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Exploring Mathematics Anxiety and Perceived Understanding in Chemistry of Selected Grade 9 Students

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Abstract

Chemistry makes extensive use of mathematics as its lingua franca, and it is necessary to explore basic chemistry concepts. However, the ability to perform fundamental mathematical skills is necessary to perform the necessary calculations, making chemistry itself very challenging. This study aims to investigate the relationship between mathematical anxiety and perceived understanding in chemistry among selected ninth grade students. To gather data, a semi-structured questionnaire with eight items was developed and given to 10 student respondents. In addition, the respondents were interviewed online on their mathematics anxiety, their understanding of chemistry, and how their math anxiety impacts their comprehension of chemistry lessons. The interviews were recorded and transcribed for further analysis. The findings from the thematic analysis of the data suggest that mathematical anxiety negatively impacts junior high school students' perceived understanding of chemistry. Moreover, the analysis reveals that various factors, such as personality factors that impede math comprehension and socio-environmental factors such as support from parents and teachers, the classroom, and the home environment, may contribute to students' mathematical anxiety.

Keywords

factors affecting, junior high school students, mathematics anxiety, perceived understanding, thematic analysis

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Introduction

Background of the Study

The Philippine K–12 curriculum requires students to showcase their grasp of fundamental scientific principles and the ability to apply scientific inquiry skills. Evidence of scientific behaviors and beliefs to tackle rigorous problems, encourage innovation, preserve the environment, enhance ways of living, make educated choices, and engage in issues relevant to science, technology, and environmental issues.

Yet according to the country's National Achievement Test, on average, the students obtained an MPS of 39.49, 37.98, and 40.53 for the school years 2004–2005, 2005–2006, and 2011–2012, respectively (Philippine Basic Education, 2013). An annual examination is normally administered to all school students throughout the country with an average mastery of up to 65% to define their level of achievement, strengths, and weaknesses in subject areas as their mean percentage score (MPS) for science (Benito, 2010). These results suggest that science education in our country is not strong.

According to the 2003 Trends in International Mathematics and Science Study (TIMSS), the Philippines ranked 34th out of 38 countries in high school math and 43rd out of 46 countries in high school science. In 2008, even with only scientific high schools participating in the advanced mathematics category, the Philippines ranked last out of ten countries (Ambag, 2018). In the latest TIMSS 2019, out of 79 countries that participated, the Philippines only participated in the ranking of our grade school students, where they were ranked last in GS Math and Science (TIMSS and PIRLS International Study Center, 2021). This only showed that our country is facing a crisis for our STEM students at the elementary level. This is affirmed in the study of Wang, Z., and Pan, W. (2020), a meta-analysis of 223 studies that found a significant negative correlation between mathematics anxiety and mathematics achievement across all age groups, including elementary, middle, high school, and college students. The effect size of this relationship was moderate, suggesting that math anxiety can have a substantial impact on students' performance.

Mathematics anxiety is a feeling of apprehension or fear that arises when faced with tasks or situations that require mathematical skills (Richardson and Suinin, 1972). It is a common experience among students, and it can have a negative impact on their performance in math and science classes and on standardized tests like the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). Every student understands how stressful it can be when math tests are approaching. Test anxiety, particularly cognitive anxiety, has a negative impact on a student's academic performance. Low math achievement is a precursor to MA, or mathematics anxiety (Krinzinger, Kauffman, & Willmes, 2009; Ma & Xu, 2004), which can also affect other subjects or disciplines that use mathematics as their language of instruction.

Being aware that chemistry students struggle with math in a chemistry environment, Hoban (2011) claims that a few factors could be at play, including the students' lack of math skills, their inability to use, apply, and comprehend crucial arithmetic concepts, or even their incapacity to relate math concepts to chemistry. Additionally, math and science professors typically work alone, concentrating on their own fields of expertise.

Although concepts like number sense, proportional reasoning, sense of measurement, and algebraic reasoning have been instrumental in the survival of mathematics education (National Research Council, 2001), researchers have not always considered the implications of these discoveries in other fields, such as chemistry. According to Hoban's (2011) study on the teaching and learning of chemistry, which highlighted several math-related challenges, the significance of these findings was not always considered from a mathematical perspective.

Ralph and Lewis (2018) have identified students who perform poorly on cognitive tests of math aptitude as being at considerable risk of struggling in chemistry courses. However, Scott (2012) indicated that even though the students' response process to mathematics problems, those that are analogous to chemistry problems, was through handwritten works, there was no notable change in the students' chemistry performance.

To enhance academic performance in chemistry, there is a need to alter both the way the subject is taught and students' attitudes towards it. One way to achieve this is by incorporating more relevant and investigative activities.

Theoretical and Conceptual Framework

The theoretical framework of the study is based on the Social Cognitive Theory (SCT) by Albert Bandura (1986). The SCT suggests that behavior is influenced not only by personal factors but also by the environment and the individual's cognitive processes. In this study, mathematics anxiety and perceived understanding of chemistry among Grade 9 students will be explored. These two constructs are influenced by personal, environmental, and cognitive factors.

According to Albert Bandura (1986), personal factors such as self-efficacy and outcome expectations can influence behavior. Self-efficacy is the belief in one's ability to perform a specific task, while outcome expectations refer to the anticipated outcomes of one's behavior. In the context of this study, self-efficacy in mathematics and chemistry and the outcome expectations of performing well in these subjects can

influence the students' mathematics anxiety and perceived understanding in chemistry. Environmental factors such as support from parents and teachers, as well as the classroom and home environment, can also influence behavior. In the context of this study, the support system from parents and teachers and the classroom and home environment can contribute to students' mathematics anxiety and perceived understanding of chemistry. Cognitive processes such as attention, memory, and motivation can also influence behavior. In the context of this study, the students' attention, memory, and motivation in mathematics and chemistry can influence their mathematics anxiety and perceived understanding of chemistry.

Overall, the Social Cognitive Theory provides a comprehensive framework for understanding the complex interplay between personal, environmental, and cognitive factors that contribute to mathematics anxiety and perceived understanding in chemistry among Grade 9 students.

Figure 1
SCT Conceptual Paradigm

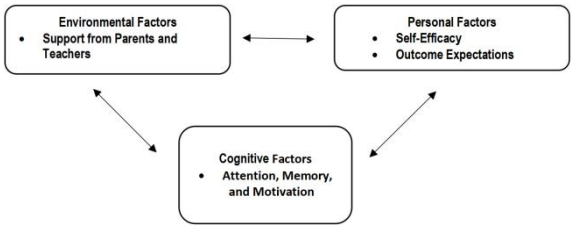

Figure 1 depicts the study's conceptual framework, which is based on Albert Bandura's Social Cognitive Theory (SCT), which contends that cognitive processes, environmental factors, and personal factors all influence behavior. In this study, the focus is on exploring the relationship between mathematics anxiety and perceived understanding in chemistry among selected Grade 9 students.

The framework consists of three main components: personal factors, environmental factors, and cognitive processes. Personal factors include self-efficacy in mathematics and chemistry and outcome expectations of performing well in these subjects. Environmental factors include the support system from parents and teachers, as well as the classroom and home environment. Cognitive processes include attention, memory, and motivation in mathematics and chemistry.

Statement of the Problem

The aim of this study is to explore the mathematics anxiety and perceived understanding in chemistry of selected Grade 9 students. Specifically, the study seeks to answer the following research questions:

1. What are the different factors that affect students' mathematical anxiety?
2. How does the students' previous learning experience in their mathematics and science classes affect their perceived understanding of chemistry?
3. How does students' mathematical anxiety affect their perceived understanding of chemistry?

Methods

Research Design

The qualitative research design for exploring the relationship between mathematics anxiety and perceived understanding in chemistry among selected ninth grade students will involve conducting individual interviews with the participants. The aim of the study will be to gain an in-depth understanding of the participants' experiences and perspectives on their mathematics anxiety and perceived understanding of chemistry.

Sample and Sampling Technique

The sample for this study will consist of 10 heterogeneous Grade 9 students from a public institution in Manila, Philippines. The sampling technique used will be purposive sampling, which involves selecting participants who have specific characteristics or experiences relevant to the research question. In this case, the participants were selected based on their grade level, enrollment in a chemistry course, and willingness to participate in the study. The purposive sampling technique allows the researcher to select participants who are most likely to provide relevant data, which increases the study's validity. The researcher selected Grade 9 students who have completed lessons in stoichiometry during the academic year 2021-2022. The study will provide a more focused analysis of the relationship between mathematics anxiety and perceived understanding in chemistry among this specific population.

Research Instrument

The instrument was submitted to knowledgeable others (MTs and former professors) to revise it and report their remarks on it. After meeting the required modifications, the final instrument consisted of 8 items, each focusing on the student's mathematics anxiety, level of understanding in chemistry, or relationship of the student's math anxiety to understanding chemistry lessons.

Data Gathering Procedure

The type of sampling method used in this study is purposive sampling. The participants for the study are 10 heterogeneous Grade 9 students from a public institution in Manila during the academic year 2021–2022. The respondents are composed of five male and five female students who have recently completed lessons on stoichiometry in their science curriculum.

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The study will begin by obtaining the necessary approvals from the school administration and the participants' parents or guardians. The researcher will provide a brief explanation of the study and its objectives to the participants. The participants will be informed that their participation is voluntary and that they have the right to withdraw from the study at any time. The participants will be asked to complete the questionnaire independently, which will consist of three parts: (1) the students' mathematics anxiety; (2) their level of understanding in chemistry; and (3) the relationship between the students' math anxiety and their understanding of chemistry lessons. After the completion of the questionnaire, the researcher will conduct one-on-one interviews with each participant through an online platform.

The respondents were interviewed through an online platform on questions about the students' mathematics anxiety, their level of understanding of chemistry, and the relationship between the students' math anxiety and their understanding of chemistry lessons. The researcher conducted one-on-one interview sessions with all the students. To ensure that there would be no bias or copying of answers, the respondents were asked to be interviewed separately.

Data Analysis

The research in question utilized thematic analysis, as described by Braun and Clarke (2006). The process involved transcribing interview recordings and progressing through coding stages. Thematic analysis was used to identify various factors that influence students' mathematics anxiety, their level of comprehension in chemistry, and the relationship between mathematics anxiety and understanding of chemistry lessons.

Ethical Considerations

Ethical considerations, such as ensuring the anonymity and confidentiality of the participants and informed consent, were obtained from both the participants and their parents or legal guardians. Participants were assured of the confidentiality of their responses, and their participation was voluntary. The study was conducted in a manner that ensured no harm to the participants.

Results and Discussion

After the thematic analysis of the transcribed interviews of the respondents, several themes were identified for each of the factors that were considered in the study. In terms of the students' mathematics anxiety, level of understanding in chemistry, and relationship of the student's math anxiety in understanding chemistry lessons, the themes were identified and listed.

Factors Affecting the Students' Mathematical Anxiety

Despite extensive research, no definitive solutions to the causes of math anxiety have been identified. Math anxiety is a personal trait that cannot be systematically changed, so researchers must create a comprehensive understanding of what causes it based on a wide range of studies. Based on the students interviewed, the causes of math anxiety can be categorized into two themes: personality factors and socio-environmental factors.

Table 1

Findings on Different Factors that Affect Students' Mathematical Anxiety

Code	Incidence	Local Theme	International Theme
Lack of confidence answering	10	Self-confidence	Personality and Socio-Environmental Factors
Anxiety in dealing problems	4	Anxiety	
Fear of embarrassment	4	Peer perception	
Difficulty understanding the lesson	6	Mentality	
Learning modality limitation	2	Environment	
Support System	2	Social	

"Kinakabahan po ako ... Minsan po ay natatakot … Minsan confident sa pagsagot ng mga problem solving sa math, kasi minsan napapaisip po kung tama ba yung sagot ko o mali … Nahihihiya po akong magkamali sa klase …" - S1 [Translation: "I feel nervous... Sometimes I get scared... Sometimes I feel confident in solving math problem, but sometimes I doubt whether my answers are correct or wrong... I feel embarrassed to make mistakes in class..."]

"Di ko po masyadong naiintindihan agad yung lessons po sa math, minsan po nanunuod po ako sa YouTube ng videos para po mas maintindihan ko po yung lessons." - S3 [Translation: "I don't immediately understand the math lessons, so sometimes I watch YouTube videos to better understand the lessons."]

"Sometimes it is hard for me to learn, and sometimes it is easy for me to learn. Because learning mathematics has always been hard for me, whether it's online or not, Because I can say that I am not really friends with mathematics … Because, to be honest, when it comes to mathematical problems and equations, I always think that it is automatically hard, even though it's not ..." – S5

"Sometimes I feel nervous, but I do not allow my nervousness to consume me, and instead I focus myself on answering it." - S7

"I am not confident in answering mathematical problems because I feel intimidated whenever I see a math problem. Especially when I don't know the formula or how to solve that problem." - S9

"Sir, ngayon po, I am not that confident in answering my mathematics activities or problems. Because these online classes really limit my understanding of certain topics po. Minsan din po, di na rin ako nakakasunod sa lessons ng mga teachers ko kasi po siguro po di pa po ako gaano nakaka-adjust sa online distance learning po." – S2 [Translation: "Sir, now, I am not that confident in answering my mathematics activities or problems. Because these online classes really limit my understanding of certain topics. Sometimes, I can't keep up with my teachers' lessons because maybe I haven't fully adjusted to online distance learning."]

"Sir, wala po kasing tumutulong sa akin sa bahay kapag nahihirpan ak sa math … Nahihiya din po ako minsan magtanong sa teacher, matatapang po kasi at namamahiya kapag di nakukuha …" – S10 [Translation: "Sir, no one helps me at home when I struggle with math... I also feel hesitant to ask the teacher sometimes, because they can be intimidating and embarrassing if I don't understand..."]

In this study, the findings suggest that mathematical anxiety experienced by students is based on two different factors, namely the personality factor and the socio-environmental factor. As for personality factors, students agreed that lack of confidence, anxiety in dealing with problems, and difficulty understanding the lesson are the most influential factors that affect their mathematics anxiety. This finding supports previous research that found that stress in the classroom contributes to the development of mathematical anxiety. As a result of the disruption to their self-concept, these students who are under stress because of learning mathematics are more likely to forget the lessons they learn. As for socio-environmental factors, students highlight limitations in their learning modality and a lack of support system. There is a low incidence in students' responses, but these factors are amplified throughout the years of repeated experiences.

Students' math anxiety is frequently the result of years of painful mathematics experiences, which can lead to low self-esteem, uncontrollable emotions, shyness, fear of embarrassment in class, and pressure. Over-expecting with less emotional parental support and unpleasant classroom experiences such as an unconducive learning environment and tackling seatwork without learning anything. These are identified as the different factors that affect math anxiety.

How Students' Previous Learning Experiences Affect Their Understanding of Chemistry

Previous experiences in mathematics classes serve as a basis for understanding mathematics-based topics in chemistry, such as stoichiometry. Three codes were identified: (1) help in answering problems; (2) make positive associations in stoichiometry; and (3) critical thinking skills. All of our respondents agreed that having a solid foundation in mathematics helps them understand or solve problems in stoichiometry.

Table 2
Findings from Previous Learning Experiences in Math and Science Classes

Code	Incidence	Local Theme	International Theme
Help in answering problems	10	Strong Foundation	Strong Foundation
Make positive association in Stoichiometry	6		
Critical thinking skills	6		

"Yes po… kasi mas madali ko na masolve yung mga problem sa science … Medyo familiar yung process … tulad po sa algebra." – S4 [Translation: "Yes, because I find it easier to solve problems in science ... The process is somewhat familiar ... like in algebra."]

"Opo. Nakatulong po siya. Napabilis po yung pagsasagot ko dahil po sa skills ko." – S7 [Translation: "It helped a lot. It sped up my answering because of my skills."]

"It is very hard and challenging because, unlike when we were in grade school, we were just taught simple problems. But whenever I encounter mathematics, I realize I am already in high school … It is more dynamic [po] in high school; it needs a lot of things to solve a problem. Unlike in grade school, you just need to multiply, divide, and just simple." – S9

"Madali ko pong narerelate yung mga skills na natutunan dati sa math sa problems po sa stoichiometry sa Science po." – S6 [Translation: "I can easily relate the skills I learned in math to problems in stoichiometry in Science."]

This study reaffirms the studies of Hoban et al. (2013) and Nakakoji and Wilson (2018) that a mathematical foundation has a significant, direct, and positive impact on students' performance in mathematics-based subjects like chemistry, physics, and engineering. This study also provides evidence that prior knowledge gained through years of experience in math and science classes will have a positive effect on their perceived understanding of chemistry. The study of Dochy, Segers, and Buehl (1999) also agrees with the study that prior knowledge is in fact a strong predictor of learning outcomes, especially in relation to "procedural metacognitive knowledge", or the ability to know and understand what to do. This translates into a connection between mathematics and chemistry. Because many chemistry topics involve mathematical concepts. Therefore, prior exposure to these basic mathematical concepts should improve your ability to apply them in the context of chemical problems.

It is commonly understood that teaching math and science is necessary to support and promote contemporary and creative economies. On the other hand, other cultures face pressing issues such as students' lack of mathematical readiness and reductions in academic achievement in STEM fields.

According to the most recent PISA results, the Philippines is one of the countries with poor academic performance, ranking last among 58 countries in mathematics and science. These concerns, dubbed the "STEM crisis," have been acknowledged in international reports from Australia, Canada, India, Japan, and the United Kingdom. If students do not have a solid foundation in math and science from elementary and high school, they may not be prepared to train for and seek employment in STEM sectors in both Canada and the United States. Prior studies have emphasized the value of transdisciplinary improvement of students' math and science skills.

How Students' Mathematical Anxiety Affects Their Understanding of Chemistry

The conjecture is that individuals who suffer from math anxiety, characterized by negative emotions and uneasiness towards mathematics, are likely to avoid mathematical activities, such as taking fewer math

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courses and pursuing fewer STEM careers, than those with lower levels of math anxiety. Three codes were identified by the researcher: (1) nonparticipative, (2) poor performance, and (3) memorization and not critical thinking.

Table 3
Findings on Math Anxiety and Perceived Understanding in Chemistry

Code	Incidence	Local Theme	International Theme
Nonparticipative	3	Affects	Affects
Poor performance	5	Negatively	Negatively
Memorization, not critical thinking	4		

"Hindi ko po makuha agad yung formula na gagamitin parang nakakalito po … kaya hindi po ako makarelate agad at makarecite kaya kapag nagsosolve po kami ng problems …" - S6 [Translation: "I can't grasp the formulas immediately; they can be confusing ... That's why I can't relate and recite quickly when we solve problems ..."]

"The formulas ... I have many formulas in my head, and it always get mixed up. So, I am trying to double check my formulas, so I have a little bit of a hard time analyzing which formula I will use." – S7

"I think I memorized the formula for what this formula is for po … kasi po dina-doubt ko po yung sarili ko po. Madalas din kasi po akong magkamali. – S9 [Translation: "I think I memorized the formula for what this formula is for... because I doubt myself. I often make mistakes as well."]

"Sa totoo lang po, medyo alanganin po ako sa science, kasi po medyo hirap po ako sa mga formulas at mga solving …" - S10 [Translation: "To be honest, I'm a bit uncertain about science because I struggle with formulas and problem-solving."]

"Pagdating po sa mga formulas in chemistry, tina-try ko po yung best ko i-memorize po. Kung hindi man isusulat sa board, mine-memorize ko na lang po sila, para po madali ko pong masolve yung problem po. Minsan po kasi napaghahalo-halo ko po yung formula, kaya nagkakamali din po yung solving ko. – S3 [Translation: "When it comes to formulas in chemistry, I try my best to memorize them. If they're not written on the board, I just memorize them so that I can solve problems more easily. Sometimes, I mix up the formulas, so my solutions end up being incorrect."]

This study supports the current hypothesis and views about mathematical anxiety, which are that it plays a vital role in suppressing learning outcomes. Also, this study reveals that the emerging codes of nonparticipation, poor performance, and memorization, not critical thinking, are the academically relevant consequences that negatively affect the perceived understanding of chemistry.

A strong mathematical foundation appears to point toward improved chemistry performance. While the reasons for this are not quantifiable, it appears clear that the link between math fluency and chemistry ability is based on some similarities between the fields. Chemistry appears to require not only science knowledge but also a strong foundation of mathematical skills and a logical way of thinking. As a result, it appears that the stronger an individual's mathematics background, the greater the likelihood of success in chemistry.

Thematic Map

Figure 2
Thematic Map of the Emerging Themes

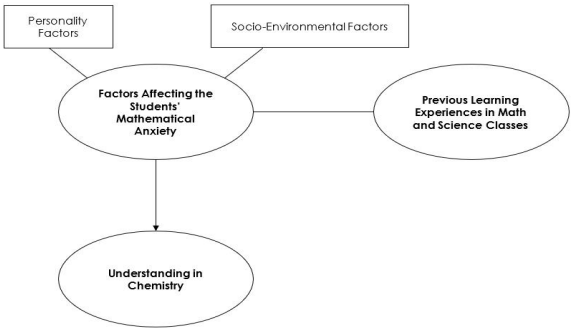

Figure 2 represents the thematic map of the emerging themes based on the responses of the participants of the study regarding the association of mathematical anxiety with the perceived understanding of the grade 9 students. As reflected, two significant factors were determined to affect the students' mathematical anxiety, namely: personality factors and socio-environmental factors. Personality factors include a lack of confidence in answering mathematical problems, students' anxiety in dealing with mathematical problems, and difficulty understanding the mathematics lessons. Socio-environmental factors, on the other hand, involve fear of embarrassment among peers, limitations in the learning modality, and a lack of support systems in the students' environment.

Moreover, previous learning experiences in Math and Science classes served as a strong foundation for understanding or solving problems in their Chemistry classes, specifically in stoichiometry. These include the following scenarios: Help them answer problems, make positive associations in stoichiometry, and develop their critical thinking skills. The findings of the study also proved that mathematical anxiety could negatively affect the students' understanding of Chemistry. Undesirable associations include students' non-participative behavior, poor performance, and dependence on memorization rather than critical thinking skills.

Conclusion

In conclusion, this study has revealed that there are multiple factors contributing to students' mathematical anxiety, including personality traits, socio-environmental factors, and a lack of foundational knowledge from previous mathematics and science classes. These factors can inhibit students' ability to comprehend mathematics problems and solve topics that require mathematical understanding, such as stoichiometry in chemistry. Furthermore, the study found that mathematical anxiety has a detrimental effect on students' perceived understanding of chemistry, particularly for junior high school students in grade 9.

These findings highlight the importance of addressing students' mathematical anxiety and providing them with the necessary support and resources to improve their comprehension and performance in chemistry.

Implications

The implications of this study are significant for educators and parents in understanding the factors that contribute to mathematics anxiety and perceived understanding in chemistry among Grade 9 students. By identifying these factors, educators and parents can develop strategies to help students overcome their math anxiety and improve their understanding of chemistry. The results of this study can also inform curriculum development in both mathematics and chemistry.

By understanding the specific areas that students struggle with in mathematics and the relationship between mathematics anxiety and perceived understanding in chemistry, educators can develop targeted interventions to improve student learning outcomes. For example, interventions that focus on building self-efficacy in mathematics and chemistry or improving the classroom and home environment can have a positive impact on student learning outcomes.

Furthermore, the findings of this study can contribute to the larger body of research on mathematics anxiety and its impact on academic achievement. This study highlights the need for continued research on mathematics anxiety, particularly in the context of science education. Additionally, this study can contribute to the development of interventions aimed at reducing mathematics anxiety and improving academic achievement in science education.

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Author(s)' Statements on Ethics and Conflict of Interest

Ethics Statement	The author/s hereby declare that research/publication ethics and citing principles have been considered in all the stages of the study. The author/s take full responsibility for the content of the paper in case of dispute.
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