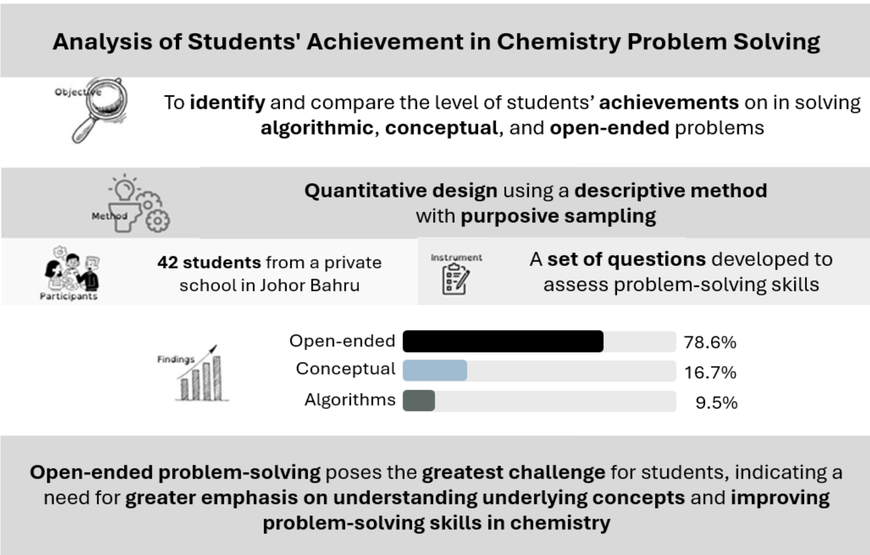
## Abstract

This study analyses students' achievements level in solving chemistry problems. Questions were designed in algorithm, conceptual and open-ended formats. The limited research on students' effectiveness in different problem types highlights the need to examine their grasp fundamental chemistry concepts. This research aims to identify and compare achievements levels across the three problems types. A quantitative design using a paper-and-pencil test was employed. The instrument, covering mole concept, acid base, and polymer topics, was administered to 42 high school chemistry students from private school in Johor Bahru through purposive sampling. Descriptive statistics including frequency and percentage, were used to summarize the achievement level. Data were analyzed using SPSS 27.0. Findings shows that open-ended problems recorded the highest low achievement rate (78.6%), compared to algorithmic (9.52%) and conceptual problems (16.7%). These results indicate that open ended problems are the most difficult for students to master, reflecting weaknesses in understanding underlying concepts. Greater emphasis on cultivating problem solving culture in classrooms is recommended.

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1. problem solving;
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## Section Editors

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## Highlights

- Students showed strong procedural skills in algorithmic problems.
- Performance declined in conceptual problems, reflecting reliance on memorization.
- Open-ended problems pose challenges but limit creativity and application.

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# 1. Introduction

Chemistry can be defined as the branch of science that relates to the properties of composition, element and compound structure, how they change and the release or absorption of energy when they change. Chemistry is an important subject as it discusses the composition and structure of things surrounding us (Sausan *et al.*, 2018). It also explains the natural phenomena that occur in our daily life, and helps us to solve our problems scientifically. However, it is an unpopular subject among students. This subject requires the students to give an effort in comprehending the concepts. Compared to language and other subjects, chemistry is more abstract because it comprises macroscopic, microscopic, and symbolic domains that describe chemical behaviors in different ways. The majority of secondary students think that chemistry is a difficult subject (Sausan *et al.*, 2018). The difficulties of learning chemistry make students have a negative perception towards chemistry. Studies show they are less interested and less motivated in learning chemistry concepts (Sausan *et al.*, 2018).

Based on results released by the Organisation for Economic Cooperation and Development (OECD), Malaysia scored 409 in Mathematics, 388 in Reading and 416 in Scientific Literacy in the Programme for International Student Assessment (PISA) 2022 (Ly *et al.,* 2022). Plus, according to Azahar and Cheng (2024), Malaysia's PISA scores in 2022 were 18% lower in reading, 14% lower in science, and 13% lower in mathematics compared with the OECD average. These differences are larger than they were a decade ago. The advancement of science and technology depends on the professional and well-skilled people who excel in science understanding and can apply scientific knowledge in our daily life (Kinge *et al.,* 2020).

Students have not been given the idea of the method to solve chemistry problems effectively. Students are not adequately equipped with the cognitive and affective skills necessary to apply their learning effectively in academic and real-life situations (Surif *et al.*, 2014; Sarwari and Kakar, 2023). To foster a greater interest in acquiring knowledge of chemistry among students, measures need to be taken. Recent studies were conducted to emphasize the importance of integrating different problem-solving approaches. These approaches include solving the problem of algorithmic, conceptual, and open-ended, which each play unique roles in enhancing students' understanding and engagement (Surif *et al.*, 2014; Sarwari and Kakar, 2023). However, there is limited evidence on how integrating these approaches could lead to improved outcomes, particularly in chemistry education.

Algorithmic problem-solving only focuses on step-by-step procedures and formulas. It is often criticized for promoting rote learning without encouraging deep understanding even it helps students solve structured problems such as stoichiometric problems. Conceptual problem-solving approaches emphasize understanding the underlying scientific principles rather than just applying formulas. This method helps students grasp fundamental concepts in chemistry, including acids and bases, atomic structure, and chemical bonding (Hagos, 2025). The last problem is open-ended which has no single correct answer and requires students to evaluate various solutions. It can encourage creativity, higher-order thinking, and the application of knowledge in real-world contexts. Plus, it also demonstrates the effectiveness of open-ended problem-solving in fostering students' abilities to tackle complex, real-life chemistry scenarios (Raman *et al.*, 2024).

Therefore, this study aims to fill these gaps by identifying the achievement levels of high school chemistry students in three types of problem-solving (algorithmic, conceptual, and open-ended), focusing on three critical areas, namely the mole concept, acid-base reactions, and polymers. These topics were selected due to their importance in understanding both foundational and advanced chemistry concepts. The mole concept addresses algorithmic skills in quantifying chemical reactions; acid-base reactions require both calculation and conceptual understanding, and polymers encourage open-ended thinking related to real-world applications and sustainability (Tsaparlis, 2021). By focusing on these areas, the study seeks to enhance chemistry education and improve student performance to meet international standards.

## 1.1. Problem-solving

A problem can be described as a situation that arises when there is a disparity between the current position and the desired goal. Problem-solving plays a crucial role in all scientific disciplines and solving problems can reveal fundamental concepts underlying those disciplines (Frey *et al.*, 2022). Problem-solving can be defined as the action taken when there is no solution to a problem. Through problem-solving, students can develop a deep understanding of chemical concepts and connect them to practical applications. These skills are also relevant in career preparation, enabling students to design experiments, analyse data, and overcome challenges. With these skills, students become proficient problem-solvers in the field of chemistry and science. However, problem-solving skills in chemistry have been identified as important skills that are lacking among students in current education. Students often encounter difficulties when solving problems as it involves critical thinking and in-depth analysis (Jamil *et al.*, 2024).

In the context of chemistry, problem-solving is crucial because it enables students to apply theoretical knowledge to real-world situations. For example, in a stoichiometry problem, students need to determine the amounts of reactants and products in a chemical reaction. This requires both algorithmic problem-solving (applying formulas and procedures) and conceptual understanding, which requires grasping the law of mass conservation. As for open-ended problem solving, such as chemical equilibrium topics, students must analyse reaction rates and the dynamic nature of reversible reactions. Here, open-ended problem-solving becomes important as students explore different conditions (such as temperature or concentration) that can influence the outcome of a reaction. This approach fosters deeper understanding and prepares students to handle real-world applications. The use of problem-solving in these areas supports students' ability to think critically and apply their chemistry knowledge to complex open-ended problems. It can bridge the gap between theoretical learning and practical application. This approach not only enhances learning outcomes but also prepares students for future careers in STEM fields.

In this research, different topics are chosen to solve algorithmic, conceptual, and open-ended problems in chemistry, assessing a range of cognitive skills and knowledge. Algorithmic problems focus on students' ability to apply formulas and perform calculations, emphasizing procedural skills in areas like stoichiometry or chemical equations. Conceptual problems, on the other hand, assess understanding of core principles and theories, such as atomic structure or thermodynamics, requiring deeper comprehension of how and why processes occur. Open-ended problems involve applying chemical knowledge to complex, real-world scenarios, thereby fostering critical thinking, creativity, and problem-solving skills. By using a variety of topics, teachers can evaluate both the practical and theoretical understanding of students across different cognitive domains.

## 1.2. Algorithmic problem

Algorithmic type of problem solving can be defined as a step-by-step process to resolve equations or numerical calculation problems. The correct formula or equations are needed to calculate this type of problem. According to Sangguroa and Surifa (2021), an algorithmic problem is a problem in which the required data are given, the solution method is known, and the objective is clearly defined. This type of problem does not assess the student's problem-solving skills but rather emphasizes their capacity to apply acquired knowledge consistently. According to Frank *et al.* (1987), algorithmic problems serve as helpful shortcuts for practicing exercises, but one disadvantage is that they can impede understanding when students encounter real-world problems. Algorithmic problems often discourage the development of students' conceptual understanding. When a student's initial approach is merely to select which algorithm to apply, it shows that the problem has not been genuinely solved (Frank *et al.,* 1987). To reduce dependence on rote learning, students must develop a strong conceptual understanding of chemistry.

A few topics in chemistry that are often difficult for students to grasp include chemical equations, stoichiometry, mole concepts, and acid-base reactions (Rosa *et al*., 2022). For instance, the mole concept is a fundamental building block in stoichiometry, which is critical for solving various quantitative problems in chemistry. The urgency in using the mole concept as test material stems from its role in bridging theoretical knowledge with practical applications. A study by Diaz and Aizman (2024), found that students in a control group struggled with the mole concept in a pretest for stoichiometry, and despite a post-test intervention, many still had trouble. This demonstrates the persistence of misunderstandings, making it an essential area to focus on for improving student learning outcomes.

## 1.3. Conceptual problem

Conceptual questions typically present students with chemical scenarios that they are unfamiliar with. This question necessitates that students justify their choices, predict future occurrences, explain processes, establish connections between various topics, recognize questions presented in a novel manner, and extract valuable information from multiple sources or broad scopes. Students are required to synthesize their answers and evaluate the problem in order to determine an appropriate mathematical tool for solving it.

According to Cracolice *et al.* (2008), a conceptual problem necessitates that students focus on enhancing their understanding of the underlying concept rather than relying on memorized procedures. A strong conceptual understanding of the relevant topics is essential for students to successfully solve conceptual questions (Haláková and Proksa, 2007; Hurrel, 2021).

One of the problems that students find difficult to understand in chemistry is acid and base concepts. A study by Yaman *et al.* (2019) showed that the main problem faced by students is the understanding of acid and base concepts. They tend to only associate acids with $H^+$ ions and bases with $OH^-$ ions, without a deep understanding of the characteristics and reactions of acids and bases. Another study by Tóthová *et al.* (2021) and Tóthová and Rusek (2021) found that students lack the skills necessary to solve conceptual chemistry problems.

Conceptual problem-solving is essential for students, as it assists students in attaining a more comprehensive and in-depth learning experience. It also helps to strengthen their comprehension and proficiency in applying the knowledge they have acquired to novel situations. Students' critical thinking abilities would be enhanced through improved conceptual problem-solving skills. It also fosters students' enthusiasm for science and the pursuit of knowledge. This type of problem-solving evaluates students' understanding of a subject matter, rather than solely assessing their knowledge and problem-solving abilities. It also offers a means to identify and address students' misconceptions through diagnostic assessment.

## 1.4. Open-ended problem

An open-ended problem is a problem that does not have a singular correct answer; instead, it has the possibility of multiple correct answers (Fitriana *et al.*, 2018). Critical thinking skills, creativity, and problem-solving skills are needed to solve this type of problem (Fitriana *et al.*, 2018). According to Authority (2010) and Aziza (2021), open-ended questions in chemistry are designed to evaluate a student's understanding of fundamental concepts rather than their ability to memorize specific facts. This approach ensures that students are not impeded from answering the questions solely due to a lack of recall, as there are always multiple alternative paths to arrive at the ultimate solution. It is important to have open-ended problem-solving skills (Bayarcal and Tan, 2023). This is because creative and adaptable solutions are required to solve many challenging real-world problems in an effective and practical way. One will come out with new ideas and innovations that can improve the world once they have mastered open-ended problem-solving skills (Bayarcal and Tan, 2023). Furthermore, collaboration and teamwork are required to solve open-ended problems which are indirectly able to learn others' perspectives and experiences.

Students must acquire problem-solving skills to develop conceptual understanding and the ability to solve real-life problems with scientific skills. Specifically, this research aims to examine students' level of ability in solving these types of problems, which include algorithmic problems, conceptual problems and open-ended problems. According to the Curriculum Development Department, in Malaysia education, the KSSM curriculum emphasizes active learning and critical thinking. Students are taught to analyze problems, collect data, identify the causes of problems, and formulate solutions in the subject of Chemistry. Thus, the KSSM curriculum helps students to develop problem-solving problems related to chemistry concepts. The change in curriculum from KBSM to KSSM may potentially affect students' performance in solving real-life problems. Therefore, a new study is needed to examine how the KSSM curriculum influences students' ability to solve problems. In response to these challenges, a study has proposed to examine the students' level of achievement in solving various types of problems in chemistry (algorithmic, conceptual, and open-ended). Thus, this study aims:

i) To identify students' level of achievement in algorithmic problems
ii) To identify students' level of achievement in conceptual problems
iii) To identify students' level of achievement in open-ended problems
iv) To compare students' level of achievement in algorithmic problems, conceptual problems and open-ended problems

## 2. Methodology

The study focuses on identifying and comparing the chemistry students' level of achievement in solving algorithmic, conceptual, and open-ended problems. This methodology section covers aspects such as research design, population and sampling, data collection instruments, and data analysis techniques.

### 2.1. Research design

A quantitative study utilizing a descriptive research design was conducted to address the research objectives. This approach involved systematically collecting numerical data to describe and assess key characteristics related to the research topic. The data collection process was executed using a paper-and-pencil test, where participants were asked to complete a series of standardized questions designed to measure their knowledge, skills, or understanding of the subject matter. This method of data collection allowed for straightforward administration and reliable quantification of results, ensuring that the data could be analysed effectively to meet the study's goals.

### 2.2. Population and sample

For this study, purposive sampling was employed by choosing 42 high school chemistry students from a private school in Johor Bahru. This school was chosen due to its diverse student population, which reflects a range of academic proficiencies and backgrounds, making it an ideal setting to examine different problem-solving abilities in chemistry. The purposive sampling method was selected to ensure that the participants included students with varying levels of proficiency in chemistry, from high achievers to those who struggle with the subject. According to Emara *et al*. (2021). This diversity is crucial for a comprehensive comparison across different cognitive domains related to algorithmic, conceptual, and open-ended problem-solving.

The sample size of 42 chemistry students was determined based on the feasibility of conducting in-depth analyses while achieving statistically meaningful comparisons. All the students selected for this study were 17 years old and had been exposed to chemistry from the same year, ensuring they had an equal foundation in the subject. This uniform exposure to chemistry provides a consistent basis for assessing their problem-solving abilities, minimizing any confounding variables related to differing levels of prior knowledge or experience. The sample was evenly distributed across gender, ensuring that the study's findings are not biased toward a particular demographic group.

### 2.3. Instruments

To collect the necessary data, a series of tests was administered to the students. These tests comprised three types of problem-solving questions specifically designed to assess students' abilities in solving algorithmic, conceptual, and open-ended problems. Each test was carefully crafted to ensure clarity and relevance to the chemistry curriculum, allowing students to demonstrate their understanding of key concepts and problem-solving strategies.

Plus, it was developed based on research objectives to ensure it effectively addressed the key areas of interest. Following its development, these tests were validated by two experts who have experience in teaching chemistry for more than 10 years. The experts provided several recommendations, such as revising certain items. Despite these suggestions, the experts confirmed that these tests met the requirements and achieved the study's objectives.

#### 2.3.1. Algorithmic problems

The algorithmic problems focused on numerical calculations and the application of formulas, requiring students to follow step-by-step procedures. Each of these questions requires students to follow a defined set of steps, which is a hallmark of algorithmic problem-solving. **Table 1** below presents a set of algorithmic questions used in the study to evaluate students' problem-solving abilities in chemistry. Each question is designed to test the application of specific formulas and procedures, reflecting the systematic and procedural nature of algorithmic problem-solving. **Table 1** includes explanations for how each question relates to the development of these skills, emphasizing the role of algorithmic learning in reinforcing students' understanding of fundamental chemical concepts.

**Table 1.** Algorithmic questions in chemistry: assessment of problem-solving skills.

| Questions | Explanation |
|---|---|
| 1. A gas jar contains 300 $cm^3$ of ammonia gas at room condition. Calculate:<br>a) The number of mole of ammonia gas. | This question typically uses the formula $n=\frac{V}{M}$, where n is the number of moles, V is the volume of gas, and M is the molar volume. Students must identify the relevant values and apply the formula to find the solution. This type of calculation emphasizes the procedural aspect of problem-solving. |
| b) The mass of ammonia gas. | This question relates to question (a). After students get the number of moles, students need to calculate the mass of ammonia using formula, Mass (g) = number of mole x Molar Mass. |
| c) The number of atoms in ammonia gas. | This question involves Avogadro's Constant ($6.02\times10^{23}$) to find the total number of atoms. Students need to calculate the number of atoms using a formula. (number of particles = number of mole x Avogadro's Constant x number of ammonia atom in one molecule of ammonia gas). |
| d) Nitrogen gas can react with hydrogen gas to produce ammonia gas under certain conditions.<br>I) Write the balanced chemical equation for the reaction. | I) This task assesses students' understanding of the stoichiometry relationships in chemical reactions, requiring them to recognize the reactants and products involved and ensure that mass is conserved in the equation. This is a critical skill in chemistry that connects algorithmic problem-solving with conceptual understanding. |
| II) Calculate the volume of hydrogen gas needed in this reaction if 300 $cm^3$ of nitrogen gas is used and measured under the same reaction condition. | II) This question typically uses stoichiometry to determine the volume of hydrogen gas required to produce a specific amount of ammonia. It emphasizes the application of theoretical knowledge to practical situations. |

**Source:** Elaborated by the authors.

Algorithmic questions in chemistry are essential because they require students to follow established procedures, reinforcing their procedural knowledge and enhancing their problem-solving abilities. By applying systematic approaches to solve specific types of problems, students learn to navigate the complexities of chemical calculations with confidence (Vo *et al.*, 2022). These questions often involve mathematical skills, allowing students to practice and strengthen their ability to perform calculations relevant to chemical concepts. Furthermore, mastering algorithmic problem-solving fosters confidence, as students become adept at tackling quantitative problems, which serves as a foundation for developing higher-order thinking skills. Additionally, these questions are valuable for educators, as they provide insight into students' understanding of fundamental concepts and their capacity to apply that knowledge in practical scenarios. Overall, algorithmic questions play a crucial role in chemistry education by enabling students to effectively solve quantitative problems and prepare for more complex conceptual challenges (Rau *et al.*, 2021; Tsaparlis, 2021).

### 2.3.2. Conceptual problems

The conceptual problems presented scenarios that necessitated a deeper understanding of chemical principles, encouraging students to connect different topics and apply their knowledge creatively (Rahmawati *et al.*, 2022). Each question targets key aspects of chemical theory, encouraging students to engage in deeper thinking rather than simply recalling memorized facts. **Table 2** outlines a series of conceptual questions used to evaluate students' comprehension of fundamental chemical concepts related to acids. Each question is crafted to challenge students to think critically and apply their knowledge in new contexts, moving beyond simple recall to engage in deeper analytical thinking. **Table 2** also provides explanations for how each question relates to conceptual problem-solving, emphasizing the integration of knowledge and the application of scientific principles.

**Table 2.** Conceptual questions in chemistry: assessment of understanding and application of acid-related concepts.

| Questions | Explanation |
|---|---|
| I) What is meant by acid? | It prompts students to articulate their understanding of acids in terms of their properties and characteristics, such as their ability to produce $H^+$ ions in aqueous solutions. This requires students to synthesize knowledge from different areas of chemistry. |
| II) State the ion that enables an acid to show its acidic properties. | This question encourages students to connect the concept of acidity with the ionization process which produce hydrogen ion that can show the acidic properties. |
| III) Suggest the name of acid P and acid Q. | It requires students to apply their knowledge of chemical nomenclature. This not only tests their ability to identify specific acids but also assesses their familiarity with common acids and their formulas. |
| IV) Acid P and acid R have the same concentration. It was found that the pH value of acid P is lower than acid R. Explain why the pH value of both acids are different. | It challenges them to apply their understanding of concepts such as dissociation and strength of acids. This question emphasizes the importance of understanding that pH is influenced by factors beyond concentration, such as the acid's inherent strength and degree of ionization. |

**Source:** Elaborated by the authors.

These questions exemplify conceptual problem-solving in chemistry because they require students to integrate their knowledge and apply it to new scenarios. They encourage critical thinking and analysis, as students must justify their answers based on scientific principles rather than relying solely on rote memorization. By engaging with these conceptual questions, students deepen their comprehension of acid-related concepts, which is essential for their overall success in chemistry.

### 2.3.3. Open-ended problems

The open-ended problems require students to explore multiple pathways to arrive at solutions, fostering critical thinking and creativity (Shanta and Wells, 2022). The open-ended questions presented here are designed to encourage students to explore complex concepts related to the use of polyvinyl chloride (PVC) in water pipe manufacturing and its environmental implications. **Table 3** presents a set of open-ended questions designed to assess students' ability to analyse and articulate complex issues related to the use of PVC in water pipe manufacturing and its environmental impact. Each question encourages students to explore practical applications, environmental considerations, and ethical implications, fostering critical thinking, creativity, and problem-solving skills. **Table 3** contains explanations for how these questions relate to open-ended problem-solving, highlighting the importance of addressing multifaceted problems that allow for several valid responses.

**Table 3.** Open-ended questions in chemistry evaluating critical thinking and application in real-world contexts.

| Question | Explanation |
|---|---|
| a) State and explain the importance of using PVC in the manufacture of water pipes. | It prompts students to consider the practical applications of PVC in real-world scenarios. This question encourages them to think critically about the material's properties, such as durability, resistance to corrosion, and cost-effectiveness, which make it a popular choice in plumbing. Students must synthesize information and articulate their reasoning, demonstrating a deeper understanding of material science and engineering principles. |
| b) Explain how PVC can cause environmental pollution. Suggest on ways to solve this problem. | It challenges students to examine the broader implications of using PVC, including its production, use, and disposal. This question invites students to engage in environmental science and ethics, requiring them to think about sustainability and the consequences of material choices. By asking for solutions, the question fosters creativity and problem-solving skills, as students must propose practical measures to mitigate PVC-related pollution. |

**Source:** Elaborated by the authors.

These questions exemplify open-ended problem-solving because they do not have a singular correct answer, allowing for a range of responses based on students' perspectives and knowledge. They encourage students to analyse complex issues, consider multiple viewpoints, and express their thoughts coherently. Such questions are essential for developing students' higher-order thinking skills and their ability to apply scientific knowledge to real-world problems, thus enhancing their overall learning experience in chemistry and related fields.

Before administration, the items in each problem were validated by two expert chemistry teachers with ten years of experience each. The tests were pilot-tested with a small group of students to ensure that the questions were appropriate in terms of difficulty and clarity. The tests were designed to be completed within 40 minutes, providing students with sufficient time to think critically and demonstrate their problem-solving abilities. Students were instructed to complete the tests independently, providing their responses in writing. The data obtained from the tests were meticulously recorded for further analysis, ensuring that each student's performance could be accurately assessed and compared.

### 2.4. Data analysis techniques

Quantitative analysis techniques were applied to analyse the collected data. A set of questions consisting of three types of questions that related to algorithmic, conceptual and open-ended problems was given to the students. The students' answers were marked, and the marks were referred to the answer scheme. The mark achievement for each problem-solving category was then analysed using SPSS 27.0. **Table 4** shows the specification table for each item.

**Table 4.** The specification table for each item.

| No | Types of question | Topic | Total marks |
|---|---|---|---|
| 1 | Algorithmic | Mole concept | 10 |
| 2 | Conceptual | Acid and base | 10 |
| 3 | Open-ended | Polymer | 10 |

**Source:** Elaborated by the authors.

Descriptive statistics such as frequency and percentage were used to summarize the achievement level of students. The Malaysian Ministry of Education classifies students' chemistry achievement into two categories based on their assessment scores. **Table 5** shows the students' achievement level. This score level of achievement was used to provide clarity and ease of assessment.

**Table 5.** Level of achievement.

| Marks | Level of Achievement | Description |
|---|---|---|
| 0-39 | Low | Unable to solve problem |
| 40-100 | High | Able to solve problem |

**Source:** Adapted from Surif *et al.*, 2014.

Based on **Table 5** a score of 40% or higher is regarded as a passing mark, indicating a higher level of achievement in the subject. Conversely, students who score below 40% are considered to have a lower level of achievement in problem-solving skills. The "low" range can help teachers identify areas for improvement, while the "high" range can reinforce proficiency and foster motivation for the students.

This score also enables teachers to quickly identify students who may need additional support, making it an effective tool for promoting skill development in Chemistry (Ely, 2019). This research was supported by interviewing five students to provide deeper insights into the students' experiences and perceptions regarding problem-solving.

## 3. Results and discussion

**Table 6** shows the frequency and percentage of students' achievement across three types of questions, which are algorithm problems, conceptual problems and open-ended problems. The data illustrates how students performed in each category.

**Table 6.** The frequency and percentage of students' achievement on the three types of questions.

| | Marks | Level of achievement | Frequency | Percentage (%) |
|---|---|---|---|---|
| Algorithmic | 0-39 | Low | 4 | 9.52 |
| | 40-100 | High | 38 | 90.5 |
| | | Total | 42 | 100.00 |
| Conceptual | 0-39 | Low | 7 | 16.7 |
| | 40-100 | High | 35 | 83.3 |
| | | Total | 42 | 100.00 |
| Open-ended | 0-39 | Low | 33 | 78.6 |
| | 40-100 | High | 5 | 11.9 |
| | | Total | 42 | 100.00 |

**Source:** Elaborated by the authors.

### 3.1. Students' level of achievement in algorithmic problems

The findings reveal that the majority of students (90.05%) achieved scores above 40% when solving algorithmic problems, indicating a strong performance in this area. Only a small percentage (9.52%) struggled with these problems, suggesting that most students are proficient in applying the required techniques. This is particularly evident in question number one, which assessed students' understanding of calculations related to the mole concept a fundamental topic in chemistry.

The high level of achievement in algorithmic problems can be attributed to students' reliance on structured problem-solving techniques and consistent practice. These results are consistent with Olubunmi (2016) findings, which emphasize that the algorithmic learning method focusing on the three steps of analysis, calculation, and evaluation effectively supports students in mastering mathematical concepts in chemistry. By adhering to these steps, students can systematically approach and solve problems, thereby improving their performance.

Algorithmic learning methods enhance students' problem-solving skills and deepen their understanding of fundamental chemical concepts by promoting critical thinking and application over rote memorization. This approach breaks down complex problems into manageable steps, encouraging students to analyze, evaluate, and synthesize information to find solutions. By emphasizing the relationships between different chemical concepts and processes, algorithmic learning helps students grasp underlying principles and apply their knowledge to new situations, fostering a more comprehensive and adaptable understanding of chemistry (Vo *et al.*, 2022).

This study contributes to existing knowledge by reinforcing the importance of teaching problem-solving techniques in a structured and methodical manner. Furthermore, it suggests that when teachers emphasize the process ensuring students demonstrate in writing how they apply specific techniques students are more likely to internalize these methods, leading to better outcomes in examinations. This insight could inform future pedagogical strategies, particularly in designing curricula that prioritize skill development through algorithmic problem-solving.

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There are five questions provided based on the information in **Fig. 1**.

1. A gas jar contains 300 $cm^3$ of ammonia gas at room condition. Calculate: [Relative atomic mass: N = 14, H = 1; Avogadro constant = 6.02 x $10^{23}$; Molar volume = 24 $dm^3$ $mol^{-1}$]

   a) The number of mol of ammonia gas. [2 marks]

   b) The mass of ammonia gas. [2 marks]

   c) The number of atoms in ammonia gas. [2 marks]

   d) Nitrogen gas can react with hydrogen gas to produce ammonia gas.
      i) Write the balanced chemical equation for the reaction. [2 marks]

      ii) Calculate the volume of hydrogen gas needed in this reaction if 300 $cm^3$ of nitrogen gas used. [2 marks]

**Figure 1.** Algorithmic question.
**Source:** Elaborated by the authors.

All students were able to answer question numbers for (a), 1(b), 1(d)(i) and 1(d)(ii). However, only 14 students can answer question number 1(c) correctly. Most of the students answered the question the same as the students' sample answers. Students' misconceptions about the types of particles because they can't differentiate between atom, molecule and ions. Plus, this misconception also occurs due to students unable to master the chemical formula (Chophel, 2022). **Box 1** show the sample students answers for question 1(c).

**Box 1. Sample students' answer for question 1(c)**

***Student 1:*** $N(NH_3) = 0.0125 \times 6.02 \times 10^{23} = 7.525 \times 10^{21}$

***Student 2:*** $N = 0.0125 \times 6.02 \times 10^{23} = 7.525 \times 10^{22}$

**Source:** Elaborated by the authors.

## 3.2 Students' level of achievement in conceptual problem

Secondly, for conceptual problem questions, 83.3% of the students scored a high level of achievement between 40 to 100 marks. Only 16.7% of students scored a low level of achievement (0 to 39%). From these findings, we can conclude that most students can solve conceptual problems. For this section, four questions were provided based on the information in **Fig. 2**.

Table 1 shows information of three different acids.

| Acid | Degree of ionisation in water | Basicity |
|---|---|---|
| P | High | Monoprotic |
| Q | High | Diprotic |
| R | Low | Monoprotic |

Table 1

Based on table 1

(i) What is meant by acid? [1 mark]

(ii) State the ion that enables an acid to show its acidic properties [1 mark]

(iii) Name acid P and acid Q [2 marks]

(iv) Acid P and acid Q have the same concentration. It was found that the pH value of acid P is lower than acid R. Explain why the pH value of both acids are different. [3 marks]

**Figure 2.** Question for the conceptual problem.
**Source:** Elaborated by the authors.

The main findings of this research reveal several important aspects of students' understanding and misconceptions in chemistry. First, all students were able to successfully answer the first question [2(i)]. It demonstrates that they are familiar with the basic concept and can effectively elaborate on it. This indicates a strong foundational knowledge in this area, suggesting that the initial teaching strategies or prior exposure to similar questions have been effective. However, the second question [2(ii)] exposed a misconception among students, with one student incorrectly identifying $OH^-$ ion instead of $H^+$ ion. This mistake likely stems from confusion between different types of ions or a lack of understanding of their charges, highlighting a common issue in chemistry education where students may confuse similar concepts.

For the third question [2(iii)], many students answered correctly but some responded with chemical formulas (e.g., HCl, $H_2SO_4$) instead of the full names of the acids. This finding suggests that while students can recall chemical formulas, they may struggle with translating this knowledge into the required format, such as using the full chemical names. This points to a gap in instruction regarding the importance of chemical nomenclature. The final question [2(iv)] proved to be the most challenging, with many students unable to correctly address all three required points. This difficulty indicates that while students may grasp individual concepts, they struggle to synthesize these concepts into solving more complex, multi-step problems. This highlights a potential area where additional instructional support or practice might be necessary. **Box 2** shows the sample students answer for question [2(iv)].

**Box 2. Sample students' answer for question 2(iv)**

***Student 1:*** This is because acid P is strong acid that its degree of ionization in water is higher than acid R, hence its pH value is lower.

***Student 2:*** The pH of R will be lower as the degree of ionization of R in water is lower, it only partially dissociates in water. Thus, the pH of R will be lower.

***Student 3:*** The pH value of both acids is different because acid P is strong acid which can dissociate fully while acid R is weak acid which can only dissociate partially. Thus, pH value of acid R is higher than acid P.

***Student 4:*** Because acid P is monoprotic acid.

**Source:** Elaborated by the authors.

To score all the points, students must state that acid P ionizes completely in water to produce a high concentration of hydrogen ions. Next, they also need to mention that acid R ionizes partially in water to produce low concentrations of hydrogen ions. Then, summarize them in a sentence such as the higher the concentration of hydrogen ions, the lower the pH value. This question allowed teachers to analyze the students' conceptual understanding and their skills in elaboration. Based on the answers given by the students, there were slight misconceptions detected in explaining the topic.

These findings contribute uniquely to the existing knowledge in chemistry education by providing insights into specific areas where students commonly experience confusion, such as ion identification and the translation of chemical formulas into names. This research underscores the importance of not only testing students' knowledge but also their ability to apply that knowledge in various forms, suggesting a need for more comprehensive instructional strategies that address these issues. Additionally, the study highlights the significance of assessment design in capturing students' true understanding and the necessity of teaching students how to navigate between different representations of chemical knowledge. Overall, this research offers valuable implications for refining educational practices in chemistry, aiming to enhance student understanding and performance.

### 3.3 Students' level of achievement in open-ended problems

Based on the results in Table 6 above, regarding the students' achievement level in solving open-ended problems, only 11.90% of the students achieved high-level marks, indicating that they are able to answer open-ended problems effectively. However, 78.60% of them were unable to solve open-ended chemistry problems. Open-ended questions not only allow teachers to assess their students' level of knowledge, but they also help students strengthen fundamental abilities like observation, analysis, and inference, as well as their creative potential in several contexts. Divergent thinking is associated with open-ended questions that permit multiple correct responses and various solution strategies. Open-ended questions also require students to construct unrestricted responses.

Polymeric which frequently seen in day-to-day life is also one of the chemistry topics that has a high volume of the notion of a low level of concept mastery (Hill, 2020). In addition, the majority of teachers disregarded the development of students' comprehension of polymer concepts. Regarding this research, Fig. 3 shows the question of open-ended problems. It consists of two sub-questions, which are about polyvinyl chloride or vinyl (PVC), and this question primarily assesses mastery of factual knowledge rather than higher-order skills. PVC is a type of polymer in which chlorine contains more than 50% of the total component by weight. According to Osama, *et al*. (2020) research, it is made through the polymerization of the vinyl chloride monomer. In Malaysia, the current curriculum, which is the Secondary School Standards-based Curriculum (KSSM), includes polymer as one of the topics in the Form Five Chemistry subject syllabus.

3. Polyvinyl chloride (PVC) is a synthetic polymer commonly used in the production of water pipes. However, the use of PVC in water pipe manufacturing also has implications for the environment.


diagram 1

a) Explain the importance of using PVC in the manufacture of water pipes. [4 marks]

b) Explain how PVC can cause environmental pollution. Suggest on ways to solve this problem. [ 6 marks]

**Figure 3.** Open-ended question.
**Source:** Elaborated by the authors.

The main findings of this research indicate significant gaps in students' understanding and ability to articulate key concepts related to the composition and environmental impact of PVC (polyvinyl chloride). When faced with open-ended questions, many students were able to identify key points but failed to elaborate on them in detail. This lack of detailed explanation suggests that while students may have some surface-level understanding, they do not possess the deeper comprehension required to thoroughly explain the concepts. Furthermore, a considerable number of students provided incorrect answers, indicating that they have not yet mastered this essential topic, which is particularly concerning given the relevance of the compounds discussed to their everyday lives.

Specifically, question 3(a) asked students to state and explain the importance of using PVC in the manufacture of water pipes. The achievement levels of students were varied. This question, contributing 4 marks, revealed that while some students could state the importance of PVC, they struggled to provide a detailed explanation, further highlighting their limited understanding. Table 7 shows the level of students' achievement for question 3(a).

**Table 7.** The level of students' achievement for question 3(a).

| Level of Achievement | Explanation | Sample Students' Answer |
|---|---|---|
| Excellent *[4 marks]* | Demonstrates a comprehensive understanding of the importance of PVC in water pipe manufacturing, providing detailed explanations and mentioning multiple benefits. | *S9. PVC is vital for water pipe manufacturing due to its durability, corrosion resistance, cost-effectiveness, lightweight design and smooth flow. PVC pipes are long-lasting, resistant to corrosion and can withstand various temperature and pressure. They are lightweight, easy to handle and reduce transportation and labor costs. The smooth inner surface minimizes friction losses and prevents scaling or blockages.* |
| Adequate *[2-3 marks]* | Provides some relevant points and explanations, highlighting the durability, corrosion resistance, cost-effectiveness, and other advantages of using PVC in water pipe manufacturing. | *S4. The importance of using PVC in the manufacture of water pipes is that it pressures drinking water quality due to their high degree of inertness and resistance to corrosion.*<br>*S5. PVC is a waterproof, isolator in heat and electric. So, it can be used as waterpipes. PVC is not degradable, so it can be using a long time and need not be replaced, PVC manufacturing is low-cos.t* |
| Limited *[1 mark]* | Provides limited or brief explanations, mentioning a few characteristics or properties of PVC without further elaboration. | *S2 & S3. PVC plastic is corrosion, resistance and chemical-resistant.*<br>*S6. Stable polymer doesn't break easily. can be used for a long time*<br>*S7. Structure of PVC plastic is stable it doesn't dissolve in water and it is an insulator of heat and electric*<br>*S8. PVC is durable and stable, easy to change in shape*<br>*S10. PVC helps to ensure energy and water by creating virtually leak-free pipes that are not corrosion and resist environmental stress*<br>*S26 & S28. PVC is chemically stable and does not easily corrode. It is easy to be shaped.*<br>*S29. PVC plastic is corrosion-resistant and chemical resistance*<br>*S35. PVC pipes are durable, as the expected lifespan is 100 years or more.*<br>*S42. The expected lifespan of a PVC pipe is 100 years or more for underground pipes. Besides, PVC water mains show a much lower failure rate than non-plastic materials. PVC pipes are safe and durable* |
| Incomplete *[0 mark]* | It does not provide an answer or explanation for the importance of using PVC in water pipe manufacturing | *S1. PVC is a polymerized substance. It has a better characteristic than other substances. It is more suitable for the manufacture of water pipes.*<br>*S11. No idea*<br>*S21. It is a high-strength thermoplastic material* |

**Source:** Elaborated by the authors.

Question 3(b) required students to explain how PVC can cause environmental pollution and suggest solutions. Table 8 shows the level of students' achievement for question 3(b) where it shows students faced even greater challenges. This question, contributing 6 marks, not only tested their knowledge of PVC's environmental impact but also their ability to propose practical solutions. The results indicated that students are not only struggling with the basic comprehension of the material but also with applying their knowledge to broader environmental contexts.

Based on Table 7 and 8, students' answers have already been arranged according to the level of students' achievement, which is excellent, adequate, limited and incomplete. This research found that most of the students can only achieve a level of limited and incomplete. Thus, the result shows that students not yet achieve the skill in open-ended questions. To overcome this ineptness, effective strategies must be implemented to ensure that students grasp the concept and are able to think critically and creatively (Black, 2018).

**Table 8.** The level of students' achievement for question 3(b).

| Group | Explanation | Sample Students' Answer |
|---|---|---|
| Excellent *[4-6marks]* | Shows a comprehensive understanding of how PVC can cause environmental pollution, mentioning harmful chemicals, additives, and toxic substances associated with PVC production, use, and disposal. They also suggest several solutions to address the problem. | *S5. PVC is a kind of plastic, it is not degradable, and it needs a variety of processes to decompose PVC, so, if the PVC is disposed of it will cause pollution. Besides, when PVC is decomposed it will release toxin gas that also causes air pollution. To solve this problem, we can use degradable materials like plant base to manufacture water pipes to replace PVC.*<br>*S9. PVC can cause environmental pollution through its production, use and disposal hazardous chemicals and additives used in PVC manufacturing can harm the environment. Improper disposal and incineration release toxic substances and microplastics, posing risks to ecosystems and human health. solution include sustainable manufacturing practices, PVC alternatives without harmful additives, improved recycling technologies, proper waste management, responsible consumption and reducing plastic waste at the source.* |
| Adequate *[3 marks]* | Mentions relevant points about how PVC can cause pollution, such as recycling difficulties and the release of harmful substances. However, their suggestions for solving the problem are limited or lack detailed explanations. | *S2. PVC release many harmful chemicals. PVC is difficult to recycle and it will remain in the environment for a long time. We should use recycled bags to replace PVC.*<br>*S3. PVC is a stable polymer. It takes such a long period to disintegrate. The discarded PVC will accumulate and end up present in a large amount of unwanted trash that will cause environmental pollution. using natural rubber or latex as an alternative of PVC.*<br>*S4. If PVC is landfilled, it leaches toxic addictive and releases toxin. To solve this problem, recycle PVC and reduce the usage of PVC.* |
| Limited *[1-2 marks]* | Provides incomplete or brief explanations, mentioning some characteristics or properties of PVC without further elaboration. | *S1. The production of PVC is not eco-friendly because it releases many harmful chemicals. Besides PVC is difficult to recycle and it will remain in the environment for a long time.*<br>*S7. Releasing the manufacture of PVC plastic. Use other eco-friendly materials. PVC is hard to dissociate. So, it is hazardous to the environment.*<br>*S10. The process of making PVC is harmful for the environment. It releases huge amounts of toxic chemicals into the environment. Discharged pollutants impact nearby drinking water supplies. Using natural rubber and latex be alternative to PVC.* |
| Incomplete *[0 mark]* | Does not provide an answer or explanation about how PVC can cause environmental pollution or suggestions to solve the problem. | *S6. –*<br>*S8. PVC is a polymer. It is a stable molecule and it can last for a long time. recycle used PVC to make new products.* |

**Source:** Elaborated by the authors.

## 3.4. Comparison of students' achievement in solving algorithm, conceptual and open-ended problems

Table 9 shows the minimum score (min), maximum score (max), mean and standard deviation of algorithmic, conceptual and open-ended questions. In algorithmic questions, the minimum score achieved by students is two out of ten, while the maximum score achieved by students is ten out of ten. The mean scores of students in algorithmic questions are 8.00, while the standard deviation of algorithmic questions is 1.87. In conceptual questions, the minimum score achieved by students is three out of ten, while the maximum score achieved by students is seven out of ten. The mean value of conceptual questions score among students is 5.60, while the standard deviation of algorithmic questions is 1.13. In open-ended questions, the minimum score of students is zero out of ten, and the maximum score of students is eight out of ten. The mean value of open-ended questions among students is 3.36, while the standard deviation of open-ended questions is 1.75.

**Table 9.** The minimum score, maximum score, mean and standard deviation of algorithmic, conceptual and open-ended questions.

| | N | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Algorithmic | 42 | 2.00 | 10.00 | 8.00 | 1.87 |
| Conceptual | 42 | 3.00 | 7.00 | 5.60 | 1.13 |
| Open-ended | 42 | 0.00 | 8.00 | 3.36 | 1.75 |

**Source:** Elaborated by the authors.

Figure 4 shows the level of students' achievement in algorithmic questions, conceptual questions, and open-ended questions. Four students scored low marks on algorithmic questions. 38 students scored high marks in algorithmic questions. Seven students scored low marks on conceptual questions. 35 students scored high marks in conceptual questions. 33 students scored low marks in open-ended questions. Five students scored high marks on open-ended questions.

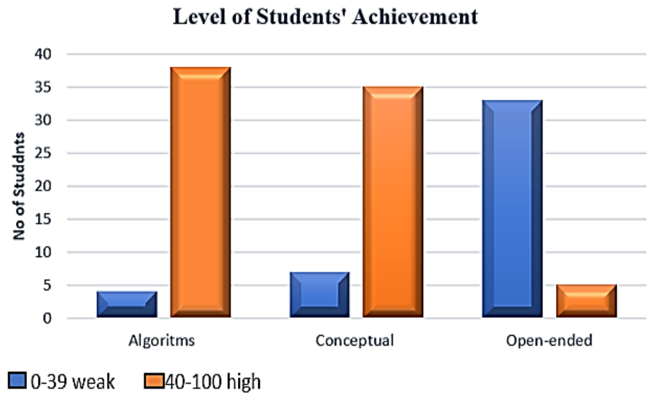


**Figure 4.** Level of students' achievement in algorithmic questions, conceptual questions, and open-ended questions.
**Source:** Elaborated by the authors.

Students are considered to have high marks for a particular type of question if they score between 40 to 100 marks, and low marks if they score between 0 and 39 marks. Among algorithmic, conceptual, and open-ended questions, it is evident that students faced the most difficulty with open-ended questions, as the mean of students' achievement in this category is the lowest.

Students tend to perform better on algorithmic questions because these questions typically require the application of a well-defined set of steps or procedures to arrive at a correct answer. The structured nature of algorithmic questions allows students to follow a clear path to the solution, reducing the cognitive load required to generate an answer. For example, in chemistry, algorithmic questions might involve calculating molar concentrations or balancing chemical equations, which are tasks that students can practice and master through repetition. Algorithmic questions often have a "yes" or "no" answer, or a specific numerical result, making them easier for students to tackle, especially those with lower proficiency (Csernoch *et al.*, 2021).

On the other hand, conceptual questions demand a deeper understanding of the underlying principles of chemistry. These questions test students' ability to apply their knowledge to new situations, requiring them to connect different concepts and think critically. While conceptual questions do not always have a straightforward answer, they still often involve a more guided thought process compared to open-ended questions. Students may struggle with these questions if they lack a strong foundational understanding or if they are not accustomed to applying concepts in varied contexts.

Open-ended questions, however, are the most challenging for students, as they require the generation of original responses based on the student's understanding and interpretation of the concepts learned. These questions do not have a simple "yes" or "no" answer; instead, they require students to express their opinions, synthesize information, and articulate their thought processes in a detailed manner (Komildjanovna, 2024). They often require a longer, more elaborated response, such as a paragraph or essay, which can be daunting for students, especially those with lower language proficiency or less confidence in their understanding of the material.

The difficulty in mastering open-ended questions lies in the need for students to not only recall information but also organize and communicate their reasoning effectively. As Nedjat-Haiem and Cooke (2021) noted, while students are encouraged to provide as much detail as possible, they often struggle to align their responses with the expected answers. This discrepancy might be due to a lack of practice in structuring their thoughts or a limited ability to apply their knowledge in a less structured, open format. Moreover, open-ended questions often assess higher-order thinking skills, such as analysis, synthesis, and evaluation, which can be challenging for students who have primarily been trained in rote memorization or procedural problem-solving.

To strengthen the research findings, it is essential to incorporate insights from the respondents' interviews. **Table 10** shows the response from five students via interview.

**Table 10.** The respondents' interviews.

| Student | Response |
|---|---|
| Student 1 | Algorithmic problems: "I like algorithmic questions since I can solve them step-by-step. They are straightforward, and I usually score well."<br>Conceptual problems: "Conceptual questions challenge me because I need to think deeply. If I don't have a solid grasp of the concept, I feel lost."<br>Open-ended problems: "Open-ended questions are the worst for me. I feel over helmed by having to come up with my own answers. I often write too little or get confused about what to include." |
| Student 2 | Algorithmic problems: "I find algorithmic questions the easiest because they follow a clear procedure. I can memorize the steps and practice them, which makes me feel confident."<br>Conceptual problems: "Conceptual questions are harder. I struggle to connect the ideas and apply them to new situations. Sometimes, I don't understand what the question is asking."<br>Open-ended problems: "Open-ended questions make me anxious. I don't know how to start or what to write. I worry about not being detailed enough." |
| Student 3 | Algorithmic problems: "Algorithmic questions are like puzzles; I enjoy solving them. I feel like I can rely on my skills and knowledge here."<br>Conceptual problems: "Conceptual questions require me to think critically, which is tough. I need more practice relating different concepts."<br>Open-ended problems: "I find open-ended questions intimidating. I can't express my thoughts clearly, and I'm afraid of getting it wrong since there's no right answer." |
| Student 4 | Algorithmic problems: "I perform best in algorithmic questions. The rules are clear, and once I learn them, I can apply them easily."<br>Conceptual problems: "Conceptual questions are tricky for me. Sometimes I can answer them if I remember the class discussions, but it's not always easy."<br>Open-ended problems: "I struggle with open-ended questions. I want to provide detailed answers but often end up writing less because I can't think of what to say." |
| Student 5 | Algorithmic problems: "I feel comfortable with algorithmic questions. They help me focus on calculations, which I'm good at."<br>Conceptual problems: "Conceptual problems make me think differently, and that can be hard. I wish we practised these more."<br>Open-ended problems: "Open-ended questions are challenging because they require creativity and articulation. I feel like I need more guidance on how to approach them." |

**Source:** Elaborated by the authors.

From the response in Table 10, it is obvious that students expressed a sense of confidence with algorithmic problems due to their structured nature and clear procedures. Most felt they could master these through practice because they managed to answer the questions based on memorized procedures. Students generally found conceptual questions more challenging, often requiring a deeper understanding and connection of ideas, which they felt was lacking. Students managed to answer the questions only when they successfully related the concepts learned to real-life examples discussed in class. However, when it comes to open-ended questions, there was a consensus that open-ended questions were the most daunting. Students reported feelings of anxiety, confusion, and difficulty in articulating their thoughts, indicating a need for more practice and support in this area.

The main limitations of this research include potential sample size issues, where a small or non-representative group may limit the generalizability of the findings to a broader population (Hennink and Kaiser, 2022). Differences in problem difficulty, where algorithmic tasks might be easier or more familiar to students, can skew results, making it harder to assess true differences in problem-solving abilities. The influence of teaching methods, time constraints, and subjective grading of open-ended problems may also affect performance, leading to potential biases (Carpenter *et al.*, 2020). Moreover, factors such as student motivation, and prior knowledge may influence outcomes across problem types. It leads to complicated interpretations of their true achievement levels in algorithmic, conceptual, and open-ended problem-solving (Vo *et al.*, 2024).

In conclusion, the differences in student achievement across question types highlight the distinct cognitive demands each type imposes. Algorithmic questions were usually more procedural and accessible for students as they involved familiar steps and methods. While, open-ended questions require independent synthesis and expression of knowledge, which can present greater challenges (Broman, 2020). This indicates that students may struggle with the cognitive load and self-directed thinking needed for open-ended questions. Examining specific difficulties, such as challenges with critical thinking, applying concepts to new situations, or organizing responses, could yield valuable insights (Tornee *et al.*, 2019). By further analyzing these issues through interviews or targeted feedback, this research could pinpoint key areas where support is needed, informing interventions to strengthen students' problem-solving and critical thinking skills in Chemistry.

## 4. Conclusions

In summary, this study underscores the importance of strengthening students' conceptual understanding of chemistry and creating a curriculum that fosters balanced problem-solving skills through algorithmic, conceptual, and open-ended questions. The results suggest that KSSM assessments should incorporate more conceptual and open-ended questions to encourage students to not only grasp theoretical knowledge but also apply it to real-life scenarios. Additionally, the study emphasizes collaborative efforts between teachers and students to cultivate a problem-solving culture in the classroom, where teachers support a student-centered learning environment and provide academic guidance for students in need. Teachers are encouraged to explore diverse instructional approaches to enhance students' problem-solving abilities. By building a framework that promotes scientific creativity and problem-solving skills through these methods, it is anticipated that students will develop a deeper appreciation for chemistry and its applications in everyday life.

## Authors' contribution

**Conceptualization**: Johari Surif; **Data curation**: Wan Nor Azlina Wan Abdullah; Syaida Ab Manaf; **Formal Analysis**: Wan Nor Azlina Wan Abdullah; Syaida Ab Manaf; **Funding acquisition**: Not applicable; **Investigation**: Wan Nor Azlina Wan Abdullah; Syaida Ab Manaf; Yam Pui Mun; **Methodology**: Yam Pui Mun; **Project administration**: Nor Hasniza Ibrahim; Abdul Hadi Bunyamin; Chee Ken Nee; **Resources**: Not applicable; **Software**: Not applicable; **Supervision**: Nor Hasniza Ibrahim; **Validation**: Nor Hasniza Ibrahim; **Visualization**: Yam Pui Mun; **Writing – original draft**: Wan Nor Azlina Wan Abdullah; Syaida Ab Manaf; **Writing – review & editing**: Wan Nor Azlina Wan Abdullah; Syaida Ab Manaf.

## Data availability statement

All data sets were generated or analyzed in the current study.

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## Conflict of interest

The authors declare that there is no conflict of interest.

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