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Profile of Students' Understanding of Stoichiometry Through Short Quizzes in a General Chemistry Course

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Abstract

Stoichiometry is a core topic in General Chemistry that requires strong conceptual understanding as well as quantitative reasoning skills. This topic is often perceived as difficult by undergraduate students because it involves abstract concepts such as the mole, mathematical calculations, and multi-step problem solving. This study aims to describe the profile of students' understanding of stoichiometry through the use of short quizzes as a form of formative assessment. The study employed a quantitative descriptive approach involving 34 undergraduate students enrolled in a General Chemistry course. The research instrument consisted of a short quiz with three items covering molar mass determination, mole–mass conversion, and simple stoichiometric applications in chemical reactions. Data were analyzed using descriptive statistics and categorized into high, moderate, and low levels of understanding. The results showed that 71.88% of students demonstrated a high level of understanding, 25.00% showed a moderate level, and 3.12% exhibited a low level of understanding. These findings indicate that short quizzes are effective as an early diagnostic tool to map students' understanding of stoichiometry and provide immediate feedback for improving the learning process

INTRODUCTION

General Chemistry is a foundational course that must be completed by undergraduate students in various science and science education programs. The course serves as a gateway to more advanced chemistry subjects by introducing fundamental concepts, principles, and quantitative reasoning skills. A solid understanding of General Chemistry is essential because many subsequent chemistry topics rely heavily on the concepts introduced in this course.

One of the core topics in General Chemistry is stoichiometry, which focuses on the quantitative relationships between reactants and products in chemical reactions. Stoichiometry requires students to integrate conceptual understanding with mathematical problem-solving skills, particularly in relation to the mole concept, molar mass, and balanced chemical equations. According to Chang (2010), stoichiometry forms the basis of almost all chemical calculations, making it a critical component of chemistry learning at the university level.

Despite its importance, stoichiometry is widely recognized as a challenging topic for undergraduate students. Numerous studies have reported that students often struggle to understand stoichiometric concepts due to the abstract nature of the mole concept and the multi-step reasoning required to solve stoichiometric problems (Gabel, 1999; Nakhleh, 1992). These difficulties frequently lead students to rely on memorization of formulas and algorithmic procedures rather than developing meaningful conceptual understanding.

Understanding students' level of comprehension of stoichiometry is therefore essential for improving the quality of chemistry instruction. Without clear information regarding students' conceptual understanding, instructors may fail to identify learning difficulties and misconceptions that can hinder students' progress in more advanced chemistry courses. Early identification of students' understanding allows instructors to design appropriate instructional strategies and provide targeted support where needed.

Formative assessment plays a crucial role in monitoring students' learning progress and identifying their understanding of complex topics such as stoichiometry. Black and Wiliam (2009) emphasized that formative assessment provides timely feedback that can be used to improve both teaching and learning processes. One practical form of formative assessment in higher education is the use of short quizzes, which can be administered efficiently and provide immediate insights into students' learning outcomes.

Short quizzes are particularly suitable for assessing students' understanding of stoichiometry because they can be designed to target specific conceptual and quantitative indicators within a limited time frame. By analyzing students' responses to short quizzes, instructors can obtain a clear picture of students' strengths and weaknesses in stoichiometric understanding. This information is valuable for making instructional decisions and ensuring that learning objectives are achieved.

Based on these considerations, this study aims to identify and describe students' understanding of stoichiometry in a General Chemistry course through the use of short quizzes as a formative assessment tool. By mapping students' levels of understanding, this study seeks to provide empirical evidence that can support more effective instructional practices in General Chemistry at the university level

Stoichiometry plays a central role in chemistry education because it connects theoretical concepts with quantitative problem-solving skills. Mastery of stoichiometry enables students to interpret chemical equations, predict reaction outcomes, and calculate the amounts of substances involved in chemical processes. These competencies are essential not only for success in General Chemistry but also for advanced courses such as analytical chemistry, physical chemistry, and biochemistry. Therefore, insufficient understanding of stoichiometry may have long-term consequences for students' academic performance.

Previous studies have consistently reported that students often experience difficulties in stoichiometry due to fragmented understanding of prerequisite concepts, including atomic structure, molar mass, and the mole concept. Students may be able to perform calculations mechanically without fully understanding the underlying chemical meaning, leading to misconceptions and procedural errors (Nakhleh, 1992). Such learning patterns suggest that assessment practices should focus not only on final answers but also on students' conceptual reasoning.

At the university level, instructors are often constrained by limited instructional time and large class sizes, which makes continuous assessment of student understanding challenging. As a result, students' misconceptions may go unnoticed until formal examinations are conducted. This situation highlights the need for efficient and practical assessment strategies that can provide rapid feedback without disrupting the instructional process. Short quizzes offer a feasible solution, as they require minimal time while still yielding meaningful information about students' learning progress.

By examining students' understanding of stoichiometry through short quizzes, this study addresses an important gap in chemistry education research, particularly in the context of formative assessment at the undergraduate level. Understanding how well students grasp stoichiometric concepts can help instructors refine their teaching strategies and support students more effectively during the learning process.

METHODS

a. Research Design

This study employed a quantitative descriptive research design aimed at describing students' levels of understanding of stoichiometry through short quizzes. A descriptive approach was selected because the study focused on mapping existing learning outcomes without implementing experimental treatments or interventions.

b. Participants

The participants of this study were 34 undergraduate students enrolled in a General Chemistry course at a university. All students who attended the stoichiometry lesson and completed the short quiz were included as research subjects using a total sampling technique. This approach was applied due to the relatively small and homogeneous population.

c. Research Instrument

The research instrument was a short quiz consisting of three multiple-choice questions developed based on the learning objectives of stoichiometry in the General Chemistry curriculum. The quiz items covered three main indicators of stoichiometric understanding:

1. Determination of molar mass of chemical compounds
2. Conversion between mole and mass
3. Application of stoichiometric principles in simple chemical reaction problems

The quiz was designed to assess both conceptual understanding and quantitative problem-solving skills related to stoichiometry.

To ensure the appropriateness of the research instrument, the quiz items were reviewed by a lecturer who teaches General Chemistry to examine their relevance to the learning objectives and the clarity of the questions. This review process was conducted to support the content validity of the instrument. Minor revisions were made to improve wording and to ensure that each item clearly represented the intended stoichiometric indicator.

Students' responses were evaluated using predetermined scoring criteria. Students who answered all quiz items correctly were categorized as having a high level of understanding. Students who answered two items correctly were classified as having a moderate level of understanding, while students who answered one or none of the items correctly were categorized as having a low level of understanding. This classification was used to provide a clear and practical description of students' levels of understanding.

The use of percentage-based scores allowed for consistent comparison among students and facilitated descriptive analysis. This approach was selected because the primary purpose of the study was to describe patterns of understanding rather than to test statistical differences or relationships between variables.

d. Data Collection Procedure

Data were collected by administering the short quiz at the end of the stoichiometry learning session. The quiz functioned as a formative assessment tool to evaluate students' immediate understanding after instruction. Students completed the quiz individually within a limited time under supervised classroom conditions.

Each correct answer was awarded an equal score, while incorrect answers received a score of zero. Students' total scores were then converted into percentage values for further analysis.

e. Data Analysis Technique

Data analysis was conducted using descriptive statistical techniques. Students' scores were classified into three levels of understanding based on their percentage scores:

1) High understanding
2) Moderate understanding
3) Low understanding

The distribution of students across these categories was calculated in terms of frequency and percentage. The results were presented in tabular and graphical forms and interpreted narratively to describe students' overall understanding of stoichiometry.

This study was conducted in accordance with ethical principles for educational research. Because the research involved minimal risk and was carried out as part of regular instructional activities in a General Chemistry course, formal ethical approval from an institutional review board was not required. Nevertheless, ethical considerations were carefully addressed throughout the research process to ensure the protection of participants' rights and well-being.

All participants were informed about the purpose of the study and the use of the quiz data for research purposes. Students were assured that their participation would not affect their course grades and that the results would be used solely for academic and research objectives. Participation in the study was voluntary, and students were allowed to complete the quiz without any form of coercion.

To protect participants' privacy, students' identities were kept anonymous during data collection and analysis. No personal identifying information was recorded, and all data were analyzed in aggregate form. The quiz results were coded using numerical identifiers to ensure confidentiality. Only the researchers had access to the raw data, which were stored securely and used exclusively for research purposes.

The short quiz used in this study functioned as a formative assessment tool and was aligned with the course learning objectives. The assessment did not introduce additional academic burden for students beyond normal classroom activities. Feedback from the quiz was used to support students' learning and to inform instructional improvement, consistent with ethical principles of beneficence in educational research. By adhering to these ethical considerations, the study ensured that participants were treated fairly and respectfully, while maintaining the integrity and credibility of the research process.

RESULT AND DISCUSSION

A. RESULT

The results of this study describe students' understanding of stoichiometry based on their performance in a short quiz administered in a General Chemistry course. A total of 34 undergraduate students participated in the quiz, which consisted of three multiple-choice items designed to assess fundamental stoichiometric concepts.

Analysis of the quiz scores showed that most students demonstrated a high level of understanding of stoichiometry. Of the 34 students, 23 students (71.88%) were classified as having high understanding, indicating that they were able to determine molar mass, perform mole–mass conversions, and apply stoichiometric principles correctly in simple chemical reaction problems. In contrast, 8 students (25.00%) were categorized as having moderate understanding, while only 1 student (3.12%) was classified as having low understanding. The distribution of students' understanding levels is presented in Figure 1.

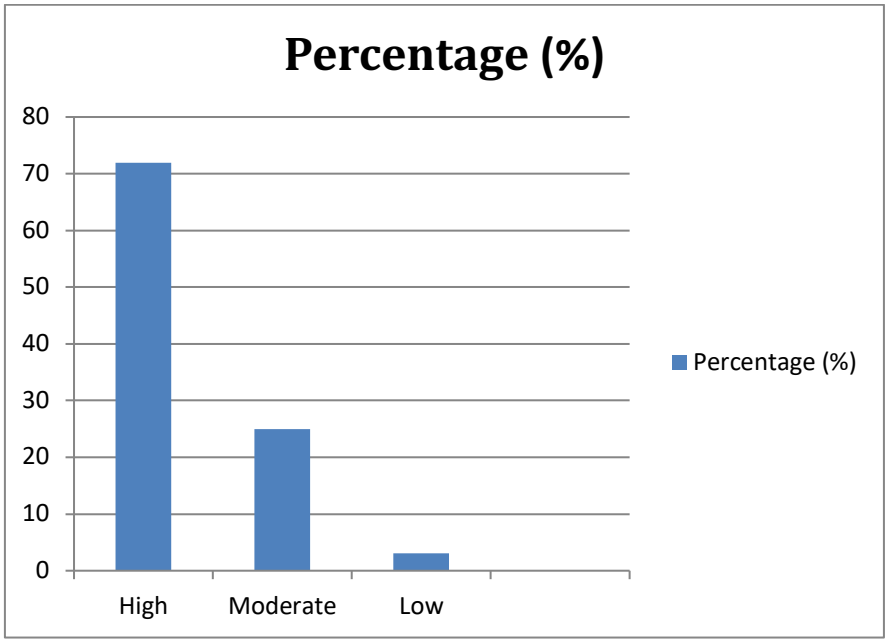

Figure 1. Distribution of students understanding levels of stoicjiometry based on short quiz result

Further analysis based on individual quiz items revealed variations in students' performance across different stoichiometry indicators. The highest level of correct responses was observed in the molar mass determination item, with 29 students (85.29%) answering correctly. This result indicates that most students had a strong understanding of atomic mass concepts and were able to use chemical formulas and the periodic table appropriately.

Performance on the mole–mass conversion item was comparatively lower. A total of 21 students (61.76%) answered this item correctly, while 13 students (38.24%) provided incorrect responses. These findings suggest that although more

than half of the students demonstrated adequate understanding, mole–mass conversion remains a challenging aspect of stoichiometry for a considerable proportion of students.

In the application of stoichiometric principles to simple chemical reaction problems, 24 students (70.59%) answered correctly, whereas 10 students (29.41%) answered incorrectly. Students who answered correctly were able to interpret balanced chemical equations and apply stoichiometric ratios systematically, while incorrect responses indicated difficulties in relating coefficients in chemical equations to quantitative calculations.

Overall, the results indicate that students' understanding of stoichiometry was generally satisfactory, with strong performance in basic conceptual tasks such as molar mass determination and moderate performance in tasks requiring integration of conceptual understanding and quantitative reasoning, particularly in mole–mass conversion problems.

B. DISCUSSION

The results of this study indicate that the majority of students demonstrated a high level of understanding of stoichiometry, as reflected by their performance on the short quiz. More than seventy percent of students were categorized as having high understanding, suggesting that the instructional approach used in the General Chemistry course was generally effective in supporting students' comprehension of fundamental stoichiometric concepts. This finding supports the view that clear conceptual explanations combined with structured practice can significantly enhance students' learning outcomes in chemistry.

The strong performance observed in molar mass determination indicates that students had relatively solid foundational knowledge of atomic structure and were able to interpret chemical formulas correctly. This result aligns with previous studies showing that tasks involving direct application of factual knowledge, such as calculating molar mass, tend to be less challenging for students compared to tasks requiring multi-step reasoning (Chang, 2010). Familiarity with the periodic table and repeated exposure to similar problems likely contributed to students' success in this indicator.

However, the lower performance observed in mole–mass conversion highlights a persistent challenge in stoichiometry learning. Mole–mass conversion requires students to conceptualize the mole as a bridging concept between the microscopic and macroscopic levels of matter. According to Gabel (1999), students often struggle with this aspect of stoichiometry because they focus on algorithmic manipulation of formulas rather than understanding the conceptual meaning of the mole. The results of this study confirm that even when students perform well on simpler stoichiometric tasks, conceptual difficulties may still arise when quantitative reasoning becomes more complex.

The application of stoichiometric principles in chemical reaction problems showed moderate success among students. While most students were able to use balanced chemical equations and stoichiometric ratios correctly, a notable proportion still made errors. This finding is consistent with research suggesting that students often fail to connect symbolic representations of chemical equations with quantitative relationships between reactants and products (Nakhleh, 1992). Such difficulties indicate the need for instructional strategies that explicitly link chemical symbols, mathematical calculations, and conceptual understanding.

The effectiveness of short quizzes as a formative assessment tool is evident from their ability to reveal detailed patterns of student understanding within a short time frame. Formative assessment emphasizes continuous feedback to improve learning rather than merely evaluating final outcomes (Black & Wiliam, 2009). In this study, the short quiz enabled the identification of specific areas where students experienced difficulty, particularly in mole–mass conversion, allowing instructors to plan targeted instructional interventions.

Moreover, short quizzes encourage active engagement and accountability in learning. When students are aware that their understanding will be assessed regularly through brief evaluations, they are more likely to stay engaged with the material and reflect on their learning progress. This aligns with findings by Nicol and Macfarlane-Dick (2006), who emphasized that timely feedback plays a critical role in promoting self-regulated learning among university students.

The findings of this study suggest that incorporating short quizzes into General Chemistry instruction can enhance teaching effectiveness by providing instructors with immediate insights into students' conceptual understanding. Rather than relying solely on summative assessments, formative tools such as short quizzes allow instructors to address misconceptions early and reinforce key concepts before students progress to more advanced topics. This approach is particularly important in stoichiometry, which serves as a foundational topic for subsequent learning in chemistry.

Despite these positive findings, this study is limited to a single cohort of students and a small number of quiz items. Therefore, the results should be interpreted with caution. Future research could involve larger samples, more comprehensive assessment instruments, or longitudinal designs to examine the long-term impact of short quizzes on students' conceptual development in chemistry.

In addition to identifying students' understanding levels, the findings of this study provide important pedagogical implications for teaching stoichiometry in General Chemistry courses. The dominance of students in the high understanding category suggests that structured instruction combined with immediate assessment can support conceptual learning. However, the presence of students with moderate and low understanding indicates that a single instructional approach may not sufficiently address the diverse learning needs of all students. This highlights the

importance of differentiated instructional strategies, particularly for students who struggle with abstract concepts such as the mole and quantitative conversions.

The use of short quizzes as a formative assessment tool also has implications for instructional planning. By administering short quizzes immediately after instruction, instructors can obtain timely information about students' conceptual understanding and use this information to adjust subsequent teaching activities. For example, additional practice sessions, concept-based discussions, or visual representations may be introduced to strengthen students' understanding of mole–mass relationships. This approach aligns with formative assessment principles, which emphasize feedback-driven instructional improvement rather than solely summative evaluation (Black & Wiliam, 2009).

Despite the contributions of this study, several limitations should be acknowledged. First, the study involved a relatively small sample size drawn from a single class, which may limit the generalizability of the findings. Second, the assessment instrument consisted of only three quiz items, which, while practical for formative purposes, may not fully capture the complexity of students' stoichiometric understanding. Future studies are encouraged to employ a larger number of assessment items and involve multiple classes or institutions to provide a more comprehensive picture of students' learning outcomes.

The findings of this study provide further evidence that stoichiometry remains a cognitively demanding topic for undergraduate students, even after formal instruction. Although the majority of students demonstrated a high level of understanding, the presence of moderate and low understanding categories indicates that conceptual challenges persist. This supports earlier research suggesting that students often experience difficulties in coordinating conceptual knowledge with quantitative procedures when solving stoichiometric problems (Nakhleh, 1992).

One possible explanation for the relatively high proportion of students with strong understanding is the structured nature of stoichiometry instruction, which typically involves worked examples and guided practice. Worked examples can reduce cognitive load and support schema construction, particularly for novice learners. However, students in the moderate understanding category may still rely on algorithmic problem-solving without fully grasping the underlying chemical meaning. This tendency has been widely reported in chemistry education literature, where students focus on numerical manipulation rather than conceptual reasoning (Gabel, 1999).

The results also highlight the effectiveness of short quizzes as a formative assessment tool in identifying students' learning needs. Unlike summative examinations, short quizzes provide immediate feedback to both students and instructors, enabling timely instructional adjustments. Black and Wiliam (2009) emphasized that formative assessment is most effective when feedback is used to inform teaching and support students' learning processes. In this study, the use of

short quizzes allowed the instructor to map students' understanding efficiently within a limited instructional timeframe.

Furthermore, the classification of students into high, moderate, and low understanding categories offers practical insights for instructional planning. Students with low understanding may require additional instructional support, such as remedial exercises or conceptual discussions, while students with moderate understanding may benefit from activities that emphasize conceptual explanations and multiple representations of chemical processes. Providing targeted instructional interventions based on formative assessment results can enhance the overall effectiveness of chemistry instruction.

From a broader pedagogical perspective, the findings underscore the importance of integrating formative assessment into General Chemistry courses. Stoichiometry serves as a foundational topic that influences students' performance in subsequent chemistry courses. Therefore, early identification of students' difficulties is essential to prevent the accumulation of misconceptions. The use of short quizzes, as demonstrated in this study, represents a practical and efficient approach to monitoring students' understanding and supporting meaningful learning.

Despite the contributions of this study, several limitations should be considered when interpreting the findings. The study was conducted in a single class with a relatively small number of participants, which may limit the generalizability of the results. In addition, the use of only three quiz items may not fully capture the complexity of students' stoichiometric understanding. Future research could expand the number of assessment items, involve multiple classes or institutions, and examine the impact of formative assessment on students' learning outcomes over a longer period.

Beyond interpreting the results, these findings also have important implications for instructional practice in General Chemistry. The findings of this study have important implications for instructional practice in General Chemistry courses, particularly in teaching stoichiometry. Given that stoichiometry requires the integration of conceptual understanding and quantitative reasoning, instructors should emphasize not only procedural calculations but also the underlying chemical concepts that explain reaction relationships. The results suggest that short quizzes can function effectively as diagnostic tools to identify students who rely primarily on algorithmic problem-solving without fully understanding stoichiometric principles.

The information obtained from short quizzes can be used by instructors to design targeted follow-up learning activities. For example, students with moderate or low levels of understanding may benefit from guided problem-solving sessions, conceptual discussions, or the use of multiple representations, such as symbolic equations, particulate-level illustrations, and mathematical expressions. These instructional strategies have been shown to support deeper conceptual understanding and reduce common misconceptions in stoichiometry (Gabel, 1999).

Moreover, the regular use of short quizzes can support continuous monitoring of students' learning progress throughout the course. This practice aligns with formative assessment principles, which emphasize timely feedback and instructional adjustment to enhance learning (Black & Wiliam, 2009). By incorporating short quizzes as part of routine classroom activities, instructors can create a learning environment that encourages active engagement, reflection, and long-term retention of stoichiometric concepts

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, it can be concluded that the majority of undergraduate students demonstrated a high level of understanding of stoichiometry in the General Chemistry course. Most students were able to determine molar mass, perform mole–mass conversions, and apply basic stoichiometric principles in simple chemical reaction problems. However, a smaller proportion of students still experienced difficulties, particularly in tasks requiring the integration of conceptual understanding and quantitative reasoning.

The use of short quizzes proved effective as a formative assessment tool for mapping students' understanding of stoichiometry in a timely and efficient manner. Short quizzes enabled the identification of students' learning strengths and weaknesses immediately after instruction, allowing instructors to obtain valuable feedback on students' conceptual mastery. The findings suggest that short quizzes can support instructional decision-making by highlighting specific stoichiometric concepts that require further reinforcement.

Based on these conclusions, it is recommended that instructors incorporate short quizzes regularly into General Chemistry instruction, especially when teaching conceptually demanding topics such as stoichiometry. Short quizzes may be used not only to assess students' understanding but also to promote active engagement and encourage students to reflect on their learning progress. In addition, instructors are encouraged to emphasize conceptual explanations of the mole concept and mole–mass conversions to reduce students' reliance on algorithmic problem-solving.

Future research is recommended to involve larger samples, more diverse assessment instruments, and longitudinal designs to examine the long-term impact of formative assessments on students' conceptual understanding of stoichiometry. Further studies may also explore the integration of short quizzes with active learning strategies to enhance students' learning outcomes in General Chemistry.

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