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# Strengthening Problem-Solving Skills in Balancing Chemical Equations through Scaffolding Framework

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**Abstract**
In this paper, the researcher examined the effectiveness of the Algebraic Expression Method, within a scaffolding framework, in strengthening Grade 11 students' problem-solving skills for balancing chemical equations. The study's ultimate objective was to determine whether this structured, mathematics-integrated approach could improve procedural fluency, conceptual understanding, and student confidence compared with the trial-and-error method. Based on Cognitive Load Theory (CLT), the study posited that the algebraic method reduces heavy cognitive load while enhancing germane cognitive processing, thereby promoting deeper and more meaningful learning.
The study used a quasi-experimental research design to analyze pre-test and post-test measures and a 5-point Likert scale. 35 Grade 11 STEM students from Valenzuela National High School were the respondents of the study. Quantitative results showed that post-test performance had significantly improved, indicating substantial learning gains. These results only show that the algebraic method is a systematic, logical, and highly effective way to reduce difficulty and improve confidence.
The Algebraic Expression Method, through a scaffolding framework, indeed enhances both the cognitive and affective dimensions of learning, as this study confirms. It effectively bridges mathematical reasoning and conceptual understanding, leading to improved procedural accuracy, conceptual depth, and learner motivation.
In conclusion, this study found that the algebraic approach, used as structured, scaffolded instruction, can significantly strengthen learners' problem-solving skills in balancing chemical equations. And the paper recommends adopting this method for teaching the particular topic in chemistry, as well as for curriculum development. With this, senior high school learners will be able to gain confidence and a higher level of mastery of concepts and competencies.

**Keywords:** Algebraic Expression Method, Cognitive Load Theory, Scaffolding, Problem-Solving Skills, Chemistry Education

## Chapter 1

### Background of the Study

Balancing chemical equations is a fundamental topic in chemistry and is generally considered one of the most challenging for conceptual understanding and procedural skills, as it requires more than just rote memorization. This particular competency requires higher-order thinking skills to coordinate symbolic representations, apply mathematical reasoning, account for particle-level changes, and maintain the conservation of mass. These are all done at the same time. That is why, even after a thorough discussion, students still guess at the coefficients to apply and resort to trial and error until they balance a chemical equation correctly. This leads to reduced understanding and performance of the procedure due to process errors.

A study by Hamerska et al. (2024) showed that some students remembered certain balancing rules, but only a few could complete the full task correctly. Success rates reported in the literature range from 50% to 100%. However, getting it fully right was uncommon, suggesting that students struggle to integrate the symbolic, macroscopic, and submicroscopic levels of chemical knowledge. Things that are usually communicated to students are not reflected in their performance. The findings are consistent with the 2022 Program for International Student Assessment (PISA), which found that only one in four 15-year-olds worldwide can score at least 25 points below the baseline in science, maths, and reading. Not only that, the mean score in mathematics fell by 15 points over 2018, and that is equivalent to three-quarters of a year of learning. That reflects widespread difficulties in algebraic reasoning, which is the key to balancing chemical equations. (OECD, 2023)

Another recent study demonstrated the effectiveness of a face-to-face classroom intervention in improving Grade 11 STEM students' ability to balance chemical equations in a Philippine science classroom. This study used particulate drawings and inquiry-based worksheets as a guided-inquiry pedagogical intervention to improve students' conceptual understanding and confidence in balancing chemical equations. This resulted in a significant improvement in students' conceptual understanding. After the intervention, the post-test scores showed substantial gains compared to pre-test performance. It was also found that there is a statistically significant positive relationship between students' conceptual understanding and confidence after the intervention ($r = .469$, $p = .004$), indicating that as students' understanding improved, their confidence in balancing chemical equations increased. Apart from that evidence, qualitative responses also showed that students found the face-to-face intervention helpful because the guided classroom activities, teacher facilitation, and immediate feedback made the lesson easier to understand and more engaging. These findings suggest that when structured, teacher-guided interventions are delivered in face-to-face settings, they can effectively address students' learning difficulties in balancing chemical equations and enhance both their performance and confidence in Chemistry (Verangel & Prudente, 2022).

The inspection method and the algebraic method are two distinct approaches in teaching balancing chemical equations. A study by Udawat et al. (2021) reported that, compared with the algebraic method, the inspection method is not a systematic approach because students tend to guess and resort to trial and error until they arrive at a balanced equation. Unlike algebraic expressions, it follows a step-by-step, logical, and structured procedure to balance equations correctly, from simple to complex reactions. In terms of this method, Gaussian elimination is used to solve linear equations. Gaussian elimination, being a mathematical tool, can structurally solve for exact, correct values to balance the equation. Since these concepts are taught at the secondary level, it is very helpful to integrate the algebraic expression method for balancing chemical equations, as it is structured, logical, and accurate, which can lead to greater proficiency in these skills and greater confidence in dealing with the topic and performing the competency.

The researcher has conducted a study to examine the relationship between the use of the Algebraic Expression Method as an instructional intervention (independent variable) and cognitive and affective learning outcomes (dependent variable). The Algebraic Expression Method, as proposed in this paper, is a systematic way of balancing equations that provides a guided, step-by-step, logical procedure, leading to the exact coefficient value rather than relying on trial-and-error strategies.

One of the dependent variables studied was the cognitive aspect, which involves the procedural and conceptual understanding of balancing chemical equations, where the learners' ability to perform the balancing procedures and apply the concepts of the Law of Conservation of Mass, as well as the relationship between the reactants and products, is measured. Another dependent variable studied by the researcher concerned the affective aspect, including students' attitudes, confidence, and perceptions toward balancing chemical equations. The reason for examining the affective lens was that learners often develop low academic confidence when they consistently encounter difficulty solving chemistry problems. This may further lead to a loss of interest in the subject matter. With that accounted for, the researcher proposed an instructional intervention in this paper that provides systematic problem-solving and positive experiences to address students' cognitive and affective aspects toward the subject matter.

Students are often misled by misconceptions when balancing equations due to a shallow conceptual understanding. Studies by Hamerska et al. (2024) and Ogundidji (2024) consistently described that the confusion on the distinction between atoms and molecules and distinguishing between coefficients and subscripts is a consistent pattern of errors that causes students to fail to apply the Law of Conservation of Mass and tend to only focus on the product part of the equation instead of considering the whole reaction. What is alarming here is that it remains a persistent problem even after years of teaching.

Problem solving in chemistry is not only about arriving at the correct answer but also about applying the right approach to achieve it, such as using heuristics. Apparently, although heuristics are significant in instruction, particularly for analyzing chemical concepts, previous studies have reported that they are not systematically and properly incorporated into classroom teaching, which is why students are not taught how to develop and apply these strategies in problem solving. Unfortunately, this gap led to a missed opportunity to strengthen students' problem-solving skills in chemistry.

Science education is not merely about helping students memorize concepts; it must also help them develop and enhance their problem-solving skills. In balancing chemical equations, it is not enough to apply a procedure to solve the equation; it must be grounded in learners' correct understanding of the underlying concept for them to process it and have a clear direction to arrive at a correct answer. However, despite repeated, thorough classroom instruction, many students still rely on crash trial-and-error because they are unsure where or how to begin. From that, they struggled to understand more advanced concepts such as coefficients and subscripts, and especially the Law of Conservation of Mass.

Recent studies suggest that many students can work with chemical symbols and compounds but do not fully understand what they represent, especially when used in equations. That is why students may be able to correctly balance some equations but do not really understand what they are for or how balancing works, indicating that balancing chemical equations is consistently difficult for many students. Considering these findings, there is an undeniable need to use an alternative instructional intervention to develop students' reasoning and understanding rather than having them memorize procedures to arrive at a correct answer. (Jammeh et al., 2023). Structured approaches like the algebraic method indeed show promise, but there is still a gap to be addressed: how to effectively implement them to bridge the gap between procedural success and meaningful understanding. Having said that, well-designed pedagogical strategies that promote both accuracy and scientific reasoning are required to address this.

With all these factors accounted for, this study aimed to examine the effectiveness of an instructional intervention based on an algebraic expression method in enhancing Grade 11 students' ability to balance chemical equations. Specifically, it investigated how a structured, equation-based approach can improve their procedural accuracy and problem-solving strategies.

## Theoretical Framework

The foundation of this study is rooted in Cognitive Load Theory (CLT). CLT provides a framework for understanding how instructional design impacts learning. This is developed by the educational psychologist John Sweller, CLT posits that learning will be effective if instruction minimizes extraneous cognitive load the mental effort required to process information not directly relevant to learning to allow a student's limited working memory to focus on constructing knowledge schemas, which are organized mental structures or frameworks that help learners store, retrieve, and apply information more efficiently(Sweller,2024). The algebraic method aligns with Cognitive Load Theory by minimizing the extraneous load associated with the trial-and-error approach of traditional inspection methods by translating the balancing task into a well-structured set of linear equations. It tends to provide a clear, step-by-step procedure guiding students throughout the process. Also, this reduces ambiguity, limiting the need for guesswork and allowing learners to focus their cognitive resources on understanding the relationships between reactants and products. With that, offering a structured approach allows students to focus on understanding the law of conservation of mass rather than being overwhelmed by unstructured problem-solving. By reducing unnecessary mental effort, this structured support enables germane cognitive load to take over, allowing students to focus purely on understanding the lesson rather than spending most of their time guessing or figuring out where to begin. With that, as they gain a meaningful understanding of the foundational concept, they can make sense of it and apply it during the balancing process to solve problems correctly. This process not only promotes deeper understanding but ultimately enables students to organize their knowledge more effectively, make sense out of it, and apply what they have learned, enhancing their problem-solving skills (Timothy et al., 2023).

## Conceptual Framework

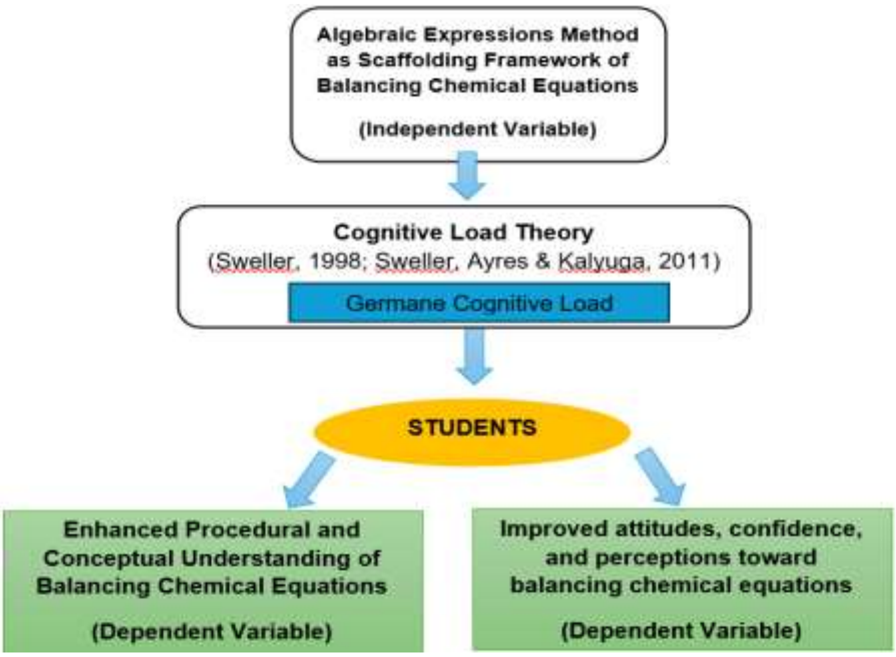


**Figure 1. Conceptual Framework for Strengthening Problem-Solving Skills in Balancing Chemical Equations**

The framework above shows that the Algebraic Expressions Method is the main instructional intervention proposed by the researcher as the independent variable, serving as a scaffolding framework for balancing chemical equations by providing a guided, structured, step-by-step procedure. Using this intervention reduces the mental effort of learners and directs their focus on understanding the foundational concept of balancing, which is the Law of Conservation of Mass, so that they can properly apply their learning to problem-solving. Instead of resorting to trial and error and navigating through guesswork. Demonstrating the lesson this way helps learners accurately balance chemical equations and achieve both fluency in balancing skills and conceptual understanding.

Cognitive Load Theory by Sweller (2024) specifically, the germane Load Theory is the core foundation of the implementation of the intervention Algebraic Expressions Method. This explains that students can learn and process information more effectively when their mental effort is reduced and directed toward understanding the lesson's concepts and core ideas, rather than diverting their focus to unnecessary workloads, which can lead to difficulties during the learning process. Integrating this principle at the core of Algebraic Expressions Method, as an intervention navigating within a scaffolded framework, it replaces the trial and error method with clear, structured, and easy-to-follow procedures in balancing, which allow students to focus their attention on understanding and making sense as to why each step is necessary instead of guessing their way to come up with every coefficient that would balance the chemical equation. As a scaffolding framework, it channels students' mental effort toward germane cognitive load, or the productive cognitive processing associated with schema construction, conceptual understanding, and procedural mastery.

The Algebraic Expressions Method reflects this theory by improving how students process and organize their learning. Rather than mere guesswork, students are guided through a sequence of structured variable identification, construction of algebraic relationships, systematic solving, and verification of results. Scaffolded process, then supports the development of organized mental schemas related to balancing chemical equations, particularly in applying the Law of Conservation of Mass and understanding the relationship between reactants and products. Through this framework, the Algebraic Expressions Method greatly helps students balance chemical equations in a more organized and meaningful way by guiding learners through each step of the process, leading to an exact, correct answer.

The researcher drew the dependent variables through the lens of both cognitive and affective aspects of the learning outcomes, where the cognitive aspect involves the manner in which the students perform and demonstrate balancing skills and understand the concepts or lessons behind it, specifically the Law of Conservation of Mass, in order to apply their learning in the process, as well as demonstrating the relationship between reactants and products. Another variable is wound up around the affective learning outcome, as it encompasses students' attitudes, confidence, and perceptions toward balancing chemical equations. Mirroring these variables, the Algebraic Expressions Method provides systematic problem-solving procedures that lead to a positive learning experience, satisfying both cognitive and affective learning outcomes among students with respect to the subject matter.

**Statement of the Problem**

This study aimed to determine the effectiveness of the Algebraic Expression Method in strengthening Grade 11 students' problem-solving skills for balancing chemical equations. The investigation sought to assess quantitative learning gains in students' understanding and attitudes resulting from the intervention. Specifically, this study sought to answer the following research questions:

1. What is the level of performance of Grade 11 students in balancing chemical equations before and after the application of the algebraic expression method?
2. Is there a statistically significant difference between the pre-test and post-test performance of the students?
3. To what Extent do students perceive the Algebraic Expression Method in terms of:

3.1 Its level of difficulty
3.2 Its usefulness in learning chemistry
3.3 Its impact on their confidence in solving chemical equations

4 How can a video instructional material on balancing chemical equations using the Algebraic Expression Method be developed based on the findings of the study to support students' learning and teachers' instruction?

**Hypotheses**

*$H_0$:* There is no significant difference between the pre-test and post-test performance of the students after application of the Algebraic Expressions Method as a form of scaffolding framework.

**Scope and Delimitation of the Study**

This study sought to determine the effectiveness of the algebraic expression method, as a pedagogical strategy within a scaffolding framework, in strengthening Grade 11 students' problem-solving skills for balancing chemical equations. Focusing on that goal, the researcher examined how the intervention affected the 35 Grade 11 STEM students' understanding of the procedures and concepts, as well as their attitudes toward the topic in chemistry, over the school year 2025 – 2026 at Valenzuela National High School.

A quasi-experimental design was used in this study to determine the effectiveness of the Algebraic Expressions Method to improve problem-solving skills among learners in balancing chemical equations. To proceed with this study, the researcher administered pre- and post-tests to assess learning before and after the intervention. Just after that, students answered a Likert scale to help the researcher determine whether there were changes in their confidence and perceptions regarding balancing chemical equations. The researcher decided to use this design because many students consistently struggle to balance chemical equations, resorting to guesswork and trial and error rather than focusing on the underlying concepts. This challenge was addressed by introducing an alternative intervention, the Algebraic Expressions Method, a structured approach that integrates mathematical skills into the subject matter, helping students connect mathematical knowledge to scientific reasoning and make balancing chemical equations easier through a step-by-step procedure.

The study recognized various limitations in its interpretation of the findings, including that the results are only applicable to the Grade 11 STEM students of Valenzuela National High School, who were the primary respondents. With that, the results and findings of this study may not apply to other groups due to differences in characteristics. Apart from that, as proposed in this study, the only intervention studied is the Algebraic Expressions Method. It did not intend to compare and study other systematic methods in balancing chemical equations. It is also important to note that the researcher has no control over students' prior knowledge, study habits, previous learning experiences, or other factors that may have already influenced student learning. Most importantly, the effectiveness of the intervention was based solely on learners' post-test results; therefore, the long-term retention of the problem-solving skills developed through the intervention was not assessed in this study.

**Significance of the Study**

This study may serve a great benefit to the following group of people:

**Students.** The intervention is a great help for Grade 11 students taking General Chemistry, as it provides a systematic way to balance chemical equations rather than guessing coefficients through trial and error. And it also helps them understand the key concepts behind the process, improving their problem-solving skills and their attitudes and confidence in balancing chemical equations.

**Science Teachers.** Based on the study's significant findings, the intervention proposed in this paper may be used and adapted by science teachers as an alternative approach to balancing chemical equations, as it can make lessons easier to explain while helping learners develop a deeper conceptual understanding.

**Curriculum Developers.** The results of this study may serve as concrete evidence of the effectiveness of the proposed intervention, Algebraic Expressions Method. It can serve as a basis for improving instructional materials and teacher guides by promoting a more structured, systematic approach to teaching, balancing chemical equations, and strengthening students' problem-solving skills while deepening their understanding of the lesson.

**School Administrators.** School principals and academics can use the results of this paper to make informed decisions about teacher training and professional development programs, ensuring that their faculty are equipped with the tools needed to improve student learning outcomes in chemistry.

**Future Researchers.** This study would contribute to the existing body of literature on chemistry education and pedagogical methods, providing a foundation for other related variables in science problem solving.

**Definition of Terms**

The listed terms are defined operationally and conceptually to clarify the paper's content.

**Algebraic Expression Method.** Referring to the systematic and logical approach to balancing chemical equations using linear equations. (Udawat et al., 2021).

**Cognitive Load.** It is the total amount of mental effort being used in a person's working memory. Specifically, this paper refers to the cognitive burden experienced by students when learning to balance chemical equations using different methods (Sweller, 2024).

**Conceptual Understanding.** This is more than just procedural knowledge because it is students' ability to learn scientific principles. As in this study, this refers to students' ability to explain the connection between a balanced chemical equation and the Law of Conservation of Mass, rather than merely applying an algorithm (Nagashima et al., 2020).

**Procedural Fluency.** This accurately and efficiently performs the computational steps required to balance a chemical equation using a given method (Atanan & Saithongdee, 2024).

**Problem-Solving Skills.** In the context of this research, this is a composite skill that encompasses a student's procedural fluency in correctly balancing equations, their conceptual understanding of the underlying chemical laws, and their confidence and strategic approach(Priyadarshini & Dasgupta, 2024).

**Scaffolding Framework.** This was used in the paper as temporary, guided support for students to help them learn to balance chemical equations through a structured procedure using the algebraic expressions method. (Huang et al. (2024).

## Chapter 2

## Review of Related Literature and Studies

This chapter presents a review of the literature and studies to support the current study. This will prove and justify the relevance of the previous study. This will also present findings from various studies and synthesize them for the current paper.

**Traditional and Alternative Methods for Balancing Chemical Equations**

The traditional inspection or trial-and-error method for balancing chemical equations is often inefficient and frustrating, especially when dealing with complex reactions (Shaikh, 2023). If the procedure is done in this way, then you will be learning chemical science as if it were just an algorithm. Having said that, more systematic alternatives were developed, like the algebraic method. For instance, the algebraic method treats balancing as a linear system of equations, offering a more structured and logical approach that yields a more accurate determination of stoichiometric coefficients and enables balancing even complex chemical equations.

Even though various alternative methods have been proposed to replace trial-and-error, the problem persists because it goes beyond the method itself; students mainly struggle with the core concepts of balancing equations and applying them correctly. Zhang et al. (2024) explained that the trial-and-error method, also known as balancing by inspection, is less effective, especially for complex equations. By guessing and trying different coefficients to balance the equation, they may arrive at the correct answer, yet be completely detached from, or have no understanding of, the concepts or principles behind it.

Seeing this as a persistent challenge, the researcher proposed an alternative intervention called the Algebraic Expressions Method, which offers a more systematic approach to balancing chemical equations that treats chemical equations as a system of linear equations, allowing learners to solve the correct stoichiometric coefficient through a logical and organized procedure instead of repeatedly guessing and relying on the trial-and-error method. Due to the clear and sequential steps that this process follows, the students can focus their attention and effort on meaningfully understanding the concepts behind the topic, like the Law of Conservation of Mass and the relationship among reactants and products, which leads to improved procedural accuracy and, more definitely, a deeper understanding of the balancing concepts and process.

Yuen and Lau (2022) explicitly noted in their study that the trial-and-error method is far less effective when dealing with long, complex chemical equations. Students fail to understand the concepts and have difficulty explaining why an equation is balanced because they rely heavily on repeated guessing and adjusting coefficients, rather than applying the underlying principles. As a result, systematic substitutes have been suggested. One purely mathematical approach is the algebraic method, which evaluates balancing as a system of linear equations. This provides a systematic and logical way to calculate stoichiometric coefficients, yielding a reliable answer regardless of how complicated the reaction is, and correcting flaws inherent in the way this is currently taught.

Likewise, a study by Smith et al. (2023) found that the trial-and-error method is ineffective for solving both simple and complex equations and commonly causes frustration for students. Balancing equations using algebraic expressions offered a logical, easier approach that required minimal effort and yielded exact results.

Another study by Valenti et al. (2022) found that the algebraic expressions method is an improvement over less systematic instruction, such as the traditional trial-and-error method. Its efficiency leads to superficial understanding, and students tend to just guess the coefficient until it balances the equations. These show no sign of learning among students, both conceptually and procedurally.

The discussion by Asemani & Rezaei (2022) emphasized the limitations of the traditional insoection method for balancing chemical equations. Because if reactions are difficult, this method prevents meaningful insight into the reaction. On the other hand, the study suggested more structured alternatives, such as the algebraic expression method, as systematic or logical approaches effective for determining stoichiometric coefficients and mitigating the drawbacks of classic instruction, offering a better pathway to chemical equations.

According to the study by Isles (2020), the trial-and-error method relies on repeated adjustments rather than a systematic, logical procedure for balancing equations, which led to difficulty for students in acquiring the skill and understanding the concepts of the law of conservation of mass. Because their priority is to arrive at a correct coefficient to solve the problem through adjustments. Mohialden et al. (2023). With this, a more effective alternative exists: the algebraic expressions method, which is the most effective and logical among all methods. Viewing chemical equations as systems of linear equations offers a systematic and reliable way to determine stoichiometric coefficients, thereby overcoming the limitations of conventional teaching (Sultan et al., 2020).

It is important to recognize, however, that although the Algebraic Expressions Method provides a more structured process for balancing chemical equations, it does not automatically or perfectly guarantee that students will understand the underlying concepts, especially when misconceptions about the principles involved are present. This underscores the importance of identifying and correcting these misconceptions to develop appropriate instructional strategies that help students build a deeper conceptual understanding.

**Common Student Difficulties and Misconceptions in Balancing Chemical Equations**

Ogundidji (2024) explained that students frequently exhibit fundamental conceptual errors when learning to balance chemical equations. A common issue that arose was confusion between coefficients and subscripts, which led them to incorrectly alter chemical formulas. This indicates a misunderstanding: subscripts denote fixed compositions, while coefficients denote relative amounts of different molecules; as a result, learners are not always able to relate the balancing process to the physical law of conservation of mass. Many look at it as a math problem where we just make sure the number of atoms on both sides is equal, rather than recognizing that a balanced equation for a real reaction means that matter can’t be created or destroyed. This indicates a serious issue with their understanding of chemical reality.

According to Lishchynska et al. (2020), in basic representations of compounds in chemistry, students have notational misconceptions that lead them to confuse coefficients with subscripts. Therefore, rather than understanding that subscripts only define the fixed atomic composition of a molecule. And coefficients indicate the number of molecules; they do not change the chemical formula. Moreover, students do not make sense of the balancing process in terms of a physical law, namely, the conservation of mass, but rather treat it as a mathematical problem. This leads to a "means-end” mentality where the aim is merely to make the number of atoms equal.

A study conducted by Hin & Riddle (2023) found a prevalent misconception: confusion between coefficients and subscripts, leading to incorrect changes in chemical formulas rather than to adjustments in the number of molecules. This shows that they do not understand that subscripts indicate the fixed atomic makeup of a species (molecule), while coefficients indicate the relative amounts of molecules. Also, students often see the balancing of a reaction as a mathematical problem, which isn't linked to the law of conservation of mass. These students miss the point that a balanced equation represents a real chemical transformation in which matter is conserved, highlighting an important misunderstanding.

One of the most common challenges students encounter when balancing chemical equations is confusion about the distinction between coefficients and subscripts. There are many studies showing that the coefficients and subscripts are used interchangeably or that learners adjust the subscripts instead of the coefficients, changing the entirety of the chemical reaction, which only demonstrates their lack of knowledge and understanding about the roles of these symbols in a chemical equation (Yovanie, 2024; Zhang et al., 2024). Subscripts represent the fixed composition of a compound, while coefficients show the number of molecules in a reaction, and confusing these important elements in a chemical equation will entirely change the identity of a chemical substance.

Another misconception is that students look at balancing chemical equations as more of a mathematical task instead of a chemical process by which they only think that the primary goal is to arrive at a correct coefficient that will equal the atoms on both sides of the equation, without considering or understanding how the Law of Conservation of Mass is applied throughout the process. With this, they may arrive at a correct value, but they will have to compromise and will fail to explain how mass is conserved during the chemical reaction.

These findings reflect not only procedural errors but also gaps in conceptual understanding that cannot be rectified solely through practice drills, but require focused procedural instruction and deeper conceptual understanding that give meaning to the process, leading to a stronger foundation for students to solve equations systematically with proper reasoning.

**Scaffolding as an Instructional Framework**

Instructional scaffolding is a teaching approach where in the teacher guides the learner in every step of the way as they learn new skills or knowledge then gradually ease or reduce the support given as the learner level up or improve confidence in doing and learning the task or concept and eventually be able to complete it on their own leading to the development of both their understanding and problem solving skills more independently and with less supervision. In their meta-analysis of online learning, Doo, Bonk, and Heo identified three core features of scaffolding derived from Wood et al. (2025): (a) contingency (tailoring support to the learner's current performance), (b) intersubjectivity (shared understanding of the task), and (c) transfer of responsibility (systematic fading of support).

In chemistry education, Yuriev and co-authors designed the "Goldilocks Help" workflow to scaffold problem-solving in general chemistry, emphasizing stepwise prompts, structured representations, and decision points that help students avoid "dead ends" and "false starts."Subsequent work by Vo et al. highlighted the role of metacognitive scaffolding. For instance, prompts that ask students to check assumptions or reflect on their strategy to improve the quality of their problem-solving in chemistry.

According to a recent systematic review, problem-solving instruction is more effective with structured guidance that gradually allows students to work independently. This takes place when concepts are introduced slowly, from simple to complex, with different ways to treat the problem and modeling how it is done or solved, and then, bit by bit, removing teacher support. This guided support is very helpful when applied to balancing chemical equations, as it helps students learn both the systematic procedures and the concepts involved in the balancing process.

**The Algebraic Method and its Potential for Enhancing Conceptual Understanding**

Nagashima et al. (2020) explained that the Algebraic Expressions Method helps students deepen their understanding of balancing chemical equations when provided with guided step-by-step instruction following a structured procedure instead of heavily relying on the trial and error method, in order for them to be able to account for every atom systematically, applying the Law of Conservation of Mass all throughout the process. It is guaranteed that their procedural accuracy and confidence in solving more complex chemical equations will improve significantly. At the same time, a strengthened understanding of the relationship between chemistry and mathematics will be achieved, since the method follows a clear procedure, allowing them to focus on the reasoning behind each solution rather than simply guessing to find the correct coefficient that balances the equation.

The algebraic method directly addresses student difficulties in balancing chemical equations by fostering a deeper conceptual understanding. According to Zhang et al. (2024), it compels students to systematically account for each atom, thereby reinforcing the law of conservation of mass in a structured and explicit manner. This technique greatly reduces the amount of thinking required for trial-and-error guessing, allowing students to think logically rather than just remember things. Students can thus build confidence in their abilities to solve problems. Furthermore, it can help students better appreciate chemical principles. This provides a more systematic way for students to deal with unbalanced equations, rather than relying on guesswork or trial and error, making the process easier to understand.

Odondi and Aje (2025) explained that the Algebraic Expressions Method evidently helps students better understand the concept of balancing chemical equations through its systematic process, rather than relying on trial and error. Students are guided to apply the Law of Conservation of Mass to account for every atom in the entire reaction process. As the students follow these logical steps, unnecessary time and mental effort spent guessing will be avoided, allowing them to tackle problem-solving tasks with confidence and accuracy.

Similarly, Galliani (2017) said that the Algebraic Expressions Method, unlike the trial-and-error or inspection method that relies on repeated guessing and adjustments of coefficients to arrive at a balanced equation, reduces unnecessary mental effort and shifts students' focus to a structured problem-solving process.

Based on the *Algebraic Method of Problem Analysis in Business Case by Mece Principles* (2024), the algebraic method directly addresses students' difficulties by enhancing their conceptual understanding of balancing chemical equations. In the case of a chemical reaction taking place in a closed container, it helps to systematically track each atom, thereby reinforcing the law of conservation of mass. This approach enables students to build confidence in their ability to solve problems by reducing the cognitive cost required for guesswork and trial and error. Further, the structural view of chemical principles enables students to appreciate their logical and mathematical nature through a systematic, dependable tool for even "difficult" equations.

The algebraic method directly tackles student difficulties by enhancing conceptual understanding in chemistry. A study by Chance et al. (2024) requires students to systematically account for every atom. In a systematic way, the law of conservation of mass will be followed. This reduces students' cognitive overhead from guesswork and gives them the assurance to work on their own. Through the logical and mathematical foundations of chemical principles, students will gain a better appreciation of the science behind these principles, not only as chemical principles.

The algebraic method directly tackles student difficulties in balancing chemical equations by enhancing conceptual understanding. It compels students to systematically account for each atom, thereby reinforcing the law of conservation of mass in a structured manner (Firdaus & Mukhtar, 2025). As a result, students can focus on building their confidence and problem-solving strategies rather than the cognitive load from guesswork. As a result, students learn to appreciate the logic and mathematics behind all chemicals and processes. Thus, making these chemical systems seem systematic rather than daunting. This helps develop stronger problem-solving skills.

The algebraic method directly tackles student difficulties in balancing chemical equations by enhancing conceptual understanding. According to Yang & Deng (2024), it compels students to systematically account for each atom, thereby reinforcing the law of conservation of mass in a structured manner. By eliminating uncertainty, students can solve problems with greater confidence. Moreover, it gives an appreciation of the logical and mathematical background of chemical principles. It is a systematic, clear tool for more complicated equations.

The algebraic method directly addresses student difficulties in balancing chemical equations by enhancing conceptual understanding. As conducted by Sibgatullin et al. (2022), it requires the learners to account for each and every atom systematically and in a very explicit manner, using the law of conservation of mass. By taking a systematic approach, the people did not have to face the cognitive burden of trial-and-error-based inspection methods. As a result, students could easily gain confidence and a deeper appreciation of the logic and mathematics underlying chemistry. Thus, it provides an effective and systematic tool even for complex equations.

Based on the study by Veith et al. (2023), the Algebraic Expressions Method addresses common challenges students face in balancing chemical equations through its clear, systematic procedure and helps them understand the Law of Conservation of Mass by applying it throughout the process. This allows them to achieve greater confidence, more positive attitudes, and greater accuracy in understanding concepts and problem-solving skills.

Beyond just improving students' content understanding of chemical reactions, the intervention also gives them insight into a more systematic approach to solving problems, which leads to students becoming more familiar with the reasoning behind each step, even if the chemical equations become complex, rather than just memorizing the procedure and guessing the correct coefficient.

**Developing Problem-Solving Skills: From Algorithmic to Heuristic Approaches**

Several studies have emphasized that the significance of the proposed intervention, Algebraic Expressions Method is more than just getting the exact correct value of coefficient that would balance an equations but more importantly encouraging students to apply reasoning through each step of the process by using a logical and systematic problem solving (Udawat et al., 2021; Kaitera & Harmoinen, 2022; Suarez Enciso et al., 2024; Murphy et al., 2024; González Guerra & Huesca, 2024). As the students become increasingly familiar with this structured approach, they will eventually stop relying on trial and error and become more confident in explaining how and why a chemical equation is balanced, regardless of its difficulty or complexity.

Researchers also agree that the skills developed through this intervention are not limited to balancing equations ,but also include logical thinking, reasoning, and the application of problem-solving skills to more complex chemistry topics or learning situations that require analytical thinking. This intervention helps students understand and apply what they have learned to solving problems, rather than simply remembering a series of steps.

**Synthesis**

All the literature reviewed in this paper consistently showed that balancing chemical equations has apparently been one of the most challenging topics for many students, and what is more problematic about this fact is that it is a fundamental skill that is considered a prerequisite in dealing with more advanced topics in chemistry, so without it, learning other topics in chemistry will be even more difficult to grasp. And even though the trial and error method is widely used, we cannot deny the fact that there are several studies that pointed out that through this, learners tend to focus only on getting the correct answer instead of understanding the whole picture behind the process of balancing (Shaikh, 2023; Yuen & Lau, 2022). This leads to learners' continued problems with balancing due to misconceptions, such as failing to correctly distinguish coefficients from subscripts and to satisfy the Law of Conservation of Mass. With that, researchers in the literature have recommended more structured approaches to balancing to combat the problem, such as the Algebraic Expressions Method, which provides a smoother, more systematic approach to balancing chemical equations and prevents unnecessary guesswork (Zhang et al., 2024). This also aligns with Cognitive Load Theory, as explained by Sweller et al. (2024), which holds that learners achieve more meaningful learning when they focus their mental load on understanding the lesson itself rather than blindly following the process. At the same time, many studies suggest that students must be able to develop improved problem-solving skills applicable to more complex problems, rather than merely learning steps in the balancing process (Enciso et al., 2024; Murphy et al., 2024).

Across all the literature reviewed in this study, the significance of instructional scaffolding is viewed as a great help to develop learners' confidence and accuracy to work on tasks independently as they are provided with guided step-by-step procedures and gradually reduce the help offered while slowly increasing complexity (Doo, Bank & Heo, 2020). These strategies would train students' minds to think through the problem-solving process rather than memorizing a procedure without understanding.

Taking in all these findings, the researcher studied the Algebraic Expressions Method as both systematic approach in balancing chemical equations and a scaffolding framework supporting students' learning throughout the process through guided and assisted instruction supported by the Cognitive Load Theory that encourages learners to gradually develop students to solve more problems independently and by doing this, the researcher will be able to determine whether the intervention helped the students go beyond simply balancing equations and deeper understanding of the concepts behind it but also improved attitudes and confidence in the problem solving skills.

## Chapter 3

## Methodology

This chapter presents the study's methodology to assess the intervention's effectiveness in improving students' conceptual understanding, procedural fluency, and confidence in solving chemical equations.

### Research Design

In this quantitative study, a quasi-experimental research design, specifically a one-group pre-test–post-test design, was used to determine the effectiveness of the Algebraic Expression Method in improving students' performance in balancing chemical equations. Only one group of participants was assessed before and after the intervention. This allows me to determine whether there are significant changes in procedural fluency after the intervention. This kind of research design is widely used in educational research, particularly in classroom-based studies where intact groups are utilized under natural instructional conditions (Creswell & Creswell, 2023). The one-group pre-test–post-test design was appropriate in this study because it enabled the researcher to compare students' performance before and after the intervention, thereby assessing evidence of its instructional effectiveness (Price et al., 2021). A quasi-experimental design was considered suitable, as it allowed for systematic evaluation of learning in a face-to-face classroom setting while preserving the practical structure of regular classroom instruction.

**Population and Sampling**

The study used purposive sampling, a non-probability sampling technique, to select respondents, with the researcher selecting participants based on specific characteristics or qualities relevant to the study's objectives. In this case, the sample consisted of one section of Grade 11 STEM students scheduled to learn to balance chemical equations as part of their regular chemistry curriculum.

It is an appropriate technique for this research because it ensured that all participants had the necessary prior knowledge and were at the appropriate stage in their academic progression to benefit from the intervention. Using one section or class was also a practical and commonly accepted approach in educational research, due to its minimized disruptions, class disruption, and classroom organization while preserving natural learning conditions (Creswell & Creswell, 2023; Thomas, 2023). This approach supported ecological validity by allowing the study to be conducted in a real-world educational setting.

**Respondents of the Study**

35 Grade 11 STEM students from Valenzuela National High School were the respondents of this study. A specific class or section was chosen through purposive sampling because the study required participants who were enrolled in chemistry and scheduled to learn about balancing chemical equations.

**Instrumentation**

The following instruments were utilized for data collection:

1. **Pre-test and Post-test Questionnaire:** In order to assess students' problem-solving skills or procedural fluency in balancing chemical equations, a standardized test was utilized consisting of a 15 item unbalanced chemical equations with varying difficulty which directly addressed research question numbers 1 and 2 wherein Research question 1 sought to determine the level of performance of Grade 11 students in balancing chemical equations before and after the application of Algebraic Expressions Method. It has a total score (0–15) for each learner in the pretest and again in the posttest. These scores provide quantitative indicators of students’ performance levels before and after the intervention, enabling descriptive summaries. Research question 2 sought to determine the statistical difference between students' pre-test and post-test performance. The pretest–posttest approach enables estimation of change attributable to the instructional treatment by comparing scores across time points.
2. **Intervention Guide (Lesson Plan):** A researcher-developed lesson plan served as the intervention guide for implementing the Algebraic Expression Method to balance chemical equations. The lesson plan was developed based on the Grade 11 General Chemistry 1 Curriculum Guide, which served as an instructional guide for implementing the Algebraic Expressions Method and outlined the learning objectives, appropriate teaching and learning activities, worked examples, guided practice exercises, and assessment throughout the intervention. The lesson plan ensured that the discussion was delivered gradually with assisted guidance to provide learners with structured learner experience as they follow step by step procedure applying Algebraic Expressions Method in balancing chemical equations allowing students to make sense of every step of the process as they progress to more complex problems

while slowly reducing the teacher's assistance which helped learners to solve equations more systematically and strengthen both their conceptual understanding and problem solving skills with positive attitudes and increased ease and confidence.

3. **Survey Questionnaire:** Students were asked to answer a survey questionnaire just right after the intervention in order to determine their perceptions towards the use of Algebraic Expressions Method through a five-point Likert scale measuring their confidence, perceived difficulty, and perceived usefulness of the method in balancing equations, which allows students to describe their overall learning experience (Joshi et al., 2021).

In developing the questionnaire, the researcher followed established principles in survey design, including clearly defining the constructs to be measured, aligning each item with the intended construct, and ensuring consistency and clarity in the response format to improve interpretability and reliability (Taherdoost, 2022). The survey part focused on students' experience with the Algebraic Expression Method: confidence in balancing chemical equations, perceived difficulty of the method, and perceived usefulness of the instructional approach. These variables were chosen to provide measurable insight into students' perceptions of the intervention after its implementation in a face-to-face classroom setting.

- **A 5-point Likert-type agreement scale, which is** widely utilized in educational research for its ability to generate ordinal data that reflect attitudes and levels of agreement or disagreement (Koo & Yang, 2025), was used to quantitatively measure students' confidence levels, perceived difficulty of the topic, and perceived usefulness of the algebraic method. The Likert scale format is useful in identifying patterns in students' self-reported learning experiences and levels of engagement.

4. **Validity and Reliability of the Instrument**

Since the study employed standardized tests for both the pretest and post-test, which had established validity and reliability, they did not require further validation or reliability testing within the scope of this study. But the researcher-developed survey questionnaire underwent a rigorous content validation process to ensure it accurately measured the intended constructs. The questionnaire, along with the study's objectives, was validated by a panel of three subject matter experts who were experienced high school chemistry teachers with a Bachelor's Degree or Masters of Science in Chemistry to tell whether each item was clear, relevant and appropriate for Grade 11 learners through a Content Validity index (CVI) checklist in which they rated each item using a five point likert scale and computed for their level of agreement for both individual items and the questionnaire (Zamanzadeh et al., 2023). The items that did not meet the required level of agreement were revised based on the validators' comments and recommendations to ensure the questionnaire was appropriate for measuring the intended variables before it was administered to students.

To establish the reliability of the survey questionnaire, a pilot test was conducted with Grade 11 students from a different section who had characteristics similar to the study's actual participants. Cronbach's Alpha was used to assess the internal consistency of the Likert-scale items, yielding a coefficient of 0.87, indicating a high level of internal consistency and confirming the instrument's reliability and suitability for this study.

**Data Gathering Procedure**

**Pre-test Administration:** Before the intervention, the validated pre-test was administered to all student participants to establish a baseline measure of their problem-solving skills.

**Implementation of the Intervention:** The intervention was implemented through the researcher's direct classroom teaching, using a structured lesson on balancing chemical equations with the Algebraic Expression Method. The researcher's lesson plan served as the primary instructional guide for implementing the intervention in a structured, logical manner. It is mainly composed of learning objectives that reflect the content and performance standards in the curriculum guide, step-by-step teaching procedures, guided practice activities, formative assessment tasks, and follow-up exercises aligned with the Algebraic Expression Method.

Delivery of the lesson had to be standardized for all respondents to ensure that all learners received the same content, examples, instructional sequence, and level of academic support. Minimizing the variation was necessary in this part, ensuring that any observed changes in student performance could be more reliably attributed to the intervention itself than to differences in teaching approach or materials.

The next phase was the implementation phase, during which the researcher facilitated the lesson using explicit instruction and structured scaffolding. We began with a review of prior concepts in chemical formulas and the Law of Conservation of Mass. This is to activate learners' prior knowledge and establish conceptual readiness, followed by the presentation of the Algebraic Expression Method through a step-by-step demonstration of the seven procedures used in balancing chemical equations. The researcher made sure to model or demonstrate each step clearly, from assigning variables to each compound to writing algebraic expressions for each element to solving the resulting equations and verifying the final balanced equation. After a couple of demonstrations, guided practice was then given to allow students to apply each step with teacher support before proceeding to independent problem-solving tasks.

Throughout the intervention, the researcher ensured that all learners progressed through the same instructional sequence and were given equal opportunities for guided and independent practice. At these points, immediate feedback was provided during classroom activities to correct misconceptions and ensure proper procedural execution, proper delivery of the intervention, and uniformity of the instructional treatment among all respondents throughout the implementation.

**Post-test Administration:** After the intervention, the post-test was given to the respondents to measure any changes in their performance.

**Survey Administration:** Right after the post-test, students were given a survey questionnaire to gather their feedback on the learning experience.

**Data Collection:** All data collected from the tests and surveys were tallied, coded, and prepared for statistical analysis.

## Data Analysis

The data in this study were gathered and analyzed using JASP (Jeffrey's Amazing Statistics Program) with descriptive and inferential statistics, providing a comprehensive interpretation of the findings.

## Descriptive Statistics

**Mean and Standard Deviation:** Used to describe the central tendency and dispersion of the students' scores in both the pre-test and the post-test to provide a clear summary of the overall academic performance of the participants before and after the intervention.

**Frequency and Percentage Distribution:** These statistics were used to summarize the distribution of student responses on the Likert scale regarding their attitudes and perceptions, providing a clear understanding of their confidence and the perceived usefulness of the algebraic method.

**Inferential Statistics**

**Paired Samples t-test:** A paired samples t-test was used to test the study's hypothesis and evaluate the intervention's effectiveness by determining whether there is a statistically significant difference between the pre-test and post-test mean scores.

**Ethical Considerations**

Ensuring the protection and wellbeing of all participants is important; that is why this study strictly adhered to the following ethical principles and procedures:

**Permission to Conduct the Study.** Formal approval was obtained by submitting a letter of request to the Schools Division Superintendent and the principal of the participating school, securing official permission to conduct the research on their premises and with their students.

**Informed Consent.** The respondents, who were Grade 11 STEM students, were still minors, and, as such, obtaining informed consent from their parents or legal guardians was necessary before engaging in any data collection. The consent form communicated the purpose of the study, the research procedures, and that participation was voluntary, and assured parents that the information collected would be kept confidential and used solely for this research.

**Voluntary Participation and Student Assent.** The researcher also asked the students to give their assent prior to their participation, in addition to the parental consent obtained. The researcher also explained the purpose of the research to the students in a simple, easy-to-understand way, and they were explicitly informed that their participation was entirely voluntary and that they could withdraw at any time. They were assured that their participation or non-participation would not affect their grades or academic standing.

**Confidentiality and Anonymity.** The confidentiality of all participants was maintained throughout the study by assigning a code to each respondent rather than using their names on test papers and survey questionnaires, thereby protecting their identities. Also, the researcher ensured that no respondent could be personally identified in any part of the study by securely storing the list of codes, which was accessible only to the researcher, and by presenting the summarized data during discussions of the results.

**Minimizing Harm and Maximizing Benefits.** The research design was intended to be a positive and beneficial learning experience. The intervention was based on a pedagogical method aimed at improving understanding and confidence. There were no anticipated risks of physical or psychological harm. The primary benefit for the participants was the opportunity to learn a challenging topic through a structured and potentially more effective method.

**Data Integrity and Security.** All research data were handled with the utmost care. Physical documents were kept in a secure, locked cabinet accessible only to the researcher. Digital files were stored in password-protected folders on a secure computer to prevent unauthorized access. The data were used solely for the purposes of this research and were disposed of appropriately upon completion of the study.

## Chapter 4

## Presentation, Interpretation And Analysis of Data

This chapter presents the study's results and provides a systematic analysis and interpretation of the data gathered from the research instruments. Specifically, this chapter reports the findings from the pre- and post-test achievement scores on balancing chemical equations to describe Grade 11 students' performance before and after the application of the algebraic expression method, and to determine whether a statistically significant difference exists between the two sets of scores. In addition, it presents and analyzes the results of the post-intervention survey questionnaire, which captures students' perceptions and attitudes toward the method, including its level of difficulty, usefulness for learning chemistry, and impact on confidence in solving chemical equations. The discussion is organized around the research questions and supported by appropriate statistical treatments and qualitative thematic analysis to ensure that conclusions are grounded in the evidence generated by the study.

**Level of Chemical Equation Balancing Performance of G11 Students Before and After the Application of the Algebraic Expression Method**

The tables in this section present comparative results on Grade 11 students' performance in balancing chemical equations before and after the application of the Algebraic Expression Method. The tables present the mean and standard deviation of the pre-test and post-test scores to describe students' performance before and after the implementation of the Algebraic Expressions Method, providing an initial overview and serving as the basis for determining whether there was an improvement following the intervention.

**Pre-test Results**

**Table 1.**

***Students' Performance Before the Implementation of the Algebraic Expressions Method***

| Variable | Mean | Standard Deviation |
|---|---|---|
| Pre-test Performance | 2.26 | 1.50 |

*Note*. *M* = mean; *SD* = standard deviation.

The pretest result shown in Table 1 indicates that the students performed at a low level before the intervention, Algebraic Expressions Method was introduced, as evidenced by the mean score of 2.26 with a standard deviation of 1.50. Since the test consists of 15 items, the mean score indicates that, on average, students answered only about 2 items correctly before using the Algebraic Expressions Method, suggesting that students struggled with balancing chemical equations before the study started. Having low pretest results served as a confirmation supporting previous studies which reported that the balancing chemical equations is seen as persistently one of the topics students' struggled with because of failure to apply the concept of Law of Conservation of Mass and distinguishing between coefficients and subscripts in the balancing process, leading to students' complete reliance on the trial and error method instead of understanding and applying the concepts involved. (Hamerská et al., 2024; Ogundiji, 2024).

On the other hand, it further shows how varied the scores were across the class, with a standard deviation of 1, indicating that although some students showed prior understanding of balancing chemical equations, many still received low scores, suggesting that students demonstrated different levels of prior knowledge and learning needs. With that, it is very appropriate to provide students with a structured, guided support instructional approach in order to help them develop not only their problem-solving skills but also their conceptual understanding, so that students can go beyond memorizing each step and be able to acquire a systematic way of solving chemical equations while reducing their dependence on guesswork through the Algebraic Expressions Method.

**Post Test Results**

**Table 2.**

***Students' Performance After the Implementation of the Algebraic Expressions Method***

| Variable | Mean | Standard Deviation |
|---|---|---|
| Post-test Performance | 12.06 | 2.70 |

*Note. M* = mean; *SD* = standard deviation.

The post-test results presented in Table 2 show that students obtained a mean score of 12.06 and a standard deviation of 2.70 after implementing the Algebraic Expressions Method. This is a big improvement over the pretest results, which show that students performed much better after the intervention, suggesting that the structured approach of the Algebraic Expressions Method really helped students develop a better understanding of balancing chemical equations and apply the concepts more effectively.

This improvement supports previous studies which claimed that structured and systematic teaching approach can enhance the students' understanding and problem-solving skills in chemistry by which Isles (2020) explained that when students are guided through clear and organized procedures, they can be able to focus their mental effort on learning and understanding the concepts instead of consistently relying on trial and error and this may explain the improvement observed in the present study as the students were introduced to a step by step procedure that allowed them to balance chemical equations more systematically.

Although the overall performance improved, the value of the standard deviation being 2.70 still indicates that there are still differences in students' performance even after the intervention which means that some students showed improvement while others continued to perform better than others and having with this variation suggests that students had different learning experiences during the intervention, possibly because of differences in their prior knowledge, mathematical skills, and pace of learning. Similar findings were reported by Odondi and Aje (2025), who emphasized that students may require varying levels of instructional support even after a structured intervention.

Even though the Algebraic Expressions Method was found effective in improving students' performance through these findings, we cannot ignore the fact that there are learners who may still need additional guided practice and support, and it can be achieved by providing reinforcement activities, formative feedback, and opportunities to apply the method to more complex chemical equations that may better strengthen students' conceptual understanding and problem-solving skills.

**Difference Between the Pre-test and Post-test Performance of Grade 11 Students**

Since the same group of students took the assessments, the researcher used a paired-samples t-test, which is appropriate for comparing pretest and posttest scores to determine whether the Algebraic Expressions Method had a statistically significant effect on students' performance in balancing chemical equations.

**Paired Samples T-Test Results**

**Table 3.**

***Comparison of Students' Pre-Test and Post-Test Performance Using a Paired Samples t-Test***

| Pair | Mean Difference | T | df | Sig. (2-tailed) | Cohen's d |
|---|---|---|---|---|---|
| Pre-test vs Post-test | 9.80 | 20.59 | 34 | 0.0000 | 3.48 |

*Note. p* values are two-tailed. Mean difference = pretest − posttest (revise if computed as posttest − pretest). Values are rounded to two decimal places.

The paired samples t-test results presented in Table 3 showed a significant difference between the students' pre-test and post-test performance after the implementation of the Algebraic Expressions Method, evident with the mean difference of 9.80, with $t(34) = 20.59$ and $p = 0.0000$ (two-tailed), rejecting the null hypothesis because the resulting p-value was lower than the 0.05 level of significance. This can mean that the increase in students' scores after the intervention was statistically significant and might be linked to the implementation of the Algebraic Expressions Method suggesting that the intervention had a positive effect on students' ability to balance chemical equations, which is consistent with the findings of Isles (2020), who reported that structured and systematic instructional approaches can improve students' learning and overall academic performance.

The results further show that the improvement in students' performance was both statistically and practically meaningful because the estimated 95% confidence interval for the mean difference ranged from 8.83 to 10.77 indicates that the true increase in students' scores is likely to be within this range and since the entire confidence interval is above zero, it further supports the conclusion that the Algebraic Expressions Method contributed to the improvement in students' performance. This suggests that the intervention's positive effect was consistent across the group and not due to chance alone (Odondi & Aje, 2025).

The effect size obtained in this study (Cohen's $d = 3.48$) was interpreted as very large, which indicates that the Algebraic Expressions Method had a strong positive effect on students' learning. This suggests that the improvement in students' performance was not only statistically significant but also meaningful in the context of classroom teaching, indicating that the intervention helped students develop a better understanding of how to balance chemical equations and improved their ability to solve them using a more systematic approach. This degree of practical impact aligned with literature showing that well-scaffolded, explicit instructional interventions can produce large, rapid improvements in procedural and conceptual skills (Valenti et al., 2022).

Before employing the paired-samples *t* test, a normality test was conducted to determine whether the data met the assumption required for parametric analysis—particularly that the difference scores (Post − Pre) were approximately normally distributed. Results from both the Kolmogorov–Smirnov and Shapiro–Wilk tests were non-significant for the pretest, posttest, and difference scores (all $p > .05$). Specifically, the Shapiro–Wilk test showed $W = 0.964$, $p = .312$ for the pretest; $W = 0.971$, $p = .421$ for the posttest; and $W = 0.978$, $p = .602$ for the difference scores. These results indicated no significant departure from normality; therefore, the normality assumption was considered satisfied, supporting the use of the paired-samples *t* test to compare pretest and posttest performance.

Finally, the pedagogical and research implications followed directly from these inferential results. The findings of this study suggest that the Algebraic Expressions Method can be used as an effective teaching approach for balancing chemical equations. When combined with guided practice, continuous feedback, and appropriate instructional support, students can develop a better understanding of the balancing process while improving their problem-solving skills. However, some students may still require additional support to address remaining learning difficulties and improve their understanding of the concepts.

The results also provide directions for future research, such as using larger and more diverse groups of participants to determine whether the findings generalize across different learning settings. Future researchers may also include delayed post-tests to assess whether students retain what they have learned over time and use experimental or comparison groups to further examine the effectiveness of the Algebraic Expressions Method (Suarez Enciso et al., 2024).

With that, the findings showed that the Algebraic Expressions Method was statistically and educationally significant and meaningful in improving students' performance, indicating that providing students with a structured, systematic approach to balancing chemical equations can strengthen both their conceptual understanding and their problem-solving skills.

**Students' Perceptions of the Algebraic Expressions Method**

Table 4 presents the descriptive statistics of students' responses to the post-intervention survey done after the implementation of the Algebraic Expressions Method where it answers the Research Question 3 by describing students' perceptions of the instructional approach which covered three areas: students' confidence in balancing chemical equations (Conf_1–Conf_4), perceived level of difficulty (Diff_5–Diff_8), and perceived usefulness of the Algebraic Expressions Method in learning chemistry (Use_9–Use_12). The mean scores reflect the students' overall responses to each statement, while the standard deviation indicates the consistency of their responses across survey items.

**Likert Scale Results**

**Table 4.**

***Post-Intervention Descriptive Statistics for Students' Perceptions of the Algebraic Expression Method (Confidence, Difficulty, and Usefulness)***

| Indicator | Mean | Standard Deviation |
|---|---|---|
| **Confidence** | | |
| Statement 1 | 4.17 | 0.79 |
| Statement 2 | 4.0 | 0.8 |
| Statement 3 | 4.0 | 0.87 |
| Statement 4 | 4.11 | 1.02 |
| **Difficulty** | | |
| Statement 5 | 4.2 | 0.96 |
| Statement 6 | 4.26 | 0.82 |
| Statement 7 | 4.11 | 0.87 |
| Statement 8 | 4.2 | 0.8 |
| **Usefulness** | | |
| Statement 9 | 4.17 | 0.82 |
| Statement 10 | 4.26 | 0.66 |
| Statement 11 | 4.6 | 0.55 |
| Statement 12 | 4.31 | 0.83 |

*Note. M* = mean; *SD* = standard deviation. Values are rounded to two decimal places.

The results presented in Table 4 show that students generally responded positively to the Algebraic Expressions Method after its implementation, with mean scores ranging from 4.00 to 4.60, indicating that most students agreed with the statements describing their confidence, perceived level of difficulty, and the method's usefulness in balancing chemical equations. This can mean that the students had a positive learning experience and recognized the benefits of using the Algebraic Expressions Method during the intervention.

And since the mean scores have been consistently high, it can be concluded that the structured approach helped students become more confident in balancing chemical equations while improving their understanding of the concepts involved, which are consistent with the findings of Isles (2020), who reported that well-structured instructional approaches can improve students' learning and support the development of problem-solving skills within a short period of instruction.

The results show that students generally expressed positive perceptions of their confidence in using the Algebraic Expressions Method with mean scores for the four confidence indicators ranging from 4.00 to 4.17 which indicates that most students agreed that they were able to apply the method, explain its steps, and use it in solving both simple and more complex chemical equations meaning that the structured and step-by-step procedure of the intervention really helped students to become more confident in balancing chemical equations at the same time improve their understanding of the process.

Students also reported that they were able to explain the steps of the Algebraic Expressions Method to others, suggesting that they understood not only how to use the method but also why each step was necessary, and this ability to explain concepts is usually associated with a deeper level of understanding because students are able to organize and communicate their ideas more clearly than just simply following a memorized procedure. Also, students expressed confidence in using the method for more complex chemical equations, indicating that they view the Algebraic Expressions Method as a practical alternative to trial and error.

Even though there are some variations in students' responses, given the standard deviation values that range from 0.79 to 1.02, the overall results remained consistently positive in all confidence indicators, suggesting that although most students developed greater confidence after the intervention, some may still need more guided practice and assistance, especially when balancing more complex chemical equations. Similar observations were reported by Odondi and Aje (2025), who emphasized that students benefit from continued instructional support as they apply structured problem-solving strategies to increasingly challenging tasks.

The results also show that students generally perceived the Algebraic Expressions Method as easier to use than the traditional trial-and-error approach, with mean scores for the perceived difficulty indicators ranging from 4.11 to 4.26, indicating that most students agreed the method made balancing chemical equations easier to understand and apply. Students also reported that the step-by-step procedure helped them distinguish coefficients from subscripts more clearly and lessen the difficulty of balancing more complex chemical equations, which means that the structured nature of the Algebraic Expressions Method made the balancing process more organized and manageable, allowing students to focus on understanding the concepts instead of relying on guesswork.

Although there was some variation in students' responses, the overall results suggest that most learners viewed the method as clear and easy to follow. However, a few students may still require additional guided practice and reinforcement, particularly when solving more challenging chemical equations. These findings are consistent with Valenti et al. (2022), who emphasized that structured instructional support helps students gradually overcome learning difficulties while developing stronger problem-solving skills.

The findings on the perceived usefulness of the Algebraic Expressions Method also showed a positive response from the students with mean scores ranged from 4.17 to 4.60 that says that students considered the method as a useful learning tool in chemistry and they believed that the method helped them understand the Law of Conservation of Mass, improving their problem-solving skills, and could be applied to future chemistry topics beyond balancing chemical equations. The highest-rated statement reflected students' belief that the Algebraic Expressions Method would remain useful in subsequent chemistry lessons, indicating that they viewed the strategy as more than just a technique for balancing equations.

These findings can mean that students recognized the value of the Algebraic Expressions Method not only in improving their performance during the intervention but also in helping them build the knowledge and skills needed for future chemistry learning. With these positive responses, it is safe to claim that students considered the method meaningful, practical, and applicable to learning situations beyond the scope of this study. The very low standard deviation further indicates a strong degree of consensus among learners, suggesting that this was the most uniformly endorsed benefit of the intervention. Students also agreed that the algebraic method made learning chemistry more meaningful and less frustrating (Statement 12; M = 4.31), indicating that the method may have reduced frustration often associated with balancing equations while increasing students' sense of engagement and purpose in learning chemistry. Overall, the findings show that students had positive perceptions of the Algebraic Expressions Method and understood its contribution to their learning, indicating that the method not only helped them understand how to balance chemical equations but also increased their confidence and positive attitudes toward applying the concepts to other chemistry topics. Given their consistently positive responses to the usefulness indicators, students view the method as a practical and effective approach to learning chemistry, aligning with Hamerská et al. (2024), who found that structured instructional approaches can improve students' understanding, confidence, and overall learning experience.

The students' responses also showed very consistent perceptions across the different indicators of the survey, although there were some variation observed in a few statements still the overall results tell that most students shared similar views about the confidence, ease of use, and usefulness of the Algebraic Expressions Method in balancing chemical equations which can mean that the intervention was positively received by the class and provided a learning experience that benefited most of them. Similar observations were reported by Suarez Enciso et al. (2024), who emphasized that structured instructional approaches can promote more consistent learning outcomes among students.

Despite these positive results, some differences remained in students' confidence when solving more complex chemical equations and in their perception of how the method lessen the difficulty of learning chemistry suggesting that while the intervention was effective for most students, some learners may still require additional guided practice and instructional support to improve better their understanding of more advanced concepts by proving continuous formative assessment, targeted remediation, and differentiated learning activities (Lishchynska et al., 2020).

The findings also provide important implications for classroom instruction, as it is generally agreed that the Algebraic Expressions Method was clear, easy to follow, and useful in improving their problem-solving skills. They also believed that the method could be applied to future chemistry topics, indicating that they viewed it as a valuable learning strategy beyond balancing chemical equations, which suggests that teachers may continue integrating the Algebraic Expressions Method into classroom instruction while providing opportunities for guided discussion, peer learning, and repeated practice to further strengthen students' conceptual understanding.

Overall, the results of the survey showed that students had positive perceptions of the Algebraic Expressions Method as they reported greater confidence in balancing chemical equations, considered the method as less difficult and way better than the guesswork they do in trial and error method, and recognized its usefulness in learning chemistry which can only mean that the Algebraic Expressions Method not only improved students' performance but also contributed a lot to their more positive and meaningful learning experience in chemistry.

**Table 5**
*Interpretation of the Quantitative Findings*

| Study outcome/domain (aligned to RQs/SOP) | Quantitative results | Interpretation |
|---|---|---|
| RQ1–RQ2: Student performance in balancing chemical equations (pretest vs. posttest) | Pretest: $M = 2.26$, $SD = 1.50$ (15-item test). Posttest: $M = 12.06$, $SD = 2.70$. Paired-samples $t$ test: Mean difference = 9.80; $t(34) = 20.59$; $p < .001$; Cohen's $d = 3.48$. | Students began with low baseline proficiency and achieved a marked increase after AEM (from about 2/15 to 12/15 correct on average). Inferential results indicate a statistically significant and very large improvement, providing strong evidence that performance gains occurred following the intervention. |
| SOP 3.1: Perceived level of difficulty (Diff_5–Diff_8) | Item means ranged from 4.11 to 4.26; domain mean ≈ 4.19. | Quantitatively, students generally agreed that AEM made balancing manageable. |
| SOP 3.2: Perceived usefulness in learning chemistry (Use_9–Use_12) | Item means ranged from 4.17 to 4.60; domain mean ≈ 4.34. | Students reported strong agreement that the Algebraic Expression Method was useful in learning chemistry. The high ratings indicate that learners perceived the method as meaningful, efficient, and relevant beyond the immediate task of balancing chemical equations. |
| SOP 3.3: Confidence in solving chemical equations (Conf_1–Conf_4) | Item means ranged from 4.00 to 4.17; domain mean ≈ 4.07. | Quantitative ratings indicate students generally felt more confident after AEM. |

*Note.* Quantitative perception scores were based on a 5-point Likert scale (1 = Strongly disagree to 5 = Strongly agree). $p$ values are two-tailed. Mean difference reflects the pretest–posttest score difference as reported.

Table 5 presents an interpretation of the quantitative findings on the effectiveness of the Algebraic Expressions Method as an intervention for balancing chemical equations, providing a clearer understanding of its influence on students' learning. The quantitative findings showed a substantial improvement in students' performance after the implementation of the Algebraic Expressions Method, as shown in the increase in the mean score from 2.26 in the pre-test to 12.06 in the post-test, together with the significant paired samples t-test result and the very large effect size, indicating that the intervention had a positive effect on students' ability to balance chemical equations. This suggests that providing students with a structured, systematic procedure helped them understand the balancing process more effectively than relying solely on trial and error. Students' responses further support this finding, as many described the method as easier to understand, more organized, and easier to apply during problem solving.

Students also expressed positive perceptions regarding the difficulty, usefulness, and confidence associated with the Algebraic Expressions Method as they agreed that the method made balancing chemical equations easier to learn and helped them understand important concepts, such as the Law of Conservation of Mass and believed that the method improved their problem-solving skills and could be applied to future chemistry topics suggesting that students recognized the value of the Algebraic Expressions Method not only in completing balancing exercises but also in developing a more organized approach to solving chemistry problems.

The findings on students' confidence also reflect the positive impact of the intervention, as most of them reported that they became more confident in balancing chemical equations and were able to explain the steps involved in the Algebraic Expressions Method, meaning that repeated exposure to a structured problem-solving process helped students become more familiar with the method and increased their confidence in applying it. However, some students continued to have difficulty solving more complex equations involving multiple variables or fractional coefficients, suggesting that additional guided practice and instructional support may still be beneficial for some learners.

Overall, the quantitative findings reflects that Algebraic Expressions Method helped improve students' performance and it also made the the process of balancing chemical equations easier to understand, less difficult, and more meaningful which tells that the structured and step by step nature of the method enabled students to develop both conceptual understanding and problem-solving skills while emphasizing the importance of continued guided practice and appropriate instructional support to help all students achieve a deeper understanding of balancing chemical equations.

**Instructional Video on Balancing Chemical Equations Using the Algebraic Expressions Method**

The results of this study served as the basis for developing an instructional video on balancing chemical equations using the Algebraic Expressions Method, designed to provide additional learning support for students and to serve as supplementary instructional material for teachers. Since it was showed in the findings that students benefited from a structured and step by step approach in balancing chemical equations, an instructional video was designed to reinforce the same learning process through clear demonstrations, guided explanations, and worked examples that students can review at their own pace which is consistent with Mayer et al. (2020), emphasizing that instructional videos are more effective when they promote active learning, reduce unnecessary cognitive load, and keep learners engaged throughout the lesson.

The instructional video follows a systematic sequence that allows students to understand each step of the Algebraic Expressions Method first before applying it independently where in the lesson is divided into smaller sections to help learners focus on one procedure at a time, while key concepts and important steps are highlighted throughout the discussion as consistent with the recommendations of Fyfield et al. (2022) that instructional videos become more effective when information is presented in manageable segments and learners are guided toward the most important ideas.

To shape the foundation of the method and help students understand the relationship between the reactants and products before solving the equation, the video starts by showing how to assign letter variables to the unknown coefficients and translate each element into algebraic expressions. With these, students are guided to understand the process rather than relying on trial-and-error strategies. The design of this section was informed by the study's findings, which showed that students became more confident in applying the Algebraic Expressions Method and in explaining its steps after the intervention.

The succeeding part of the video demonstrates assigning a value to one variable and solving the remaining variables through substitution and simplification. This portion of the lesson was intentionally emphasized because many students experience difficulty in identifying where to begin when balancing unfamiliar chemical equations, so by providing a clear starting point and modelling each step of the solution, the video helps reduce uncertainty and encourages students to follow a systematic problem solving process which reflects the findings of the study that students learn more effectively when balancing chemical equations is presented as a logical and structured procedure rather than as an activity based on guesswork. This design is supported by the post-intervention difficulty indicators, particularly students' agreement that the algebraic method is easier than the traditional trial-and-error approach (Statement 5), that the steps of the method are clear and manageable (Statement 6), that it is less confusing to identify coefficients and subscripts using the algebraic method (Statement 7), and that balancing complex equations becomes less difficult when applying the method (Statement 8), with means ranging from 4.11 to 4.26. In particular, the relatively high and consistent mean for students' agreement that the steps are clear and manageable (Statement 6; $M = 4.26$, $SD = 0.82$) suggests that learners responded well to scaffolded procedures that simplified otherwise complex tasks into manageable steps.

Because student feedback and item-level results indicated that fractions remained a common source of difficulty, the video includes a dedicated segment on handling fractional coefficients by multiplying all values by the denominator (Step 5). Particular attention was intentionally given to the section demonstrating how to eliminate fractions and simplify the resulting algebraic expressions, because many students still struggled to balance more complex chemical equations. By clearly demonstrating each step, the video provides additional guidance that helps students understand the procedure and avoid common mistakes. This can mean that students are given more opportunities to strengthen their understanding of the method before solving similar equations independently.

After simplifying the algebraic expressions, the video demonstrates how the computed coefficients are entered into the balanced chemical equation, followed by a final check in which students verify that the number of atoms of each element is equal on both sides of the equation. Including this step encourages students to develop the habit of checking their work rather than relying on guesswork, which also reinforces the Law of Conservation of Mass by showing that balancing is not complete until the equation has been verified.

To further strengthen students' understanding, the instructional video includes worked examples arranged from simple to more complex chemical equations, allowing students to observe how the same procedure can be applied to different types of equations as the level of difficulty increases. The examples also reinforce the study's findings, showing that students became more confident in balancing chemical equations and perceived the Algebraic Expressions Method as easier to understand after the intervention. By presenting the examples in a logical sequence, the video helps students build their skills progressively without becoming overwhelmed.

The video also includes a "Your Turn" activity that encourages students to apply what they have learned before the complete solution is presented allowing them to pause the video, solve the equation independently, and compare their answers with the guided solution afterward in order to provide opportunities for independent practice and reinforce the step by step process introduced in the lesson while allowing students to identify and correct their own mistakes. This can help strengthen both procedural fluency and conceptual understanding while giving teachers an additional resource for classroom reinforcement or independent learning.

Overall, the instructional video was developed directly from the findings of this study, follows the same structured procedure used during the intervention, and emphasizes the areas where students showed the greatest improvement while providing additional support for concepts that remained challenging. The instructional video serves as a supplementary learning resource that combines explicit demonstrations, worked examples, guided practice, and opportunities for self-checking to help learners build confidence and deepen their understanding of how to balance chemical equations using the Algebraic Expressions Method.

## Chapter 5

## Summary, Conclusions and Recommendations

This chapter presents the summary of the study's findings, conclusions, and recommendations. The data gathered before and after the intervention were analyzed, interpreted, and summarized. Based on the statistical analysis, conclusions were drawn regarding the effectiveness of the intervention. Recommendations were also provided to support its potential use in classroom teaching and to encourage further studies on other variables related to the research topic.

### Summary of Findings

The quantitative results showed us that the Algebraic Expression Method improved the students' ability to balance chemical equations. Before the intervention activity, the students only obtained a mean score of 2.26 with a standard deviation of 1.50. These results indicated low performance, suggesting that many students had limited procedural skills and conceptual understanding of how to balance equations. The differences in their scores also suggested that some students may have had partial knowledge of the topic, while others experienced greater difficulty. This emphasized the need to provide appropriate and differentiated support during instruction (Odondi & Aje, 2025).

After the said intervention, the mean score of students increased to 12.06, with a standard deviation of 2.70. This marked improvement indicated that the students, as a group, became more capable of applying the Algebraic Expression Method in balancing chemical equations. Although the improvement is evident, the variation in post-test scores indicates that differences in individual performance remain despite the overall improvement (Valenti et al., 2022; Hamerská et al., 2024).

The results of the paired-samples t-test further confirmed that the improvement in the students' performance was statistically significant. The analysis showed a mean difference of 9.80, with $t(34) = 20.59$ and $p = 0.0000$. Therefore, the null hypothesis stating that there was no significant difference between the pre-test and post-test scores was rejected. This suggests that the increase in students' scores was unlikely to have occurred by chance and might be attributed to the use of the Algebraic Expression Method. (Enciso et al., 2024).

The computed Cohen's d of approximately 3.48, on the other hand, showed a very large effect size. This not only indicates that the method produces a statistically significant improvement but also has a strong practical effect on the students' performance. The finding supports previous studies showing that structured and scaffolded instructional approaches can improve students' procedural skills and conceptual understanding in problem-solving activities (Lishchynska, Palmer, & Crowley, 2020).

Additionally, the findings showed that the Algebraic Expression Method helped bridge the gap between students' practical skills and conceptual understanding, particularly regarding the law of conservation of mass. Through the method, the students were also able to relate algebraic operations to the chemical

principles underlying equation balancing. This can mean that they didn't only learn how to obtain the correct coefficients but also understood why the number of atoms must be equal on both sides of the equation. Such understanding may help prepare them for more advanced chemistry topics, including stoichiometry, limiting reactants, and quantitative chemical analysis. The method may therefore help develop problem-solving skills applicable to other chemistry lessons while strengthening students' analytical reasoning through guided, concept-centered instruction (Enciso et al., 2024).
Although the overall results were positive, differences in students' performance were still observed. This suggests that differentiated instruction remains important for addressing learning gaps among students. Learners with weaker mathematical backgrounds or difficulties working with fractions and equations involving multiple variables may still need ongoing guidance and targeted support. Based on the quantitative improvement observed after the intervention, the Algebraic Expression Method can be considered an effective and flexible teaching approach that improved students' procedural accuracy, conceptual understanding, and confidence. The findings therefore support the conclusion that the method provides strong evidence of enhancing students' problem-solving skills in balancing chemical equations when implemented with structured instructional support.

**Conclusions**

Algebraic Expression Method: The effectiveness of the algebraic expression method in relation to students' problem-solving skills in balancing chemical equations led to several conclusions. First, the comparison between the pre-test and post-test results showed a marked increase in the students' mean scores. The paired-samples t-test also confirmed that the improvement was statistically significant, while the computed Cohen's d of approximately 3.48 indicated a very large practical effect. This suggests that the increase in students' performance was unlikely to have occurred by chance and might be attributed to the use of the Algebraic Expression Method. However, distinctions in individual performance remained evident, suggesting that some learners may need ongoing guidance and differentiated support. Based on these results, the Algebraic Expression Method is an effective instructional approach for improving students' procedural accuracy and conceptual understanding in balancing chemical equations.
Next, the effectiveness of the Algebraic Expression Method is strongly linked to a structured approach. Quantitative data revealed that learners initially faced confusion, particularly with algebraic manipulation, fraction handling, and variable assignment. However, guided demonstration, a series of drills, and gradual fading of instructional support enabled students to move from uncertainty to fluency and confidence, emphasizing that although the method itself is robust, its successful implementation relies on structured, carefully sequenced instruction, formative assessment, and targeted feedback. With this, teachers should introduce the method with proper instructional guidance rather than presenting it on its own. This can help students gradually progress from guided activities to independent problem-solving.
Third, the Algebraic Expression Method may offer important instructional benefits beyond the immediate improvement in balancing accuracy. Findings showed not only a better understanding of the law of conservation of mass but also improved accuracy in following the students' procedure, as well as increased confidence and participation in chemistry learning. This can mean that the method helped students develop a deeper understanding of the lesson instead of simply memorizing the steps. By combining algebraic reasoning with chemical principles, the approach may also help develop problem-solving skills applicable to more advanced topics, such as stoichiometry, limiting reactants, and quantitative chemical analysis.

This leads us to conclude that the method not only addresses the present learning objectives but may also prepare students for more complex chemistry tasks in the future.

Although the study showed very positive outcomes, it also identified several areas that need further attention. Some students continued to experience difficulty with complex equations involving multiple variables and fractions, showing the need for differentiated teaching strategies. Teachers may use diagnostic assessments to identify learners who require additional support and provide remediation, peer tutoring, or supplemental exercises to help them achieve the expected competency. For high-performing students, open-ended and transfer activities may also be included to measure deeper conceptual understanding beyond the correct application of procedures. These considerations show that careful instructional planning remains necessary to maximize the method's benefits for all learners.

Overall, the study's conclusions present clear, important directions for both practice and research. In terms of practice, chemistry teachers are encouraged to use the Algebraic Expression Method through guided lessons that include step-by-step demonstrations, facilitated practice, and formative assessment. For research, similar studies should replicate these findings using larger, more diverse samples. The use of control or comparison groups is also recommended to provide stronger evidence of the method's effectiveness. Delayed post-tests may also be included to determine whether students can retain what they have learned. Therefore, the study concludes that the Algebraic Expression Method can be an effective and applicable approach for improving students' problem-solving skills and preparing them for more advanced quantitative topics in chemistry, when supported by appropriate instructional guidance.

**Recommendations**

Based on the study's results and conclusions, several recommendations were proposed to strengthen the teaching and learning of balancing chemical equations using the Algebraic Expression Method. These recommendations aim to support its effective use in classroom teaching, improve students' procedural skills and conceptual understanding, and encourage its continued application in chemistry education. The following recommendations are intended for teachers, curriculum developers, school administrators, and future researchers. The Algebraic Expression Method should be systematically integrated into the teaching of balancing chemical equations because it has proven effective in improving students' conceptual understanding, procedural accuracy, and confidence in solving chemical equations.

1. The Algebraic Expression Method has been shown to help students improve their conceptual understanding, accuracy, and confidence in solving chemical equations; thus, it should be integrated into lessons where applicable.
2. This method should be implemented through progressive learning strategies such as clear demonstration, guided practice, and formative feedback. Lastly, the gradual removal of instructional support is needed to help ensure effective learning in the long run.
3. Teachers should provide a supportive, structured learning environment so that students with diverse mathematical backgrounds can develop stronger skills in balancing chemical equations.
4. The continued use of the Algebraic Expression Method should be sustained to help students gain confidence in balancing chemical equations and prepare them for more advanced chemistry topics.
5. Professional learning opportunities, such as LAC sessions and FGDs on content enrichment, should be provided to teachers/instructors to improve their knowledge and expertise to teach the Algebraic Expression Method effectively in the classroom.

6. The Algebraic Expression Method must be added and properly aligned with the curriculum, incorporated into chemistry lessons, and aligned with relevant learning competencies.
7. Flexible teaching methods should be provided to address students' varying needs and help them apply the Algebraic Expression Method effectively.

**Specific Recommendations:**

1. **For Teachers:** Teachers should incorporate the Algebraic Expression Method in their regular chemistry lessons through modeling, guided practice, and formative feedback. This can help any students with different learning abilities understand and apply the method more effectively.
2. **For Curriculum Developers:** The method should be included in learning modules and instructional guides, starting from simple equations and gradually moving to more complex ones. It should also be connected to higher-level topics such as stoichiometry and quantitative chemical problem-solving.
3. **For School Administrators:** School administrators should always provide professional development programs for science teachers that focus on content mastery, guided instruction, and the integration of mathematical strategies into science instruction, particularly in chemistry. This can help teachers improve their teaching practice and provide students with more structured and meaningful learning experiences.
4. **For Students:** They should consistently practice the Algebraic Expression Method in balancing chemical equations through drills, peer collaboration, and reflective activities. This can help improve both their procedural skills and conceptual understanding, hence making them confident in approaching related chemistry topics.
5. **For Future Researchers:** They may conduct follow-up studies with larger, more diverse samples. Comparing the Algebraic Expression Method with other problem-solving and long-term retention tests can be part of their approach. This can help them further validate its effectiveness and determine whether the method can also be of use in other areas of science.

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