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A Narrative Inquiry into Chemistry Teachers' Experiences with Stoichiometry

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Abstract — This narrative inquiry investigated chemistry teachers' experiences in teaching stoichiometry, a challenging topic in senior high school. Using a qualitative methodology to delve into the lived experiences of seven experienced chemistry teachers with three years of experience chosen by purposive sampling, face-to-face/phone call interviews were conducted, and the interview guide underwent a rigorous multi-stage validation process involving expert review to enhance credibility. Data analysis followed narrative analysis principles, aiming to identify key themes and patterns within the teachers' stories. The study showed that teaching chemistry was both challenging and rewarding for educators. Educators emphasized the importance of problem-solving practice, visual aids & hands-on demonstrations, individualized support, and technology integration to enhance student understanding of stoichiometry. Key insights suggest that effective instruction includes a step-by-step problem-solving approach, balancing equations and solving stoichiometric problems, using manipulatives and laboratory activities, providing intervention and assessment, offering timely feedback, and utilizing multimedia resources and online learning management systems (LMS) and software. This analysis also led to the creation of a new visual framework called the Stoichiometry Teaching Experiences Thematic Diagram "STETD", which gives a structured overview of these interconnected factors. The STETD was a useful tool for figuring out how to teach stoichiometry better. It showed that teachers need more training, more resources, and new ways of teaching to help students understand and do better, which will give them more power in the future.

Keywords: innovative teaching strategies, narrative inquiry, pedagogical approaches, stoichiometry

I. INTRODUCTION

The field of chemistry education is dynamic and continually evolving, driven by a constant need for innovative methods that engage students and foster effective learning. Chemistry is a foundational subject, essential to various disciplines, including science, technology, engineering, and business (Hinampas & Fajardo, 2024). Given its importance, chemistry education demands significant attention, particularly in its role in the technological advancement of developing nations. However, the instruction of chemistry is complex and presents multifaceted challenges. The abstract nature of its concepts, such as atomic structure, molecular bonding, and chemical reactions, necessitates carefully designed pedagogical strategies (Bunuan, 2024). These challenges are further compounded by the need for rigorous safety protocols in laboratory work and are often exacerbated by limitations in resources such as equipment, chemicals, and technology (Bunuan, 2024). This combination of abstract concepts, safety concerns, and resource constraints poses a significant hurdle to effective chemistry education.

One of the persistent challenges in chemistry education is the teaching and learning of stoichiometry, a cornerstone of quantitative chemistry (Malcolm et al., 2019). Stoichiometry is fundamental for understanding advanced chemistry topics like titration and equilibrium (Fitrian et al., 2022), and the mole concept's application is vital in laboratory practices (Suparman et al., 2019). Yet, both teachers and students often find stoichiometry challenging. Teachers grapple with effectively conveying its abstract nature, which requires students to connect macroscopic observations with submicroscopic interactions and symbolic representations. Students, on the other hand, often struggle with the conceptual understanding and the necessary mathematical skills, including the manipulation of fractions and ratios. This difficulty in mastering stoichiometry arises from macroscopic chemical reaction features originating from submicroscopic interactions (Lausin, 2019). These difficulties can lead to poor stoichiometric understanding, negatively impacting overall chemistry comprehension (Malcolm et al., 2019).

The challenges in chemistry education extend beyond stoichiometry. Students often enter chemistry courses with fragmented knowledge and pre-existing misconceptions, which are persistent and difficult to change (Abenes & Caballes, 2020). These misconceptions can arise from student misunderstandings and ineffective teaching methods. Moreover, students may exhibit negative attitudes towards chemistry due to its perceived difficulty and other factors related to the classroom environment. As Reyes (2023) discusses, there are strategies and implications for educators in addressing students' negative attitudes towards chemistry within the Philippine education system.

While research has explored various aspects of teaching practices and student outcomes in science education, a gap remains in the literature regarding the personal and professional narratives of chemistry educators. Specifically, there is limited exploration of chemistry teachers' experiences in teaching stoichiometry. Given the foundational importance of stoichiometry and the persistent difficulties encountered by both teachers and students, a deeper understanding of this issue is urgently needed.

This narrative inquiry seeks to address this gap by delving into the lived experiences of chemistry teachers as they navigate the complexities of teaching stoichiometry. By listening to their stories, we can gain valuable insights into the challenges they face, the strategies they employ, and the successes they achieve. Drawing on the lived experiences of teachers, this research aims to illuminate the specific hurdles and effective strategies within the Philippine educational landscape, ultimately contributing to a more enriching and successful learning experience for both teachers and students in their journey through the world of stoichiometry

LITERATURE REVIEW

Chemistry education, despite its fundamental importance in technological advancement (Hinampas & Fajardo, 2024), faces significant obstacles. Students consistently exhibit low performance in core concepts (Musengimana, 2020), struggle with abstract ideas such as atomic structure and molecular bonding (Bunuan, 2024), and harbor persistent misconceptions (Salame & Casino, 2021). These misconceptions are not merely a result of student deficits but are also influenced by instructional methods and the complex nature of chemistry itself, which requires navigating macroscopic, submicroscopic, and symbolic representations (Fitrian et al., 2022). Similar to Chiu (Musengimana et al., 2020), multiple researchers have found that students have misconceptions in concepts such as electrolysis, redox reactions, acids and bases, states of matter, and organic compounds.

Stoichiometry, a cornerstone of quantitative chemistry (Malcolm et al., 2019), emerges as a particularly problematic area. Its abstract nature, coupled with the need for robust algorithmic skills and the manipulation of complex concepts like the mole (Fitrian et al., 2022), contributes to significant learning difficulties. Teachers often find it challenging to teach conceptually (Malcolm et al., 2019; Stott, 2021), and students frequently resort to memorization rather than deep understanding (Lausin, 2019). This highlights the need for instructional strategies that address the interplay between conceptual, mathematical, and representational understanding (Sunyono & Meristin, 2018).

Chemistry teachers are pivotal in overcoming these challenges hence effective instruction requires not only strong content knowledge (Abenes, 2020) but also an awareness of common misconceptions (Taber, 2021) and the ability to employ engaging, student-centered pedagogies (Sugano, 2022). The review emphasizes the importance of Pedagogical Content Knowledge (PCK) (Marifa et al., 2023), which integrates subject matter expertise with instructional techniques, understanding student needs, and effective evaluation methods. Teachers must move beyond traditional lecture-based approaches (Abudo, 2024) and adopt strategies that foster active learning and address pre-existing misconceptions. Reyes (2023) and Taber (2019) all highlight the necessity of teachers understanding the students' perspective.

Finally, the review highlights the potential of active learning methodologies, particularly group work (Abudo, 2024), as a promising avenue for enhancing student engagement and promoting deeper conceptual understanding. Group work encourages collaboration, discussion, and problem-solving, which are crucial for mastering complex topics like stoichiometry (Abudo, 2024). However, successful implementation requires careful planning, facilitation, and awareness of potential challenges, such as unequal participation and social loafing (Abudo, 2024).

It was clear with the aforementioned related literature and studies that improving chemistry education, especially in challenging areas like stoichiometry, necessitates a holistic approach. This involves addressing student misconceptions through targeted interventions, enhancing teacher PCK through professional development, and implementing active learning strategies that foster engagement and collaboration. Furthermore, there is a clear need for further research, especially in the Philippine context (Sugano, 2020), to explore effective pedagogical strategies and curriculum improvements that can enhance student learning and foster positive attitudes towards chemistry. This review points to the necessity of moving beyond simply identifying problems to developing and implementing evidence-based solutions that can transform chemistry education.

STATEMENT OF THE PROBLEM

This study aims to determine teachers' experiences teaching stoichiometry in chemistry education. Specifically, it seeks to answer the following questions:

1. What are the stories of chemistry teachers about their experiences teaching the concept of stoichiometry?

2. What core narratives can be drawn from the stories shared by the participants?

3. What insights can be derived from the core narratives?

4. Based on the study's insights, what may be proposed? examined how school

II. METHODOLOGY

This study utilized a qualitative research design, specifically narrative research. According to Ntinda (2019), narrative research sought to reveal important life stories that people told in their own words and the world. Co-participants in this study were interviewed about their experiences as chemistry teachers teaching Stoichiometry concepts. In addition, they learned about problems encountered in teaching Stoichiometry, responses to these problems, and ways to stimulate and guide students' interests in learning chemistry.

The researcher sent a letter to conduct a study to the principals of selected campuses. The purpose and importance of the research was explained to ensure the principal's approval and support in conducting the study. Upon obtaining the approval, the researcher sent the selected participants a consent letter to participate in the study. Upon receipt of the informed consent form, the researcher scheduled interviews according to the guidelines. In this study, the researcher used a purposive (non-probability) sampling technique in which seven participants were selected based on the following criteria: They had to be full-time chemistry teachers with at least three years of experience in teaching chemistry specifically Stoichiometry concepts. Collection and Data Analysis Stage. Individual interviews were conducted face-to-face. The required information and data were collected from the participant's narratives, which lasted 50 to 60 minutes. The researcher transcribed the audio and video recordings of the Interviews and analyzed the data using the narrative analysis method. To ensure the interview guide effectively captures the experiences of chemistry teachers with stoichiometry, it underwent a multi-step validation process. First, the guide was submitted to my research adviser for initial feedback. Following their review, a chemistry teacher with expertise in stoichiometry was invited to provide additional insights. Finally, two faculty members from the Graduate School were asked to offer their perspectives. All comments and suggestions were carefully considered and incorporated before finalizing the interview guide.

Narrative Analyses is an umbrella term for a family of methods that share a focus on stories (Smith, 2020). Narrative Analyses will be used in analyzing the data following these steps; Create a Research Question: Qualitative research projects typically began with the formulation of a research question. This question served as the cornerstone of the study, guiding data collection and analysis. Gather a Narrative: Once the research question was established, data collection began. This often involved gathering narratives through interviews, video conferencing, or other methods that empowered participants to share their stories in a safe and comfortable environment.

Identify Core Narratives: After collecting the narratives, researchers embarked on the analysis phase. This involved identifying the central themes that emerged from the data. A common approach was to utilize open coding techniques, which allowed for the categorization of data segments based on their content and meaning. Analyze and interpret the Data: With key themes identified, the researcher delved into a deeper analysis and interpretation of the data. This involved searching for recurring patterns and considering their significance for both existing theories and practical applications in the field. Draw conclusions: The culmination of the research process involved summarizing the key insights gleaned from the analysis. This entailed not only synthesizing the findings, but also considering their broader implications for both theoretical frameworks and practical applications within the field.

III. RESULTS AND DISCUSSION

This thesis clarifies the outcomes of the respondents' responses, as seen in the following section. The section presents thorough information from the respondents, highlighting the significant results and patterns discovered. Furthermore, it provides an in-depth explanation of the results, providing useful insights into the implications and relevance of the responses.

1. The seven educators featured in the study are all experienced and passionate individuals who have dedicated their careers to shaping young minds. They all feel that being a chemistry teacher is a demanding but fulfilling job. Their commitment to education is evident in their pursuit of advanced degrees, their dedication to fostering a love of learning in their students, and their involvement in various extracurricular activities and community initiatives. Each educator has a unique story to tell, but they are all united by their passion for teaching and their desire to make a positive impact on the lives of their students

While they all face common hurdles, like students lacking foundational knowledge in balancing equations, struggling with mathematical concepts, and needing to cater to diverse learning styles, they find immense satisfaction in witnessing student growth and understanding.

Despite these challenges, these dedicated chemistry teachers share a deep sense of purpose, finding fulfillment in their role of shaping young minds and inspiring a future generation of scientists. They are committed to finding innovative ways to make stoichiometry accessible and meaningful for their students, recognizing the importance of their work in fostering a love of science and preparing students for future success.

2. On Emphasis on Problem-Solving Practice for Stoichiometry Mastery. The findings indicate that the co-participants consistently emphasized the critical role of problem-solving practice in mastering stoichiometry. The findings highlight that stoichiometry instruction is enhanced by reinforcing foundational math skills, such as unit conversions, types of chemical reactions, and balancing equations. Co-participants employ various problem-solving activities, including board work, worksheets, and workbook exercises, to reinforce learning. There is a strong belief that engaging in regular problem-solving activities helps students develop critical thinking skills, strengthen their understanding of fundamental principles, and build confidence in tackling challenging chemistry problems. Several co-participants shared specific problem-solving strategies they utilize to help students grasp stoichiometry concepts more effectively. There's a consensus among the co-participants that a variety of practice problems, including both routine and challenging exercises, are essential to reinforce student understanding. Notably, one co-participant described combining different problem-solving approaches and incorporating peer teaching to support students, while also stressing the importance of step-by-step guidance.

On the Importance of Visual Aids and Hands-on Demonstrations in Understanding Stoichiometry. The findings reveal that the co-participants underscored the significant value of visual aids and hands-on activities in enhancing the comprehension of abstract stoichiometric concepts. Co-participants frequently employ visual aids like molecular models and diagrams to help students visualize the abstract nature of stoichiometry. Hands-on activities, such as using physical models to represent molecules, were reported to lead to significant improvements in students' understanding and confidence. Manipulatives, like molecular kits, allow students to physically build and balance chemical equations, effectively making abstract concepts more concrete. Co-participants also incorporate technology tools, such as interactive simulations and stoichiometry calculators, to provide dynamic visuals and engage students in problem-solving. However, it's important to acknowledge that co-participants also noted challenges related to limited equipment or resources, time constraints in setting up hands-on activities, and the potential for variability in experimental results.

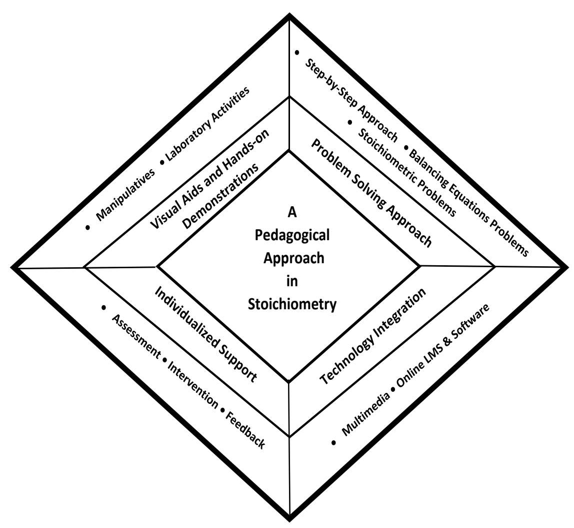
On the Importance of Individualized Support in Learning Stoichiometry. The findings of the study emphasize that effective stoichiometry instruction, as described by the co-participants, involves providing individualized support, creating a positive learning environment, and adapting teaching strategies to meet diverse student needs. Co-participants offer individualized support through one-on-one tutoring or small-group interventions for students who require additional assistance. Differentiated instruction is a key strategy employed by co-participants to cater to the diverse learning needs of students. Furthermore, co-participants utilize assessments, such as formative assessments, to identify students' misconceptions and provide targeted feedback. The provision of timely and targeted feedback to students on their understanding and performance is considered a crucial aspect of individualized support.

On Technology Integration in Teaching Stoichiometry. The findings highlight that technology integration is considered crucial for enhancing stoichiometry education. Co-participants utilize multimedia resources like videos and images to illustrate real-world applications of stoichiometry. They also employ simulations and animations to help students visualize abstract concepts. Furthermore, co-participants incorporate online learning management systems (LMS) and software to provide practice problems, facilitate immediate feedback, and streamline assignment distribution and grading. Several co-participants reported using MS Excel to aid in balancing equations and solving stoichiometry problems, which helps to reduce computational errors and allows students to focus more on conceptual understanding.

3. Several key insights emerged from the core narratives of the co-participants. Within the domain of problem-solving, these include implementing a step-by-step approach, explicitly addressing balancing equation problems, and providing ample practice with varied stoichiometric problems. Within visual aids and hands-on activities, effective instruction involves utilizing manipulatives and incorporating laboratory activities to enhance conceptual understanding. In the area of individualized support, effective strategies include employing intervention, varied assessment methods, and timely feedback to cater to diverse learner needs. Finally, technology integration involves leveraging multimedia resources and online learning management systems (LMS) and software to engage students and facilitate learning.

4. Based on this study's insights, the Stoichiometry Teaching Experiences Thematic Diagram (STETD) is proposed as a visual framework for understanding and improving stoichiometry instruction. This diagram provides a structured overview of the challenges, effective pedagogies, and opportunities for growth identified in this study, visually representing the complex factors influencing stoichiometry instruction as experienced and reported by chemistry teachers. It serves as a readily accessible tool for educators and researchers, allowing them to quickly grasp key elements impacting stoichiometry teaching and to inform the development of targeted interventions and strategies to enhance student learning and achievement in this crucial area of chemistry.

The Stoichiometry Teaching Experiences Thematic Diagram (STETD): A Framework for Understanding and Improving Stoichiometry Instruction



The Stoichiometry Teaching Experiences Thematic Diagram (STETD) is a novel framework designed to provide a comprehensive understanding of the elements influencing teachers' experiences in stoichiometry instruction. The STETD offers a visual representation of key themes and sub-themes related to teachers' experiences. This facilitates a more detailed understanding of the complexities involved in teaching stoichiometry. Its primary goal is to provide a comprehensive understanding of these experiences to inform and enhance stoichiometry instruction. The framework is structured around a central theme of A Pedagogical Approach in Teaching Stoichiometry.' Its diamond shape allows for a clear and concise representation of the interconnected nature of these elements, making it a valuable tool for both researchers and educators. The framework's clear structure and intuitive design make it accessible to both researchers and educators, promoting collaboration and knowledge sharing. Further research could explore the STETD's applicability in diverse educational contexts and its potential for informing the development of targeted interventions to improve stoichiometry instruction. The STETD serves as a valuable resource for advancing our understanding of and improving the teaching and learning of this crucial chemical concept.

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