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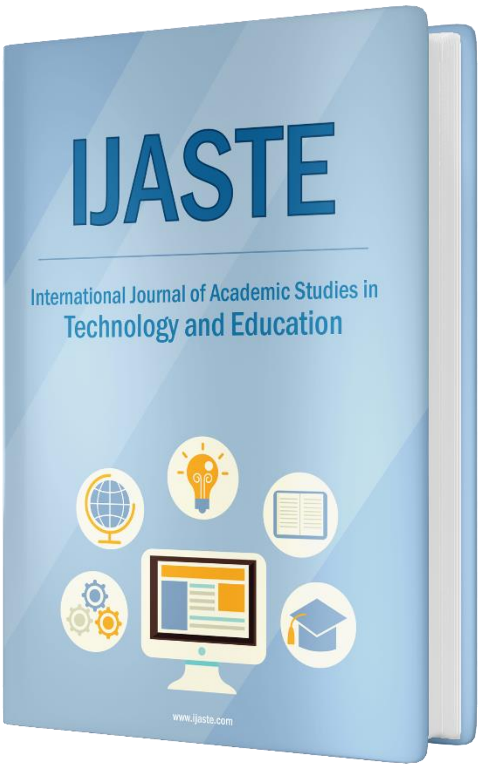

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OPEN ACCESS

A STEAM Activity to Design a Virtual Rectangular Prism Museum for 5th Graders

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Abstract

This study proposes a STEAM activity for teaching rectangular prisms to 5th-grade students, aiming to integrate science, technology, engineering, art, and mathematics. The activity is designed for four class hours, following the 5E instructional model. In the engagement phase, it was aimed to attract students' interest in the museums. In the exploration phase, students will be asked to research rectangular prisms and rectangular prisms that exist in nature and are used in architecture, and the research phase, they will be asked to create draft drawings and concrete 3D models on the computer about rectangular prisms. In the explanation phase, the teacher explains the fundamental elements of a rectangular prism, the drawing of surface area configurations, and information about whether different configurations belong to a rectangular prism in accordance with the Grade 5 learning outcomes. In the elaborating phase, students design a virtual museum of rectangular prisms and acquire achievements from the fields of science, technology, engineering, art, and mathematics. During the evaluation phase, the prepared museums will be rated via a rubric form. The proposed activity has not been implemented yet and leaving room for future studies to explore its impact on students.

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Introduction

In the 19th and 20th centuries, characterized by industrialization, individuals were expected to engage in trade, adhere to systematic rules, demonstrate fairness and honesty, and think professionally within a relatively static system (Hamarat, 2019). However, towards the end of the 20th century, as the world entered an era encompassing knowledge, technology, and globalization, it became evident that the skills individuals possessed fell short of meeting the expectations of the new century. With the advent of the digital age, creativity, and problem-solving skills have become highly valued, and individuals are now expected to excel as part of a team (Larson & Miller, 2011).

In the 21st century, the use of information and technology has become increasingly crucial. To access quality information and effectively utilize technology for personal development and growth, individuals need to possess certain skills. 21st-century skills refer to the abilities that enable individuals to be self-sufficient and more competitive in the world of technology (O'Neal et al., 2017). These skills generally encompass collaboration, communication, digital literacy, problem-solving, critical thinking, creativity, and productivity (Hebebci & Usta, 2022; Voogt & Roblin, 2012). The 21st century is characterized by rapidly evolving technological and scientific advancements. These developments have brought about a shift in the skills needed by societies and the business world. In response to these changing needs, the STEAM (STEM+ART) education approach has emerged as a highly relevant and effective method. The STEAM (Science, Technology, Engineering, Art, and Mathematics) approach combines the disciplines of science, technology, engineering, and mathematics (STEM) with the arts, providing a comprehensive and interdisciplinary framework that fosters critical thinking, inquiry, and dialogue (Cook, 2012; Belardo, 2015; Turner, 2017; Hebebci, 2021; 2023). STEAM is used as a tool/method that can make significant contributions to the development of students' cognitive, affective, and psychomotor skills (Topuz et al., 2019). According to Türk and Korkmaz (2023), STEM activities improve students' problem-solving abilities and success levels in mathematics courses.

STEAM is an interdisciplinary approach that encompasses the fields of science, technology, engineering, art, and mathematics. It is regarded as a significant instructional technique in modern education, emphasizing experiential learning and fostering connections between industry, academia, and society (Tsupros et al., 2009). The need for individuals who are well-equipped, capable of working collaboratively, and proficient in utilizing technological tools has increased in response to evolving technologies, changing needs, and new requirements. STEAM provides students with opportunities to engage in project-based, collaborative work and experiential learning, enabling them to gain tangible experiences and make sense of the world around them. Students who receive STEAM education can apply their knowledge gained from the fields of science and mathematics to create solutions for real-world problems, utilizing engineering principles and technology (Kennedy & Odell, 2014). One of the most popular technological educational tools recently is virtual museums.

A Virtual Museum is defined as a museum that hosts digital objects and their information prepared by utilizing different media possibilities, in uninterrupted communication with the visitor, going beyond the usual communication methods to meet various forms of access, and not requiring a physical space to enable worldwide access (Schweibenz, 2004). Düzgün (2007), on the other hand, explained it as museums that host digital objects and their information prepared by utilizing different media opportunities, in uninterrupted communication with the visitor, going beyond the usual communication methods to meet various forms of access, and not requiring a physical space in order to enable worldwide access. The most functional feature of the virtual museum is that it provides an easily accessible virtual circulation by digitizing the museum collection and presenting it to the museum audience online (Çolak, 2006). It makes art and culture livable for those who cannot spare time to visit museums or live in geographically distant regions (Teather, 1998 as cited in Barlas Bozkuş, 2014) and provides visitors with the opportunity for simultaneous discovery, interaction and participation (Salar, 2009). Thus, it saves visitors from being passive and encourages them to be active sharers and participants in a democratic environment (Karadeniz et al., 2015).

In conclusion, virtual museums can be incorporated into educational programs as conveniently accessible learning settings thanks to their extensive and rich collections. However, the interaction between the student and the learning environment is essential for the effective use of virtual museums as a teaching tool. The teachers, who are meant to direct the learning process, are anticipated to play the main role in this interaction (Arabacioglu & Okulu, 2021). Lesson plans can serve as models for lessons and show a teacher's pedagogical style, method of teaching, or technical expertise for the benefit of a learning community's professional growth (Morales et al., 2020). According to Namdar and Kucuk (2018), tests on lesson plans can give prospective teachers experience in a variety of areas, including developing science-based questions for an inquiry-based course, alternative assessment and evaluations, and data gathering and analysis. The fact that the STEAM approach is new in Türkiye and that resources on sample lesson plans and activities are more limited is seen as a need in the literature (Kızılay, 2021). It is believed that the inclusion of a sample activity for this need in the study will be beneficial for teachers and the literature.

Aim of the Research

This study aims to propose an activity for 5th-grade students, aligned with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach and based on the 5E instructional model. The proposed activity focuses on designing a virtual museum of rectangular prisms. Through this activity, students will have the opportunity to acquire knowledge and skills in the fields of Science, Technology, Engineering, Arts, and Mathematics (STEAM).

Method

This research includes an activity proposal that deals in detail with the process of preparing a virtual museum about rectangular prisms. According to Bybee (2009), activity based school programs that include instructional models have the potential to develop 21st century skills. This research includes an activity proposal designed according to the 5E Model that deals in detail with the process of preparing a virtual museum about rectangular prisms.

Designing the Lesson Plan

The 5E instructional model enables learning a new concept or trying to understand a concept in depth. It includes skills and activities that stimulate students' research curiosity, satisfy their expectations, and focus them on an active search for knowledge and understanding. It is suitable for students of all ages, including adults. Each of the 5E phases begins with the letter "E" and represents a distinct stage of the learning process: Engage, Explore, Explain, Elaborate, and Evaluate (Eisenkraft, 2003). The phases of the 5E Model are presented with details in Figure 1.

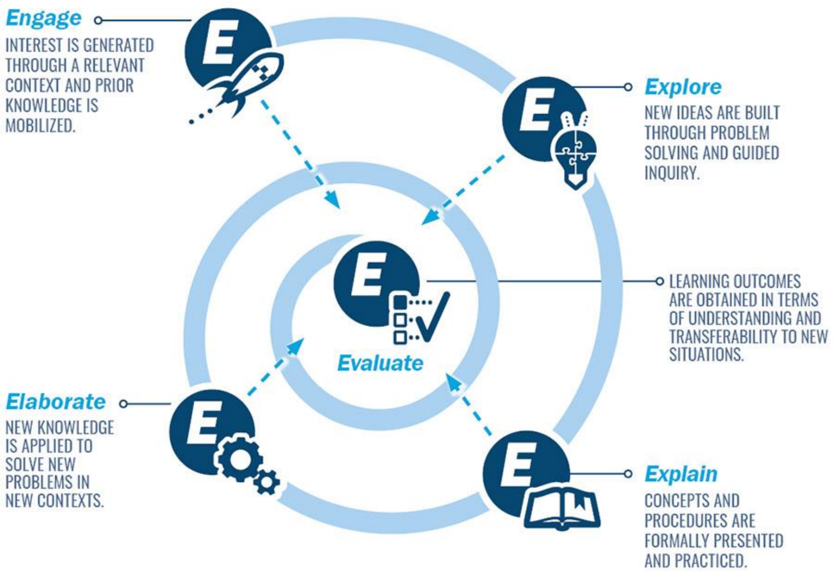

Figure 1. The 5E Model (International Science Teaching Foundation, 2022)

The learning outcomes for different disciplines, the activity plan, and the rubric form to be used as an assessment tool were selected and created based on the opinions of experts (a mathematics education specialist, a science education specialist, a visual arts education specialist, an information technology education specialist, and a technology design education specialist).

Results

Activity Title: Virtual Rectangular Prism Museum
Grade Level for the Activity: 5th grade
Recommended Duration for the Activity: 4 class hours
Learning Outcomes:

Mathematics (MEB, 2018a)

M.5.2.4.1. Recognizes rectangular prisms and identifies their fundamental elements.
M.5.2.4.2. Draws surface area configurations of rectangular prisms and determines whether given configurations belong to rectangular prisms.

Science (MEB, 2018b)

F.4.8.1.1. Defines a problem in daily life.
a. The problem should aim to develop tools, objects, or systems used or encountered in daily life.
b. At this stage, the problem should be approached within the criteria of materials, time, and cost.
F.4.8.1.2. Generates potential solutions for the problem and selects the appropriate one based on comparisons and criteria.
F.4.8.1.3. Designs and presents the product.
a. Product design and construction should be done within the school environment.

Engineering (MEB, 2018c)

TT.7.B.2.1. Makes draft drawings for his/her design.
TT.7.B.2.2. Converts draft drawings into two-dimensional visuals with the help of a computer.
TT.8.B.1.2. Converts draft drawings into three-dimensional visuals with the help of a computer.
TT.8.C.3.4. Designs a product using the engineering design process.
Art (MEB, 2018d)

G.6.1.2. Utilizes different materials and techniques when creating visual art.
G.6.1.4. Reflects ideas in visual art based on selected themes and subjects.
G.6.1.5. Uses perspective in visual art.
G.6.1.9. Applies art elements and design principles when creating visual art.

Technology (MEB, 2018e)

BT.5.D2.3. Uses information technology tools for research.
BT.3.D3.1. Conducts basic-level research on the internet.
BT.3.D4.1. Researches a topic using the internet.
BT.3.D4.2. Shares research findings with classmates in the classroom.

Stages of the Activity

Engagement Phase

The teacher initiates the activity by captivating the students' attention through the presentation of various museum photographs, followed by a virtual tour of the Tales Mathematics Museum (Figure 2). Subsequently, the teacher engages the students with the following inquiries:

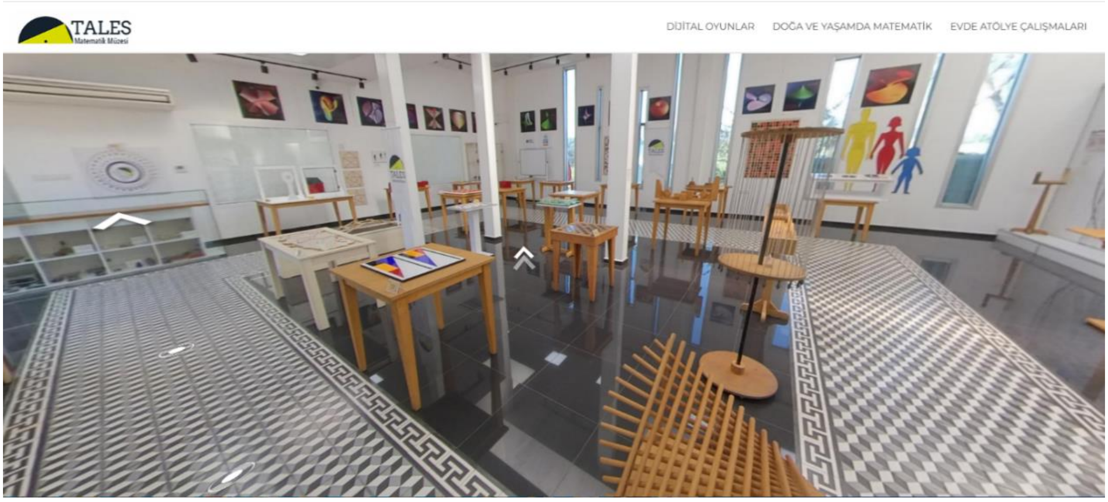

Figure 2. Tales Mathematics Museum (QNB Finans Bank Tales Mathematics Museum, 2021)

- Have you ever visited a museum before?
- What exhibits did the museums you visited showcase?
- Have you ever taken a virtual museum tour?
- Have you ever encountered a mathematics museum?
- If you were going to design a museum focused on rectangular prisms, what elements would you include?

Moreover, the teacher poses questions regarding the definition of a rectangular prism and its fundamental elements.

Exploration Phase

Building upon the responses gathered during the introduction, the teacher prompts the students to conduct research as part of the exploration stage. The students delve into the topic of rectangular prisms, their fundamental elements, and surface area configurations while examining visual representations. Based on their research findings, the students create draft drawings depicting the characteristics and surface area configurations of rectangular prisms, subsequently utilizing the Paint 3D program to transform their drafts into three-dimensional models.

Explanation Phase

During this stage, the teacher facilitates a discussion based on the students' research and visuals, delving into the concept of rectangular prisms, their fundamental elements, and various surface area configurations. The students present their research and visuals to the class, allowing for a collective evaluation of their accuracy and completeness. Subsequently, the teacher explains, summarizing the topic and addressing any misconceptions.

Elaboration Phase

In this stage, the teacher informs the students that they will design a virtual museum dedicated to rectangular prisms. The students are divided into groups of five and, under the guidance of their teacher, proceed to design a virtual museum by creating user accounts on the "www.artsteps.com" website. Following a set of steps provided by the teacher (Figures 3-6), the students incorporate their drawings, non-copyrighted visuals, and information related to the characteristics, fundamental components, and surface area configurations of rectangular prisms. The information must be displayed upon clicking on the visuals. Additionally, the students pay attention to the principles of visual art design during the creation of their museum designs.

Evaluation Phase

Upon completing their virtual museums, the students generate links using websites that offer free QR code generation. These QR codes can be displayed within the school premises, providing access for all students to explore the virtual museum through the school's website and social media accounts. Utilizing virtual reality goggles and smartphones, students can embark on a virtual museum tour where they encounter photographs, three-dimensional visuals, and explanations related to rectangular prisms, their fundamental elements, and surface area configurations. The designs of the groups that complete their museums are evaluated by a committee comprising an art teacher, a science teacher, a mathematics teacher, a technology and design teacher, and an information technology teacher using the rubric form depicted in Figure 7.

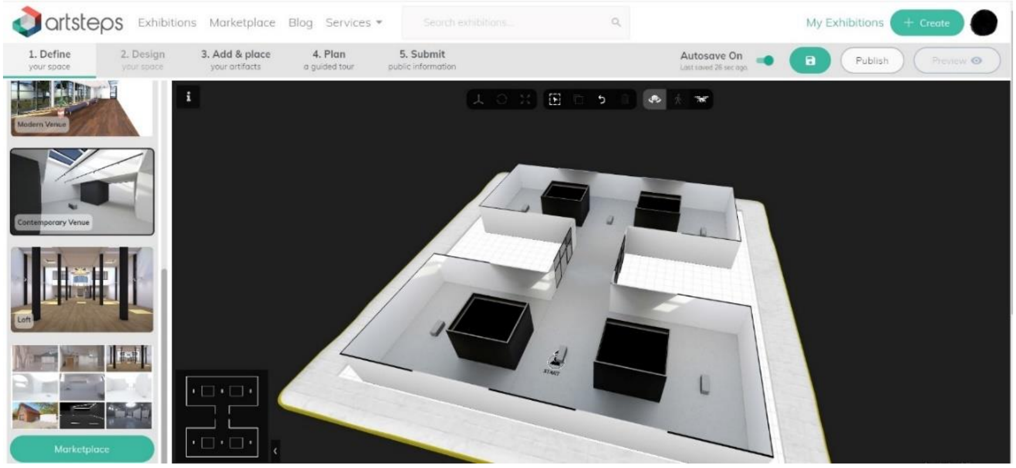

Figure 3. Designing the Museum

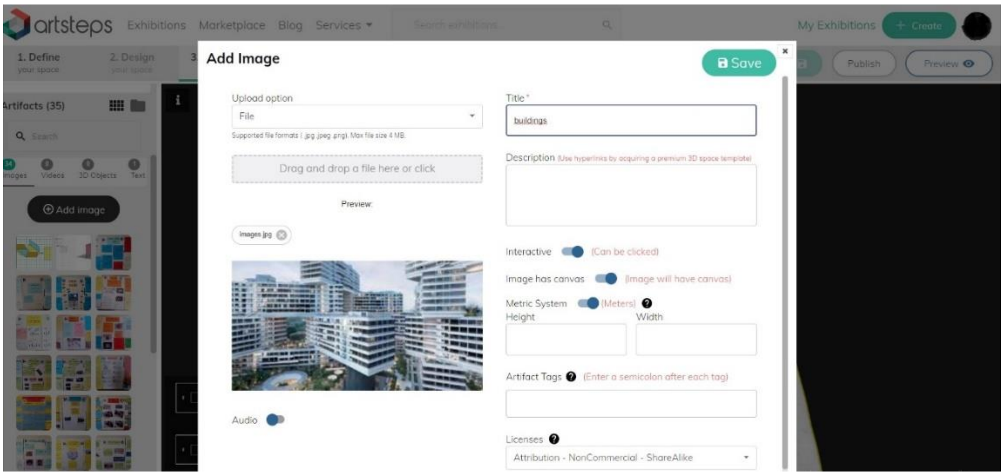

Figure 4. Uploading Images

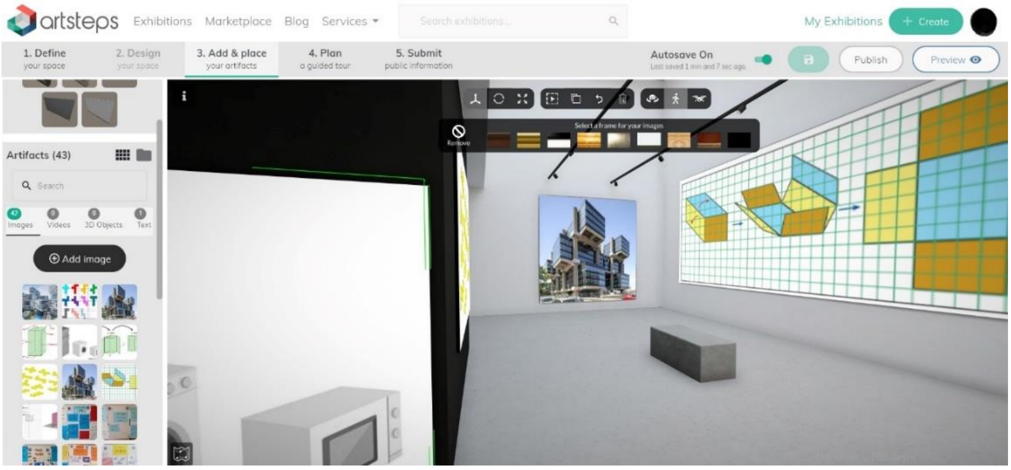

Figure 5. Adding Items

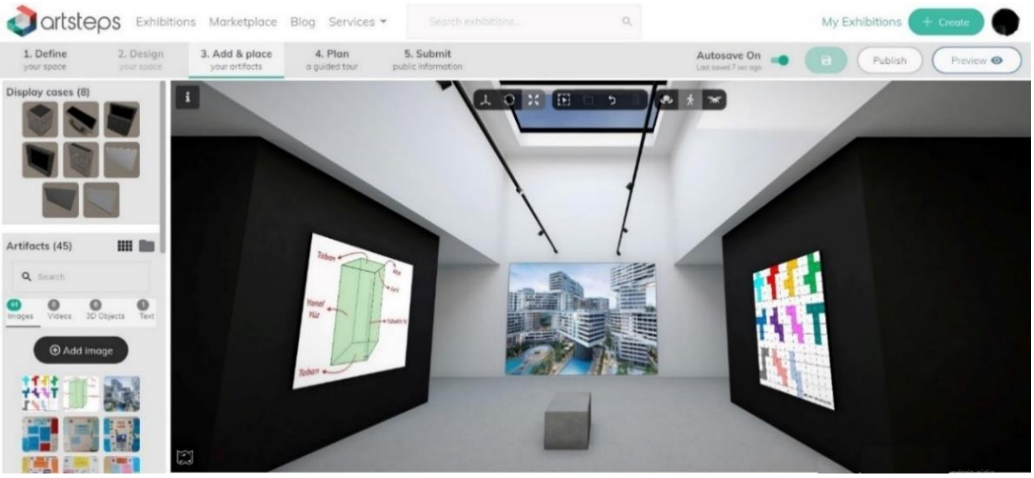

Figure 6. Preview of the Museum

	Virtual Museum Design Rubric Evaluation Form				
	Criterias				
	Scoring	**1**	**2**	**3**	**4**
A	**Content**				
1	Is the subject and purpose of the museum clearly stated?				
2	Are the exhibited artworks or information relevant, accurate, and complete?				
3	Does the content offer variety and richness?				
B	**Visual Design**				
1	Are the colors, graphics, and visual elements harmonious and appealing?				
2	Is the page layout and navigation user-friendly?				
3	Is visual hierarchy and emphasis used appropriately?				
C	**Interactivity**				
1	Are there interactive elements for user engagement?				
2	Have interactive experiences been effectively utilized to enhance the learning experience?				
3	Is it easy for users to navigate between exhibits?				
D	**Technical Implementation**				
1	Has the virtual museum been presented on a user-friendly platform?				
2	Are there any technical issues or errors present?				
3	Does it function smoothly on mobile devices and different browsers?				
E	**Creativity**				
1	Does the design incorporate original and creative ideas?				
2	Does it demonstrate a unique and interesting approach to the museum experience?				
3	Are there original content and design elements utilized?				
	Scoring Scale				
	4: Excellent - The criterion is met exceptionally well.				
	3: Good - The criterion is met satisfactorily.				
	2: Needs Improvement - The criterion is partially met and requires improvement.				
	1: Weak - The criterion is inadequately met and requires significant improvement.				

Figure 7. Evaluation Form

Discussion and Conclusion

This study aims to present an activity proposal that is compatible with the STEAM approach and based on the 5E instructional model. The proposed activity focuses on designing a virtual museum of rectangular prisms and offers students the opportunity to gain knowledge and skills in Science, Technology, Engineering, Art, and Mathematics. In this study, the steps of a virtual museum activity developed in accordance with the STEAM approach are presented in detail. The activity aims to integrate the outcomes of science, technology, engineering, art, and mathematics disciplines in an interdisciplinary manner (Kennedy & Odell, 2014). In the process of transferring the outcomes related to the mathematics course to the students, students can use their technology skills to acquire outcomes in this field. In addition, students can develop engineering skills by participating in the design process. In the activity, examining the rectangular prism, its fundamental elements, and different surface area configurations aims to increase students' acquisition of the rectangular prism. It is assumed that paying attention to visual elements in the design process will contribute to the development of students' competencies in the fields of art, technology, and engineering.

Since the STEAM activity was proposed in the study, it is limited in terms of concrete results regarding its impact on students. For this reason, in different studies, the effects on students can be examined by using the activity proposed in the study. This activity can be used as a sample lesson plan that effectively combines STEAM education and virtual learning tools. Educators can use this activity to develop students' STEAM skills and concretize mathematical concepts. In addition, this activity is also suitable for building students' research skills and developing their ability to use technology effectively. Going further, sharing virtual museum designs and encouraging students to visit each other's virtual museums can be encouraged (Karadeniz et al., 2015). This can enable students to learn from each other and exchange ideas in an interactive learning environment.

When the students have finished their virtual museums, they create links utilizing websites that provide free QR code generation. These QR codes can be put on the school premises, allowing all students to explore the virtual museum via the school's website and social media profiles. During the implementation process, after the activity is designed, the application of the site can be installed on mobile devices and placed on virtual reality glasses, allowing students to virtually walk around the museum. Thus, taking into account the fact that virtual museums are independent of space (Schweibenz, 2004), the number of participants who can visit the museum can be increased, and the event can be spread to large masses.

Recommendations

This virtual museum activity, under the STEAM approach proposed in the study, was prepared according to the 5th-grade level in the subject of the rectangular prism. . Due to the dearth of such studies (Kızılay, 2021), similar activities can be developed and used at different grade levels, in different courses and subjects. In this context, virtual museums can be adapted to teaching methods other than the 5E Model in mathematics education. The activity proposed in this article has not yet been implemented. Therefore, it leaves room for future studies to investigate its impact on students.

Acknowledgements or Notes

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* The museum illustrations on this paper were obtained from the www.artsteps.com website.

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Portraits of Scientific Inquiry and Scientific Literacy Skills Development in Students

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Abstract

Parental involvement generally occurs in elementary school and begins to diminish in middle school. Enlisting parental involvement in high school science is particularly challenging given parents tend to lack their own competencies in terms of scientific knowledge while simultaneously beginning to afford students increased independence. Research was conducted for employing active, meaningful constructivist-grounded parental involvement in high school science. Students participated in constructivist science learning activities with parents that utilized a facet of involvement strategies and socially supportive practices. Parents actively participated and communicated with students during science investigations via collaborative inquiry-based activities, self-assessments, and dialogue journaling. Parents and students participated in interviews, surveys, and questionnaires, as well as maintained dialogue journals for identifying themes. Triangulation of data identified the most effective strategies for involving parents in science learning and the impact of involvement on the development of student scientific inquiry and scientific literacy skills. Data indicated an increase in the development of scientific inquiry and scientific literacy skills in both parents and students, as well as student social, emotional achievement.

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Introduction

A student's home environment and varying levels of parental support are amongst the most influential factors that impact student learning (Epstein & Sheldon, 2022; Shymansky, Yore, & Hand, 2010). Data indicates factors such as family influence and student self-interests beyond the traditional school-learning environment

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impact students' interests in core science areas and Science, Technology, Engineering, and Mathematics (STEM) education (Funk & Hefferon, 2016). In addition, collaborative learning and integrated learning experiences impact students' interests in both science and STEM and are influential in providing supportive science and STEM learning experiences for students (Barakos, Lujan, & Strang, 2012; Brown et al., 2011). While parental involvement in student learning is more pervasive at elementary grade levels as opposed to high school grade levels, highly structured, core-specific science and STEM learning takes place in high school as opposed to elementary school. The ability to support the development of scientific inquiry and literacy skills in student courses is enhanced by home engagement, and while STEM ad STEAM (Science, Technology, Engineering, Art, and Mathematics)-specific course enrollment increases during high school, parental involvement tends to decrease as students' progress from elementary grade levels high school (Epstein & Sanders, 1998; Funk & Hefferon, 2016).

Parental involvement creates a dialogue that enables an environment to exist that supports a free exchange of ideas and statements (Epstein, 1995). Social support is central in developing an environment that supports not only learning but also empowers students to attain knowledge (Mahoney et al., 2021). When students engage in group learning activities and reflect on learning, they develop an increased understanding of central principles (Luft & Pizzini, 1998). The benefits of family involvement in improving students' academic performance is well documented, as is the influence of parental involvement in science learning (Maiorca et al., 2021; Wang, Haertel, & Walberberg, 1997).

Enabling parents to participate in hands-on science activities with students facilitates direct involvement and acts as a catalyst in helping students take ownership of key concepts and the learning. Many parents report performing hands-on science activities with their children as engaging and are interested in being actively involved in their student's learning (Russell, 1996). However, parents perceive their abilities as lacking in terms of content knowledge and capacity in guiding students to develop conceptual and concrete understanding and knowledge (Silander et al., 2018). Involving parents is imperative if students are to make the connections necessary in taking ownership of new concepts. Parents provide guidance in challenging students' abilities in which the learning becomes more relevant in developing understanding of concepts (Huitt & Hummel, 2003). Utilizing parental involvement in science activities that extend to the home fosters active, collaborative engagement of students, the ability to construct knowledge, and ownership of the learning.

Constructivism

Constructivism is a teaching methodological process tool for instructors to employ in science classrooms that provides students with more control of the learning and a forum to demonstrate the acquisition of knowledge.

Constructivism provides learners opportunities to construct knowledge via experiential learning (Kolb, 2014; Piaget, 1972). Providing students and parents opportunities to engage in experiential, constructivist learning provides a forum for both parental engagement in high school science as well as home-school supports. Additionally, the process of constructing knowledge provides learners with opportunities to design investigations and utilize inquiry skills through collaboration, making decisions, and developing answers for understanding (Bruner, 1996). When students engage in constructing knowledge and self-assess their own progress, they develop a deeper understanding of curricular objectives and outcomes that enhances constructivist constructs (Dewey, 1933; Perkins, 1999).

Utilizing constructivist-grounded, interactive homework, activities, and investigations provides foundational supports for actively engaging parents to support both student self-concept and academic achievement (Battle-Bailey, 2003). Utilizing experiential, interactive homework, activities, and investigations also supports students when they partner with parents, draw conclusions, and construct knowledge regarding home learning activities. The interaction of parents on homework, activities, and investigations supports the academic and social development of students by providing continual feedback, guidance, and suggestions for improvement. Thus, constructivist, experiential, interactive parental involvement provides opportunities for the facilitation of ownership of science learning in students (Kolb et al., 1984; Piaget, 1972).

Supportive relationships result in emotional attachments, interpersonal skills development, and systems of supports for students to achieve and succeed (Darling-Hammond et al., 2020). In an effort to promote constructivist scientific inquiry and literacy skills development in students, enlisting supportive, reciprocal home engagement and involvement supports the whole child in terms of science learning and social skills development. Thoughtfully designed systems of supports promote social, emotional, and academic achievement for all learners (Osher et al., 2018). Engaging parents and providing homework, learning activities, or scientific investigations ground in inquiry provokes active learning, questioning, and applications of knowledge (Darling-Hammond et al., 2020).

Factors in Declining Parent Involvement

Home-school relationships decline at the secondary level, which often inhibits active parent involvement. The decline in parental involvement at the high school level is influenced by students beginning to establish independence as adolescents and parents enabling student self-sufficiency (Catsambis & Garland, 1997; Epstein & Sheldon, 2022). Moreover, parents perceive diminished confidence in terms of their own science content knowledge, which severely lessens and challenges parental involvement in high school science learning. Adolescents do, however, need the continued guidance and support of parents as they mature and assume greater and responsibilities. Major areas of decline include discussions about school, homework, and assisting students with homework (Epstein et al., 1999).

As a countermeasure to this phenomenon, teachers at the secondary level can foster greater support by engaging parents in learning activities to form partnerships and support students. Actively engaging and creating dialogue with parents in learning activities facilitates enhancing learning opportunities. (Epstein & Sanders, 1998; Epstein et al., 1999; Rutherford, Anderson, & Billig, 1995). Relationships between parents and children change as students mature. Children tend to become more confident in their abilities while parents tend to become less confident in their ability to engage in course content. A supportive, trusting atmosphere between the home and school is crucial for facilitating a relationship in which students and parents' partner with the school on interactive inquiry activities and self-assessments (Darling-Hammond et al., 2002; Darling-Hammond et al., 2016).

Facilitating the Development of Scientific Inquiry and Scientific Literacy Skills

The National Science Teaching Association (NSTA) encourages parents to become actively involved with science learning at school, partner with students, and engage in direct communications with science teachers to encourage students to engage in STEM (NSTA, 2009). Likewise, the National Parent Teacher Association (NPTA) provides a framework for how families, parents, and students should work together as active partners with schools. The NPTA's standards advocate for family-school relationships that are welcoming for all families, proactively communicative, and to forge partnerships for setting academic, social, and emotional goals for contributing to classroom learning and at home learning (NPTA, 2022).

Factors, such as the learning environments of learners and teachers' pedagogical and methodological positionality directly impact scientific literacy development of students (Palines & Cruz, 2022). Data also indicates that high school students with poor scientific inquiry and literacy skills do not use critical thinking skills for analyzing information. Probable cause data indicates these students obtain little joy in learning and that the development of higher-level thinking skills directly correlates to the degree students take ownership of the learning. Additionally, a number of influential factors impact academic achievement, including home learning resources and parental instruction and involvement (Shymansky, Yore, & Hand, 2010). For students to be actively involved, they need to become self-directed in learning. When students analyze and prioritize questions they propose with parents, they are empowered to derive explanations about the world around them. Students are better able to take control of the learning and make connections based on their inquiries.

Students develop scientific literacy through processes that provide them opportunities to experiment, employ hypothetical-deductive reasoning, and evaluate findings (Bowyer, 1990). Scientific literacy is also a predictor of student inquiry behavior, which supports the acquisition of literacy skills (Wen el al., 2020). Increasing student scientific literacy skills is a life skill students can employ as lifelong learners. Providing students a guided inquiry-based learning environment supports students' science achievement for developing both scientific inquiry and literacy skills (Wen el al., 2020).

Instructional Strategies for Engagement and Learning

Interactive Homework

Although parents begin to feel less confident about helping students with science homework as they progress from primary to secondary school, parent involvement impacts student perceptions and motivation to learn. Interactive homework is situational and socially constructed to directly engage parents or family members in homework activities (Epstein et al., 2021). Providing students repeated interactive, socially supported homework facilitates the development of individual interest in science learning (Renninger & Su, 2012). When parents demonstrate a genuine interest in homework, their interest facilitates student interest, which influences self-directed and self-managed homework assignment completion (Battle-Bailey, 2003). Interactive homework is a catalyst for essential interactions amongst the school and home, and for child rearing by the adults responsible for providing care for learners (Walker et al., 2004).

Reflections via Dialogue Journals

Providing parents and students opportunities to engage one another via interactive homework facilitates students leading conversations regarding school learning. These positive, student-led conversations are pro-social and lead to positive feelings in parents regarding insight of high school student learning (Epstein et al., 2021; Howard et al., 2020). Providing Parents and students interactive homework also provides opportunities for parents and students to ask questions, self-reflect, and self-assess. Dialogue journal writings can be pen-and-paper or electronic, but either way, they provide further opportunities to memorialize perceptions, questions, and knowledge for deeper learning. The process of recording thoughts is relational and creates a back-and-forth rapport between teacher, students, and parents (Chan & Aubrey, 2021; Stillman et. al., 2014).

Self-Assessments and Formative Assessments

Student self-assessments positively impact student achievement and self-regulated learning. When self-assessments occur through meaningful learning activities, students engage in learning-oriented self-reflections for improvement (Yan, 2020). Students are frequently evaluated through the use of summative assessments, which are final grades for a particular assignment, exam, or unit of study. Formative assessments are ongoing and afford students opportunities through feedback to repeat performances for mastery. Formative assessments also influence self-regulated learning. Science teachers should develop and employ both formative and summative assessments to provide students experiences with multiple modes of assessing (Artler & Spandel, 1992). Enabling students to initiate self-assessments during learning activities also augments the effectiveness of formative assessments (Lee et al., 2020).

Conceptual Framework

The conceptual framework of this qualitative phenomenological study involved employing an in-depth analysis of a phenomenon using multiple data sources within bounded, real-life, contemporary contexts or settings (Creswell & Poth, 2018; Merriam & Tisdell, 2016; Teddlie & Tashakkori, 2009). Literature reviewed supports the assertion that it is imperative for parents to be central in their child's education. For this reason, this study utilized the involvement strategy of requiring parents to conduct an interactive investigation inquiry activity with their child and to document growth and performances by maintaining weekly entries in dialogue journals. These personal reflections and self-evaluations by students and parents served as a method for documenting the development of scientific inquiry and literacy skills and ownership of the learning in students.

Research Objective

The objective of this study was to identify a model of the most effective strategies and methodologies that could be successfully employed at the high school level to enlist parental participation with students during science inquiry investigations. As children progress from lower grade levels to upper grade levels, the level of parental involvement decreases. These data present a negative correlation in an inverse relationship of home-school involvement, which was the impetus for the research conducted. Parents and families may possess a partnership with the school during the duration of a child's education, but parent and family involvement decreases as students advance from elementary to high school (Epstein & Sanders, 1998).

Research Questions

This study was conducted to determine the following research questions:

1. What are the most effective strategies and methodologies that can be successfully employed at the high school level to enable and empower parents to research with their child and document growth and performances during science inquiry investigations?

2. In which ways does parental involvement in high school impact or contribute to the development of scientific inquiry and scientific literacy skills in learners?
3. What are the social, emotional implications of parental involvement with students as a result of strategies and methodologies employed in this study?

Method

Research Design

This study employed a qualitative, emergent phenomenological design based in the tradition of portraiture, which shares many of its features with ethnography, case study, and narrative (Lawrence-Lightfoot & Davis, 1997). Utilizing a qualitative, emergent phenomenological design also provided objective and subjective perspective with respect to the impact of shared experiences on parental involvement and scientific knowledge acquisition. (Creswell & Poth, 2018). The intersection and interconnectedness of shared experiences provided an understanding of the essence of the phenomenon being studied (Prosek & Gibson, 2021). Collectively, utilizing a qualitative, phenomenological construct provided a framework for interpreting emergent themes, analyzing data, and making meaning of the influence of parental involvement in high school science.

Data Collection Procedures

Dialogue Journals

One hundred thirty-one parents and students created and maintained weekly dialogue journals. As students engaged in constructivist, interactive science activities with parents, students first completed journal entries, read and responded to by parents and then provided to the classroom teacher at the end of each week. The classroom teacher reviewed, commented, and returned journals to students at the onset of the next week.

Parent Ranking Survey

One hundred twenty-six parents completed a ranking survey with respect to the most effective strategies employed during the study. The survey included the possible ways parents may have been involved and interacted with their child during the inquiry activity.

Open-Ended Questionnaires

During the course of this study, 118 parents completed the open-ended questionnaire. One hundred nineteen students completed the open-ended questionnaires. Parents and students participated in completing self-assessments regarding dialogue journals and designing rubrics during the study to measure and record student growth and success as a result of students constructing understanding.

Student Survey

One hundred twenty-nine students completed a survey on the most effective strategies utilized over the course of the study. Students were provided self-assessment opportunities on surveys. These data were triangulated and utilized to discern the development of self- responsibility and ownership of the learning based on student self-assessment responses.

Interviews

The researcher conducted one-on-one interviews with 20 pairs of participating parents and students. Interviews were one-hour in length and were employed to qualify findings and develop an understanding of parent and student feelings and perceptions. Interviews were transcribed and coded by employing inter-rater reliability. Participants were provided opportunities during interviews to provide self-assessments regarding the development of self-responsibility and ownership of the learning. Interviews also focused on the impact the study had on students' scientific research development.

Results

Emergent themes between participants were codified to determine correlations. Cross-interpretations and triangulation of attitudinal data assisted in the identification of emergent themes and improved trustworthiness of these data through inter-rater reliability. Themes from data were compared to one another from participants' dialogue journals, open-ended surveys, questionnaires, and one-on-one interviews. Student self-reflections empowered students and served in accurately measuring progress and the acquisition of scientific inquiry and scientific literacy skills. Consequently, these data were also indicators of students developing self-responsibility and taking ownership of the learning.

Students and parents engaged in creating self-assessments and rubrics for use in classroom activities with teachers. These strategies and multiple forms of data measured the development of problem-solving skills and the accuracy of student-developed products and rubric effectiveness. Themes identified from these data were compared to data in students' self-assessments to view patterns more clearly. Triangulating these forms of inter-rater data enabled the identification of relationships amongst themes and subthemes by comparing and contrasting codified data. Data collected through parent and student self-reflections and self-assessments in dialogue journals enabled the discernment that engaging in constructivist problem solving with parents at the high school level resulted in an increase in students developing self-responsibility and ownership of the learning. Students maintained portfolios with parents regarding scientific engagement artifacts for self-review.

Dialogue Journals

These personal reflections and self-evaluations by students and parents served as a method for documenting the development of scientific inquiry and literacy skills, feelings regarding experiences, and ownership of the learning in students.

Parent Ranking Survey

The survey provided insight regarding the ways parents were involved and interacted with their child during the inquiry activities. Parents indicated the methods they employed and ranked the methods according to feelings of their individual importance or effectiveness (Table 1 and Figure 1).

Table 1. Parent involvement methodologies of perceived importance ranked

Methodology	Percentage of Importance
Self-Assessing Your Child's Work	34.9%
Writing Dialogue Journal Entries	28.6%
Completing Homework Activities	11.9%
Making a Rubric with Your Child	8.7%
Talking with Your Child About Performance, or Progress	7.9%
Making Self-Reflections	5.5%
Other	2.5%

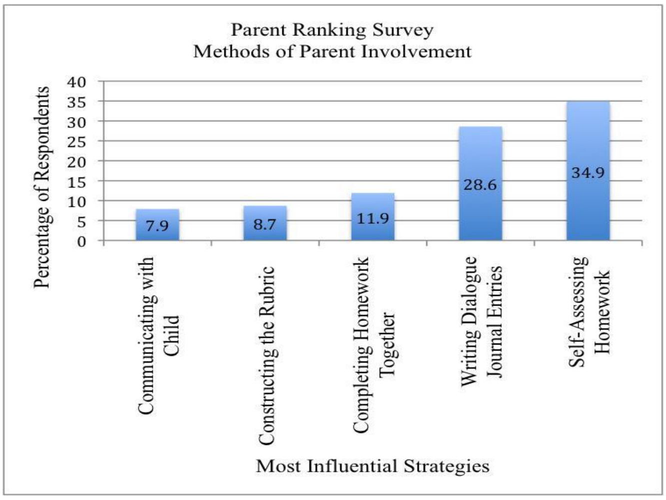

Figure 1. Parent rankings of most influential strategies

Open-Ended Questionnaires

The questionnaires revealed students' reflective practice in terms of the various products they produced and self-assessed information that was important and vital. Student self-reflections empowered students and served in accurately measuring progress and the acquisition of scientific inquiry and literacy skills. Consequently, these data were also indicators of students developing self-responsibility and taking ownership of the learning.

Student Survey

These self-assessment opportunities enabled the investigator to identify patterns and themes. Data indicated students were empowered to take ownership of the learning through reflecting and modifying their performances to achieve and succeed (Figure 2).

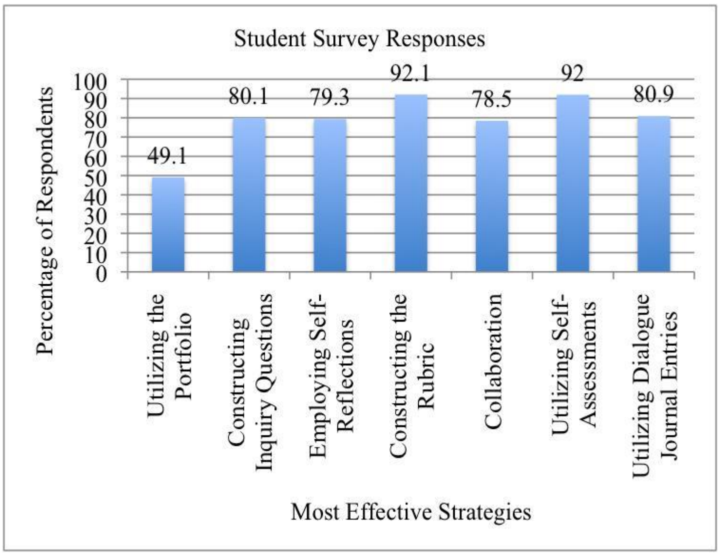

Figure 2. Student rankings of most effective strategies

These data were compared, contrasted, and correlated with findings from parent survey responses regarding the most effective strategies for engaging students and facilitating acquisition of student learning (Figure 3). Correlations were performed between all of these data sources in determining effectiveness of these strategies and methodologies.

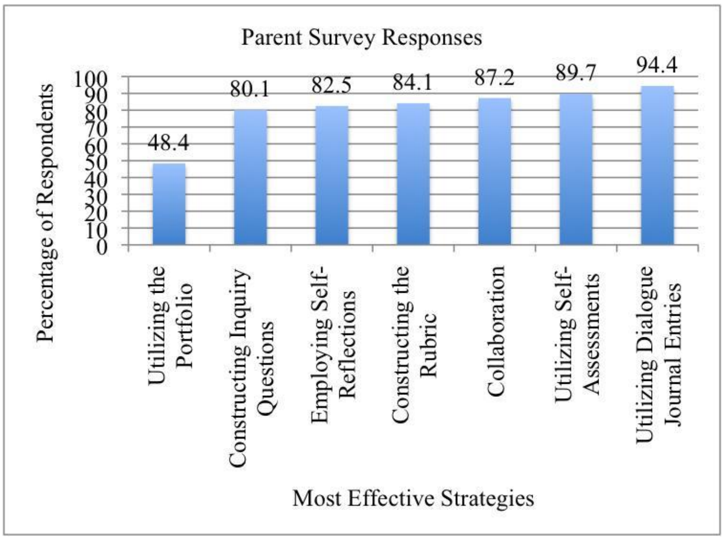

Figure 3. Most effective strategies for engaging students

Interviews

The researcher conducted one-on-one interviews with 20 pairs of participating parents and students. Interviews were employed to qualify findings and develop an understanding of parent and student feelings and perceptions. Interviews were transcribed and coded by employing inter-rater reliability. Participants were provided opportunities during interviews to provide self-assessments regarding the development of self-responsibility and ownership of the learning. Interviews also focused on the impact the study had on students' scientific research development. Parental and student reflections indicated that students were provided opportunities to make self-evaluations and self-assessments of their progress and performances to make much needed adjustments to flourish as lifelong learners. Parent responses are illustrated in Figure 4 below.

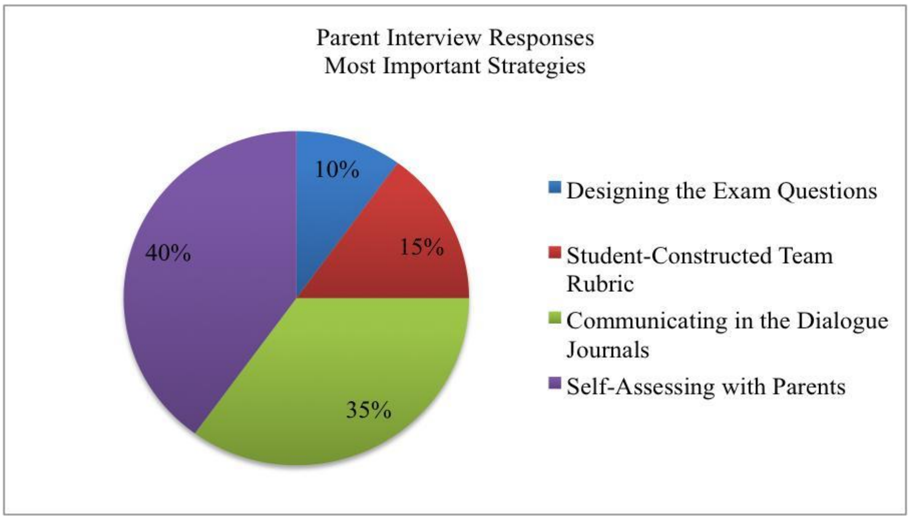

Figure 4. Parent interview responses of most important strategies

Interview data indicated the most important involvement strategies for assisting students in developing scientific inquiry and scientific literacy skills were utilizing self-assessments, designing self-assessments, and communicating in dialogue journals. Both parents and students (Figure 5) indicated the ability for students to self-assess progress was the most effective strategy. While students indicated creating a team-rubric with parents, followed by journaling, were the next most effective strategies, parents indicated the same two involvement strategies with dialogue journals followed by the rubric as most important. All three strategies are interconnected and correlate with one another, as they empower students to continually measure performance while constructing evaluations of progress.

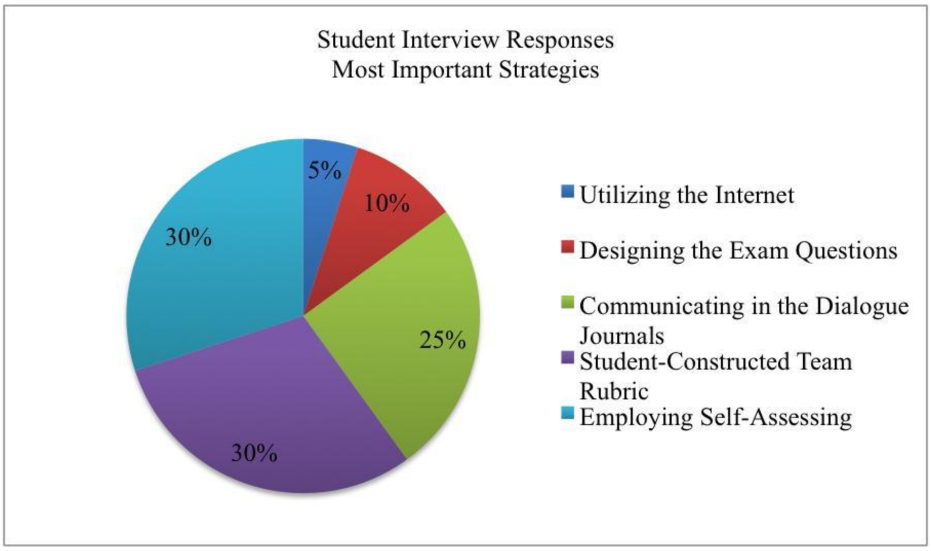

Figure 5. Student interview responses of most important strategies

Discussion

Three emergent themes were identified in all data sources (collaborative, communicative, and supportive). In addition, three major relationships were identified (interactive, proactive, and motivative). The identification of emergent themes and relationships resulted in the identification of the most effective strategies and methodologies that can be successfully employed at the high school level to enable and empower parents to research with their child and document growth and performances during science inquiry investigations. In terms of the most effective strategies and methodologies that can be successfully employed at the high school level to enable and empower parents to research with their child, interactive homework, collaborative inquiry-based activities, self-assessments, and dialogue journaling were most effective.

Data also revealed parental involvement in high school science contributes to the development of scientific inquiry and scientific literacy skills in students. The ability of students to assess their own learning in concert with reflecting and constructing rubrics enables learners to consider learning objectives and skills that reflect mastery of learning outcomes. As a result, students are positioned to proactively develop, employ and then assess scientific inquiry and scientific literacy skills. Students are empowered to develop scientific inquiry and scientific literacy skills via interactive and collaborative constructivist learning opportunities that are communicative.

In addition, parental involvement with students during high school science activities possesses social, emotional implications. The strategies and methodologies employed in this study demonstrated collaborative, involvement strategies are supportive and facilitate the development of self-responsibility and self-management skills in students. Both students and parents reported feeling motivated to learn, with data also indicating an increase in student efficacy as a result of collaborating, communicating, and self-assessing science learning.

The outcomes also indicate parental involvement must be interactive to ensure increased parental involvement. In order for this model to be effective in other schools and communities, parents and students must be provided interactive, collaborative opportunities supported by dialogue journaling. It is not enough to simply invite parents to perform science learning activities with students. Parents must be provided opportunities to engage in active, reciprocal dialogue and constructivist learning opportunities that are challenging and motivational. Parents believed they possessed ownership in the academic and social aspects of this study, which resulted in increased efficacy and social change in the learning community. In order for this model to be applied in other communities, schools, and districts, teachers need to utilize their skills and employ interactive inquiry activities that enable parents and students to utilize questioning strategies and ongoing self-assessments. Parents and students believed the self-assessments and self-reflections they created resulted in a collegial environment conducive to fostering scientific inquiry and scientific literacy acquisition. The science learning parental involvement proposed in this study emphasized social learning opportunities concurrent with cognitive learning opportunities.

Conclusion

The outcomes of this study supported the active involvement of parents in high school science fosters motivation, ownership of learning, improved efficacy, and a holistic mindset to develop in students. The interactive, collaborative parent involvement strategies utilized in this study also fostered improved social skills in students. Supportive collaboration fostered motivation in students, while self-evaluations and self-reflections provided opportunities for a supportive, collaborative, and communicative environment to develop. In addition, self-responsibility and self-management skills in students increased. The results were improved student efficacy and a holistic mindset to develop not only in students, but also in parents. Lastly, authentic, interactive involvement of parents motivated parents to both engage in science learning in addition to actively partnering in learning with teachers.

The involvement strategies parents and students employed motivated parents and students to develop scientific inquiry and scientific literacy skills and take ownership of the learning. As a result, parental and student efficacy was increased and instructional practices were improved. Data indicated the increased success of students were the result of students participating in activities that utilized a facet of involvement strategies and provided students with authentic and socially constructive learning opportunities. Students believed their experiences were genuine and relevant. Many students believed the learning was memorable and meaningful. Students were an integral component of the learning and controlled the knowledge ascertained. Parents actively participated and communicated with students, which created a supportive network and partnership. Students were enabled to gain knowledge as a result of utilizing questioning strategies to derive solutions and construct meaning. Students believed they were empowered to develop scientific inquiry and literacy skills and were enabled to take control of the learning. Students were able to use these skills in developing criteria in rubric construction to note their understanding of the key concepts and learning goals. It can be concluded that utilizing these strategies on a daily basis enables students to develop skills they can use throughout a lifetime of learning.

Recommendations

Data indicates the active involvement of parents in science learning activities at the secondary level supports students' acquisition of scientific inquiry and scientific literacy skills and increased parent and student efficacy. The participants in this study believed they were able to form strong partnerships as a result of utilizing proactive communications and interactive collaborations during scientific inquiry activities. Students believed their willingness to collaborate with parents increased during the inquiry activity, which was contrary to student beliefs prior to engaging parents. Therefore, utilizing involvement activities grounded in proactive communications should be employed to encourage collaboration and improve the efficacy of both parents and students.

While parental involvement declines at the secondary level, this study provided a salient example of utilizing supportive, communicative, interactive inquiry activities to reverse this trend. In addition, parents are less likely to participate in high school science learning with students as a result of insecurities regarding parent science knowledge and inquiry skills. This study demonstrates augmenting practices to develop partnerships between the home and school enlists parental involvement in high school science. The outcomes clearly support constructing supportive high school science learning environments to form partnerships between the home and school. In an effort to reverse parental involvement trends, a combination of shared decision-making and the ability to reflect and self-assess progress are central in constructing science involvement learning environments.

Data indicated motivational support and interactive collaboration are the conditions required to successfully construct a supportive learning environment to form partnerships. Parents and students increased their sense of ownership of the learning as a result of the supportive, communicative relationship formed between teachers, parents, and students. Parent and student data indicate the most important strategy utilized in this study was the use of the dialogue journals. Dialogue journal data indicated parents felt they were partners in the decision-making and engaged in a participatory, supportive and communicative activity between the home and school. Parents perceived their involvement as genuinely received. Parental confidence increased, which resulted in parents believing they could succeed as a team with their child. High School science involvement activities must include opportunities for participatory, reciprocal, self-reflections for assessing progress. The utilization of dialogue journals provided students and parents to reflect on their performances as a team and as individuals.

The most effective strategies that can be successfully employed at the high school level to enable and empower parents to research include interactive, collaborative inquiry-based activities, self-assessments, and designing rubrics. Therefore, programs should be designed to include opportunities for students to consider curricular outcomes of their science learning by considering elements for inclusion in rubrics. The development of scientific inquiry and scientific literacy skills in students was enhanced through students being able to self-assess learning and construct rubrics for use in science learning. Collaborative parental involvement enables and empowers parents to research with their child to document growth and performances during science inquiry investigations. Parent and student data indicates self-assessments are highly effective in supporting collaboration and enables students to form questions and look for answers to their questions. Self-assessments and rubric construction are catalysts for providing a forum for these strategies to be employed and are central in designing similar programs for student success.

The outcomes of this study support actively involving parents in science learning fosters communication and collaborative skills, which fosters the development of social skills in students. The active involvement of parents fosters motivation, ownership of learning, improved efficacy, and a holistic mindset to develop in learners. The interactive, collaborative parent involvement strategies utilized in this study fostered improved social skills in students and should be employed in similar programs. Supportive collaboration fosters motivation in students. Utilizing this strategy facilitates self-responsibility and self-management skills development in students. Utilizing this programmatic design construct results in improved student efficacy and a holistic mindset to develop not only in students, but also in parents.

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Online Learning by University Students for Improved Performance in Emerging Economies: A Systematic Literature Review

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Abstract

The main purpose of this study was to investigate the uptake of online learning as a new normal by university student for improved performance in emerging economies. Objectives of this study is to determine the uptake of online learning by university students, establish effect of online learning on university student performance, and to develop a framework that promote the uptake of online learning by university students in improving their performance in emerging economies. Emerging technologies and practices, such as online learning, are reported and predicted to have the potential to influence the future of global higher education teaching and learning. Lecturers and students in emerging economies contexts are less familiar with the use of digital technologies and had to struggle hard due to the lack of proper training and skills to utilize digital technologies which are inevitable for online learning, be it synchronous or asynchronous. A systematic literature review approach was used. 219 articles were found in the Scopus database, 69 papers were selected for the study. Results showed that online learning has bought positive impact on the lives of students in improving their academic performance for universities in emerging economies. There has been limited research into the use of digital technologies and their effects on student engagement and performance in emerging economies context. The present study was therefore designed to address this gap by focusing on the use of online learning by establishing various digital tools and their roles in fostering students' online performance. This study therefore recommends a framework that promotes the uptake of online learning by university students in improving their performance in emerging economies through the four pillars of legislative framework, online leaning platforms, infrastructure, and human capital. The theoretical findings of this study therefore offer insights on policy implications for online learning practitioners and policymakers.

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Introduction

The disruption caused by Covid-19 has pushed academic institutions to focus their efforts on facilitating a swift, rapid, and unexpected transition to online education and assessment (Li, 2022). Online learning is defined as a type of e-learning which is the process of acquiring knowledge using electronic technology (El Mourabit et al., 2023). The result of these efforts is a substantive rise in e-learning, whereby teaching and learning activities are taking place remotely via digital platforms. Across the world, existing lockdowns exposed some inequalities and challenges for equal education access, especially in emerging economies (Oyedotun, 2020). During the outbreak of the COVID-19 pandemic, the abrupt shift of teaching and learning activities from the physical classroom setting to an emergency online learning environment had a significant impact (Tan et al., 2022) on student performance.

Emerging technologies and practices, such as artificial intelligence, micro-credentialing, blockchain and open educational resources, are reported and predicted to have the potential to influence the future of global higher education teaching and learning. However, a full understanding of how these technologies can be applied to facilitate teaching and learning is still lacking (Salman & Soliman, 2023). While engaging students in physical classes remains a challenge, engaging them online becomes even more challenging since online learning occurs at different times and spaces without a real sense of face-to-face interaction (Rafique, 2023). Besides, the teachers and students in emerging economies contexts that are less familiar with the use of digital technologies had to struggle hard due to the lack of proper training and skills to utilize digital technologies which are inevitable for online learning, be it synchronous or asynchronous (Rafique, 2023).

The sudden transition to online pedagogy as a result of COVID-19 in emerging ecomomies has exposed some inequalities and challenges, as well as benefits. The lack of participation and responses from the students was also mentioned as a challenge which made it difficult to know how effective classes were in online environments (Khan et al., 2020). These challenges and inequalities have now become the new realities in the educational sector of (Oyedotun, 2020) for emerging economies. Present researchers' observation and experience established that online learning is not implemented effectively in universities for emerging economies even at the postgraduate level. This is because online learning is in the early stage of the emerging economies education system. In line with this, poor internet access and students' internet skills deficiency are the major challenges to using the internet for universities in emerging economies (Endris & Molla, 2023). These problems affect the effective implementation of online learning and student performance.

In addition to these problems, the sudden transition from face-to-face to online instruction might have resulted in an entirely different learning experience for students. Lack of preparation and planning also affects the practice of online instruction (Atmojo & Nugroho, 2020). Although various studies have been conducted related to online learning, only a few studies have investigated the students' perceptions and practices of online learning and their performance. For instance, (Kulal & Nayak, 2020) conducted their study on the perception of teachers and students toward online classes in emerging economies, and the findings of the study showed that students have positive perceptions toward online learning classes which subsequently improves their performance. Thus, the main purpose of this study was to investigate the uptake of online learning as a new normal by universities for students' performance in emerging economies.

Recent research Oyedotun (2020) has emphasized the multifaceted benefits of the use of technologies in online classes and offered various strategies to employ in online learning environments. However, there has been little research into the use of digital technologies and their effects on student engagement and performance in emerging economies context. Available studies reported mostly on the constraints of online learning e.g (Nusrat, 2021; Shrestha et al., 2022) and a planned implementation and evaluation of using digital technologies. This gap in research necessitated investigation into the ways digital technologies such as online learning can be utilized in emerging economies contexts to enhance student performance. The present study was therefore designed to address this gap by focusing on the use of online learning by establishing various digital tools and their roles in fostering students' online performance by proposing a framework for online learning for university students in emerging economies. The following are therefore the study objectives; 1) determine the uptake of online learning by university students in emerging economies, 2) establish the effect of online learning on university student performance in emerging economies, and 3) to develop a framework that promote the uptake of online learning by university students in improving their performance in emerging economies. The next sections will discuss the literature review methodology, results, discussions, conclusions, and recommendations.

Literature Review

Virtual learning has been christened with varieties of names among which are online learning (Shahzad et al., 2021), distance learning, e-learning (Harsasi & Sutawijaya, 2018) and remote learning. The belief is that online learning should ameliorate some of the difficulties posed by the COVID-19 pandemic to the teaching and learning process. This medium of learning was favored because it does not require physical contact. It provides teachers and students the opportunity to achieve what traditional face-to-face teaching and learning mode does. According to (Hettiarachchi et al., 2021), virtual learning is the only medium in the contemporary world where seclusion is prioritized over socialization. The education sector has not been immune from the impact of COVID-19, as it has affected all levels of global education systems from the pre-school to the university and has also caused cancellation or postponement of academic conferences. Therefore, teaching and learning approaches have changed dramatically since the COVID-19 outbreak on (Tan et al., 2022).

Conceptualising Online Learning

Online learning (OL), also known as 'e-learning', refers to the teaching and learning online where interaction between learners and the instructor is mediated by technology and the design of a learning environment (Patricia Aguilera-Hermida, 2020). Online learning is the delivery of instruction to a remote audience using the Web. Fry (2001) also defined online learning as the use of the Internet and some other vital technologies to develop materials for education purposes, instructional delivery, and management of programs (Fry, 2001). Online learning refers to as the use of the Internet to access learning materials; interact with the content, instructor, and other learners; and to obtain support during the learning process, to acquire knowledge, construct personal meaning, and grow from the learning experience (Endris & Molla, 2023). The above definitions indicate that accessibility, flexibility, and interaction are the main components of effective online learning.

Approaches To Online Learning: Synchronous and Asynchronous

Synchronous online learning refers to live online lectures requiring students to attend the lesson in real time. Lecturers or instructors and students join in a common place real-time situation (Alzahrani et al., 2023). Synchronous learning is also supported on the virtual podium where cooperative learning occurs; instructors interact with learners through video conferencing, live chatting, live streaming, etc (Teng et al., 2012). On the other hand, asynchronous online learning uses recorded lessons uploaded by instructors to be retrieved by students at their convenience (Alzahrani et al., 2023). While the asynchronous online learning approach enables students to learn with flexibility at their own pace and comfort zone, synchronous online learning encourages students to get engaged with asynchronous activities (Fernandez et al., 2022). This shows that online classes are student-centered, which offers more flexibility for students to work cooperatively and therefore increase their performance in emerging economies. That is, there is an active involvement of students in the process of online learning, particularly in the synchronous approach which poses a challenge for emerging economies because of challenges such as network connectivity, power outages, and digital divide.

Tools Used for Online Learning

Digital technologies are inevitable for online teaching and learning as it entails both synchronous and asynchronous modalities (Rafique, 2023). Within days of the directives, many educators and colleagues at the university started exploring all forms of available video-conferencing applications and platforms (Oyedotun, 2020). Forms such as GoToMeeting, Skype, WhatsApp, ezTalk, emails, BlueJeans, and Zoom were used in addition to the Moodle platform used by some universities in emerging economies. Based on the relatively positive experience of many colleagues with the use of the, the universities purchased Zoom Enterprise versions for use by lecturers and with the help of their University's Software Department, this can be integrated into the university's learning platform, Moodle (Oyedotun, 2020). Rafique (2023) argued that creating a virtual learning environment (VLE) using learning management systems (LMSs) such as Canvas, Blackboard, Google Classroom, and Edmodo is beneficial as these contain individualized student and staff entry portal, message board, discussion forums, sections for course information, timetables, and learning resources. Various collaborative technologies can support learning including G Suite applications such as Google Docs, Slides, Forms, Jamboard, Sites, and Blogger, Microsoft applications, and Web 2.0 tools such as Padlet, Nearpod, Stormboard, Socrative, and so on. Such technologies offer various features for participation and interaction between and among its users. In general, the online learning process is influenced by various sociocultural factors related to universities, online learning platforms, peers, and lecturers. Thus, students can learn and interact with instructors and other students online wherever they want (independently) (Singh & Thurman, 2019), and instructors act as facilitators. In many platforms, embedding videos, audio clips, or external links provide access to a wide range of content and materials. Alongside, using wikis or blogging sites as LMS can be effective yet low-cost implementation. These platforms assist in enhancing student performance as these sites generate lot of interest among students.

Theoretical Framework - Models of Online Learning

The models in Table 1 below have been used in this study to inform the proposed online framework for university students' performance in emerging economies and their explanation is highlighted.

Table 1. Models of technology

Model	Explanation
(Garrison et al., 2000) 'community of learning' model	The model confirmed the value of using technologies that are pedagogically and structurally modelled. They referred to creating a cognitive, social, and teaching presence for deep and meaningful learning in online environments.
Technology Acceptance Model (TAM)	TAM proposes that perceived ease of use and perceived usefulness of technology are predictors of user attitude towards using the technology, subsequent behavioral intentions, and actual usage (Masrom, 2007).
(DeLone & McLean, 2003)	DeLone and Mclean Success Model proposed in 2003 incorporates six interrelated components of information success achievement: system quality, net benefit, information quality, user satisfaction, service quality, and use.

In the past years, it has been noted in different related research that learners have difficulty understanding chemical nomenclature and chemical formula writing. In the investigations done by Savoy (1988) and Hines (1990), it was shown that learners struggle to write chemical formulae. If learners are not able to fully understand chemical formula writing and naming, the tendency is that they will be hard up in learning concepts related to stoichiometry, chemical reactions, and balancing equations among others. This is supported by the findings of Lazonby, Morris, and Waddington (1982) in their research that learners' failure to accurately write chemical formulae is linked to their ongoing struggles in solving problems concerning stoichiometric calculations. Furthermore, in the series of tests conducted by the West African Examination Council (WAEC), the association responsible for establishing examinations in West Africa, it was revealed that many of the test takers in 1995 and 1999 had problems in naming inorganic compounds systematically and generally cannot give the IUPAC names of selected ionic compounds (WAEC, 1995 & 1999).

Since learners have issues with naming inorganic compounds, this has led to their incapability to accurately write chemical formulae (WAEC, 1994; WAEC, 2001; WAEC, 2004; & WAEC, 2005). Similarly, Baah and Krueger (2012) tested 334 senior high school students in terms of their ability to name and write the chemical formula of ionic compounds. Their study determined that students have trouble in naming and chemical formula writing and that they lack understanding of the meaning of the Roman Numeral in brackets and the role of valency in writing chemical formulae. In addition, Naah and Sanger (2012) explored learners' alternative conceptions of stoichiometric equations for electrolyte solutions.

One of the results of the study shows that among the 37 college students who participated in the semi-structured interview, there are students who exhibited confusion on how to properly use subscripts and coefficients. Confusion about the use of subscripts concerning simple compounds containing polyatomic ions was also documented by Habiddin (2014). Related to this, Habiddin (2014) also noted that learners tend to misname compounds with radicals because they fail to memorize the names of polyatomic ions. Espinosa et al. (2016) also recorded a misconception among learners in writing chemical formulae regarding putting charges to supposed to be neutral species. While students show difficulties in naming compounds and chemical formula writing, it is also good to point out that one of the results from the study of Amazona, Jr., and Vallejo (2020) shows that the student's performance in writing formulae is categorized as "nearly proficient". It appears that the students quite easily remember how to write chemical formulae.

Given the past and recent studies, it is important to note that students have difficulties in chemical formula writing and naming ionic compounds. Thus, this study is formulated to understand the misconceptions related to the difficulties of General Chemistry 1 learners in formula writing and naming ionic compounds. This present study is also considered worthwhile because it appears that little research has been done in this area. The following questions are used in conducting the study: (1) What are the students' misconceptions about formula writing and naming ionic compounds? and (2) What are the challenges of the students in formula writing and naming ionic compounds and how do they address these challenges?

Method

For this study, a systematic literature review approach was used to unpack issues pertaining to online learning on and its effect to university student performance in emerging economies. PRISMA framework was therefore used to perform the systematic review analysis, which seek to discover, assess, and synthesize the findings of all relevant individual research on online learning, student performance, universities, and emerging economies topics. Scopus database was utilised to search for relevant journal sources which then was evaluated in relation to the study objectives. The definition of the search terms served as the basis for the research. The adopted strategy to search and select the articles included in the review was defined using the following queries in Figure 1 below, the search string was restricted to Title, abstract and keywords.

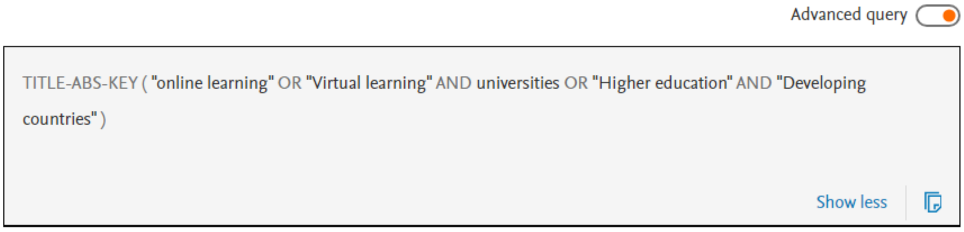

Figure 1. Search queries

The study utilized a two-tier test to gauge the performance and misconceptions of the Grade 11 learners in formula writing and naming ionic compounds. The top 10 and bottom 10 learners have undergone an interview to dig deeper into their reasons or conceptions for answering the questions in the test. The students were asked about their challenges or difficulties in answering the test and how they addressed them. The interview followed the interview protocol prescribed by Creswell (2009). After the collection of data, the gathered sets of information are summarized, taking into consideration the students' misconceptions, reasons, and processes to systematically interpret the results and understand misconceptions of students on formula writing and naming ionic compounds.

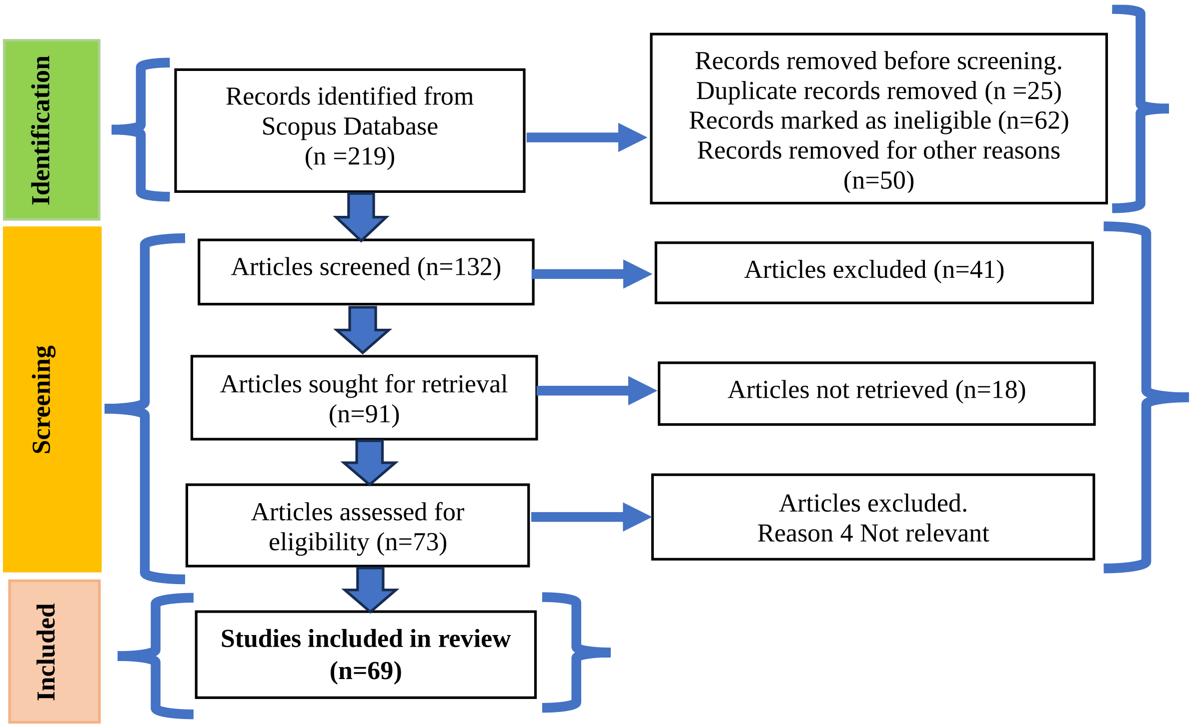

Figure 2. Systematic literature review process

Results and Discussion

This study decided to adopt some inclusion criteria to refine the sample. Only articles and reviews, papers written in English and only articles and reviews published between 2018 and 2023 as shown in Figure 3 below. The search was from all subject area documents of type- Article, review and article in the press were selected. Articles with no access to their full text were excluded. Initially, 219 articles were found in the Scopus database. The duplicate articles were removed, which led to only 132 articles left out. Now 91 articles were screened thoroughly by the authors and left with 73 articles, and 69 papers were selected for the study, which aligns with the research objectives of determining the uptake of online learning by university students in emerging economies, 2) establish the effect of online learning on university student performance in emerging economies, and 3) to develop a framework that promote the uptake of online learning by university students in improving their performance in emerging economies.

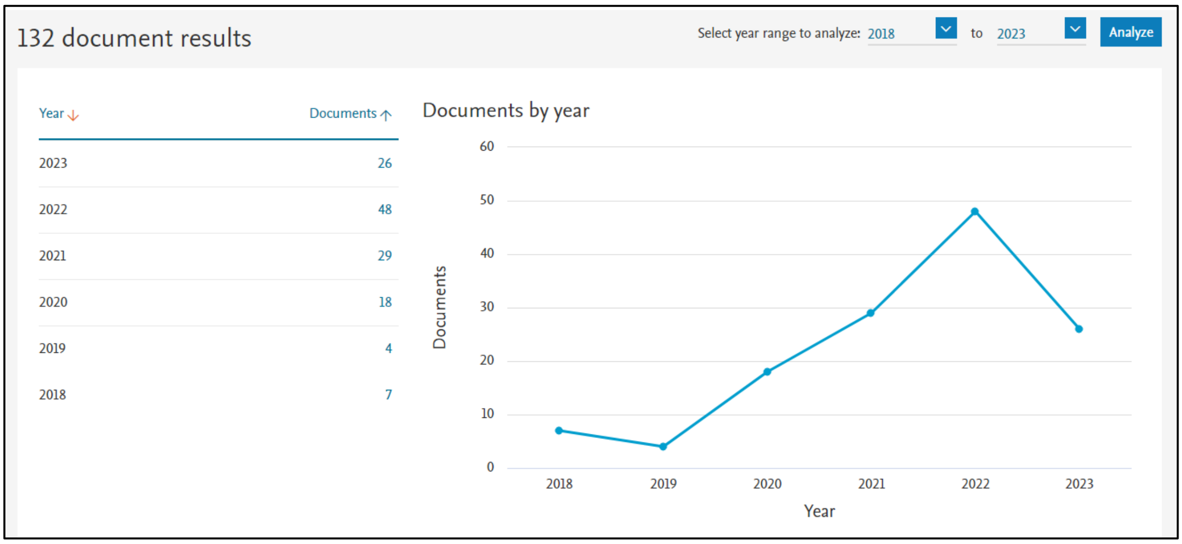

Figure 3. Screened Articles

Challenges of Online Learning for University Students in Emerging Economies

This study established that online courses might be completely or partially inaccessible to the students in emerging economies due to a poor internet connection and in many cases students may stay logged out (Mohamed Abd El-Hamed Diab & Fouad Elgahsh, 2020; Sangster et al., 2020). In emerging economies, several students, especially those who are living in rural and underprivileged areas do not have access to sufficient and efficient internet connection, which leads to several problems in their education. Figure 4 below.

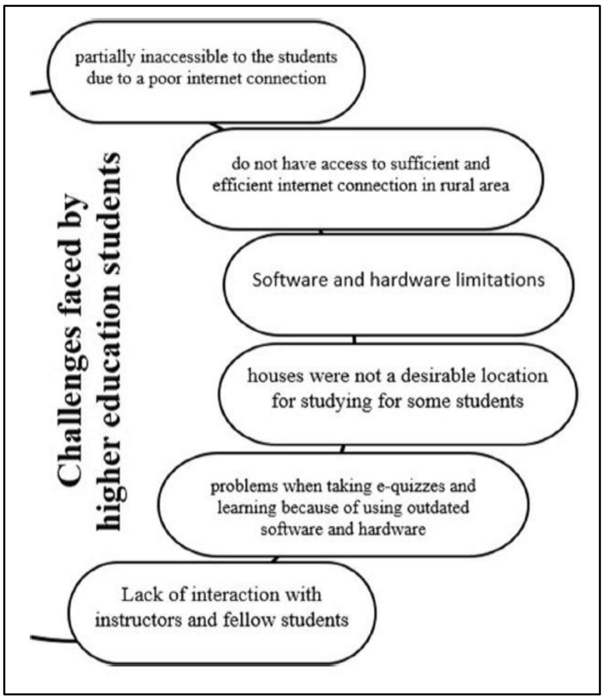

Figure 2. Challenges faced by students (Zarei & Mohammadi, 2022)

Table 2 below shows some of the challenges of online learning for students in emerging economies. These challenges inform the appropriate online leaning framework for universities in emerging economies for this study.

Table 2. Challenges of online learning

Nature of challenge	Explanation	Author
Lack of resources	• Unavailability of computers, laptops and/or tablet facilities for students to use in connecting to the online mode.	(Oyedotun, 2020)
Course delivery problems	• Reduced student–teacher engagement: As can be noted in some of class experiences while teaching, many students no longer engage in class discussion as they do in the traditional face-to-face class and there is often little or no feedback when questions are asked.	(Lavy & Naama-Ghanayim, 2020; Orkibi & Tuaf, 2017)
	• Slow and extended work: Students are unable to submit assignments when due, lecturers are unable to keep up with their schedules because of either power-cuts or internet problems.	(Oyedotun, 2020).
	• Compromise with deadlines: On many occasions where students and staff were unable to use technological tools to get work done in a timely manner, they were compromising with deadlines and even with the standard expected of their delivery because of	(Tan et al.,

	other constraining factors they are confronted with.	2022)
	• The disadvantaged students preferred recorded lectures as the content delivery method, and they perceived their groupmates as supportive in their learning activities.	(Oyedotun, 2020)
Problems facing students	• Malpractices: With the online method of testing and the realities of many students' inability to utilise video services during some live class exercises and tests because of the limitation of the technological devices, students could receive assistance and help that the instructor may not be privy to • Students' inflexibility: Many students who were accustomed to the traditional face-to-face method of teaching found the online method burdensome, with some becoming rude and impolite to lecturers because of the stress experienced as a result of adjusting to online education. • Domestic affairs: The online delivery mode forced many students to be working at home where they are under enormous distractions and other domestic issues and as such, most students found it challenging to maintain focus during online teaching • Mental health challenges: Fear and anxiety surfaced among some students as a result of the sudden change.	(Sutton et al., 2020); (Oyedotun, 2020).
Cybersecurity problem	• With computers and other portable technological devices being entrenched in our daily educational and teaching lives driven by the migration of traditional learning to online mode, there abounds various kinds of breaches, exposure to viruses, hacking potentials, and other cybersecurity threats.	(Nam, 2019)
Digital divide	• The term "digital divide" refers to the disparity between those students who have and those who do not have access to computers and internet. • Generally, digital divide poses a threat to students for epistemological access. Firstly, poor digital, computer, and internet access affected student learning opportunities and outcomes. • Geographical divisions affected digital access. A negative correlation between rural dwellers and the internet access was reported in the literature, highlighting the struggle of students in rural areas. • These students are more likely to lack necessary resources for academic achievement.	(van Dijk, 2006) (van Dijk, 2006) (Lai & Widmar, 2021)
Poor	• Slower internet speed at home due to sudden and unprecedented	(Oyedotun,

infrastructure	internet traffic, and the lack of preparedness of internet providers for the sudden enormous demands on their services • Inconsistent power supply: Unlike the developed countries, universities in emerging economies are yet to guarantee a stable power supply as there are occasions of power-cuts during the delivery of lectures, affecting both students and lecturers especially in countries like south Africa, Zimbabwe and other countries.	2020).
Lack of training of lecturer on the use of online platforms	• The study reveals that students are comfortable with online classes and are getting enough support from teachers but they do not believe that online classes will replace traditional classroom teaching. • It also finds that teachers are facing difficulties in conducting online classes due to a lack of proper training and development for doing online classes. • Technical issues are the major problem for the effectiveness of the online classes.	(Kulal & Nayak, 2020).

Can Online Learning Improve Student Performance?

This review established that online-based teaching and learning is interactive (Citation: Johnston et al., 2005) and online teaching creates environments where students actively engage with the material and learn by practical activity and also refers to their understanding as they build new knowledge thereby improving their performance. Effective online engagement requires certain key components. Engaged students are attributed to have positive attitudes toward their peers and be more active in their effort in learning thereby improving their performance. Interaction has a key role here as (Muirhead & Juwah, 2005) argued that student-student interaction promotes inter-and intra-peer collaboration. Since students may lack "self-monitoring skills required for the online environment", they need more academic and peer support to excel academically. This study found out that the role of online lecturers is also crucial because they help learners become self-directed and more active in learning, thereby increase their academic performance. In a similar vein, Czerkawski and Lyman (2016) proposed an instructional design framework to foster students' online engagement which includes performing needs analysis, defining instructional goals and objectives, and developing learning environments. Building a community of learners in an online environment where a sense of trust and safety exists between its participants is important for increasing university student performance in emerging economies as illustrated in Figure 5 below.

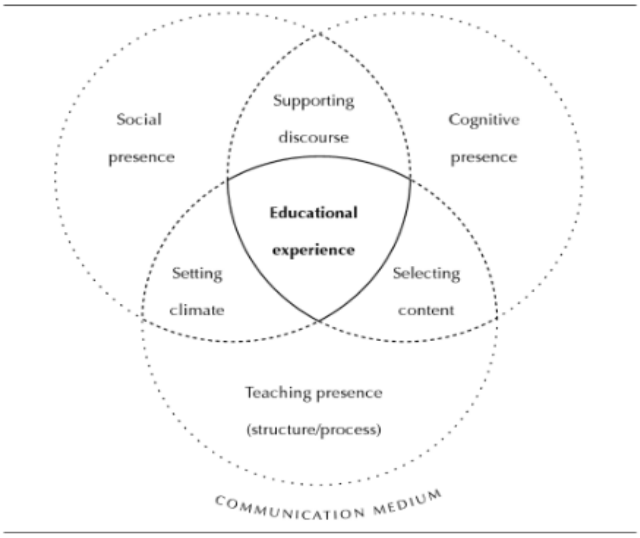

Figure 3. Community of inquiry

This study established that the most important measure of the effectiveness of teaching and learning activities is students' satisfaction, irrespective of where the learning activity takes place and when and how it is organized. To achieve this (satisfaction) as a measure of effectiveness, the lecturer has a key role to play in higher education. (Hettiarachchi et al., 2021) asserted that satisfaction can make the academic performance of students better, improve the online teaching and learning itself and encourage students to remain in the program. In the same vein, (Topala & Tomozii, 2014) described online learning satisfaction as the general feeling of students toward online teaching and learning processes and this has a direct influence on student performance.

Further, the finding that they learned new things through their overall use of technologies seems to support (Oyedotun, 2020) findings which affirmed that engaging in online learning led to personal development and growth of students. This can suggest that adult learners learn better when they take responsibility for their learning. It might be assumed that the activities using digital technologies required them to think, create, and contribute which led them to experience a better learning environment and enjoy participating and collaborating with peers thereby increasing university student performance in emerging economies.

Moreover, Oyedotun (2020) findings described how digital inequalities and even access to devices affected students' online participation. Since many students reside in rural areas in the researched context, it may be assumed that they have limited access and connection to the internet which seems to affect their active participation and interaction in synchronous sessions as well as responses in latter activities in asynchronous sessions. Further, students and the teacher's data regarding pre-tutorials of technologies seem to differ (Rafique, 2023). One feasible interpretation could be that the lecturer misinterpreted students' needs for digital skills whereas ensuring digital skills in tech-mediated learning is a key element. This mismatch in perception and the need for proper orientation are also reported in the studies by (Mannan et al., 2020), which can subsequently affect the student performance.

Figure 6 below indicates the most common online tools used by universities in emerging economies.

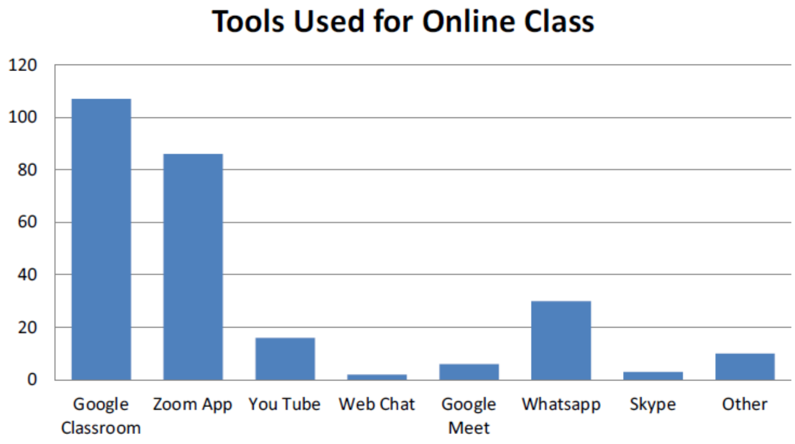

Figure 4. Tools for online class (Kulal & Nayak, 2020)

The study found out that google classroom and zoom application are the most commonly used online tools in emerging economies. The study established that google classroom is created by google which is a free website service that focuses on the distribution and grading of assignments for educational institutes. Its basic purpose is to smooth the process of sharing documents between students and teachers (Hilal et al., 2022). On the other hand, the study established that Zoom is a web-based application in which live video broadcast is used by many teachers for delivering their lectures effectively. This meeting event is organized by one host and other participants have equal footing. Similarly, the host of the event can allocate responsibilities of hosting with other participants of the meeting and participants can easily share the display with the meeting participants (Hilal et al., 2022).

The study review also found out that the sensing presence of users to different social networking applications, for example, Myspace, Skype, and Facebook with implicit communication and a new intensity of connection to the friends on social network platforms. This system is enabled on sensor-enabled and standard number mobile phones which is also being used in emerging economies. Its services are enabled on the basses of per buddy for the user's exposure to a different degree of sensing a presence. The system services consist of friends feed, social interaction, buddy search, my presence, buddy beacon, and significant places (Chen & Rahman, 2008). Google Classroom and Zoom meetings had secured solid positions in the field of online studies in the period of COVID-19. They both have a user-friendly environment for their customers and are easily accessible by a user, but the zoom application had a less quality mobile app which creates problems for the users at some point. Zoom application offers a wide variety of meetings settings for the users which make their work easy and more effective communication between the students and teachers. But on the other hand, google had a more efficient setup of sharing documents, assignments, and grading policy which creates opportunities for the students and teachers to keep track of their files (Hilal et al., 2022).

Benefits of Online Learning

Table 3 below illustrates the benefits of online learning for university students and lectures in emerging economies.

Table 3. Benefits of online learning

Benefit of online learning	Author
• Studying anywhere and anytime, having more time for thinking and feedback and increasing flexibility in learning.	(Endris & Molla, 2023)
• Allows learners to become more active participants in the learning process regardless of the size of the classroom or the time.	
• The ability for students to employ self and personalized learning as well as to select their own learning environments. This helps to meet the needs of students and outperforms traditional learning.	
• Cost-effective compared to traditional learning as a cheap mode of education that helps students improve their technology skills.	(Bączek et al., 2021; Johnson et al., 2021)
• Offers the possibility of cross-access the global gap in education, can help students living in areas where infrastructure, such as roads or suitable transportation, is lacking, and can reduce travel expenses.	
• E-learning eliminates the geographical barriers and time scale that are often associated with traditional learning.	
• Learners can control their own learning pace, and activities can be flexible according to students' learning styles.	(Clarke & Hermens, 2001)
• Online learning can create a suitable learning environment for instructors and students; using authentic learning materials like videos and other multimedia.	(Halim & Hashim, 2019; Pazilah et al., 2019)
• Online learning is beneficial to create a digital learning community, improve students' digital learning skills and stay connected during tough times like COVID-19.	(Ajibo & Ene, 2023; Li, n.d.-b)
• Online education presents a long-lasting solution to the constant interruption of university education in developing countries like African countries.	
• Flexibility and self–control within the learning environment, and they also perceived that online class would be a convenient method of teaching compared to traditional classroom learning.	(Kulal & Nayak, 2020)
• It fills the gap of literacy rate by reaching to the rural areas	(Bordoloi, 2018)

Conclusions

Research on online learning has decreased in 2023 as compared to 2022 when cases of Covid-19 was at peak world over. Online learning is an exciting new way to learn about almost anything and therefore its research should continue despite the low rate of reported cases of Covid-19. Online learning has bought a positive impact on the lives of students in improving their academic performance as well as lecturers at universities in emerging economies. The increasing use of technology in the field of learning has improved the quality of education in emerging economies. Both students and lecturers have optimistic views about online classes. However, there is always much room for improvement as far as online learning goes (Kulal & Nayak, 2020).

The sudden transition to online pedagogy education as a result of COVID-19 in emerging economies has exposed some inequalities and challenges as well as provided some benefits (Oyedotun, 2020). Despite the positive experiences, the findings revealed certain constraints that seemed to affect students' online engagement and their performance in emerging economies. Technical aspects have been a key challenge which could be the reason for students' reduced participation and engagement might be affected due to the contextual factors. The issue of unreliable network and connectivity has been reported in numerous findings, which seemed not only a contextual issue but also a concern in emerging economies Moreover, (Oyedotun, 2020) findings described how digital inequalities and even access to devices affected students' online participation and their performance in emerging economies.

Recommendations

The findings of the study showed that synchronous online learning has not been implemented properly yet; it is likely to conclude that there is a discrepancy between the student's perceptions and actual practices. The migration process of the universities to online instruction without adequate planning and designs and students' lack of awareness on how to use online learning technologies might be among the major factors that affect the effective practice of (synchronous) online learning (Endris & Molla, 2023). Therefore, this review proposed the following online learning framework - Figure 7 below for students at universities in emerging economies in a bid to improve their performance.

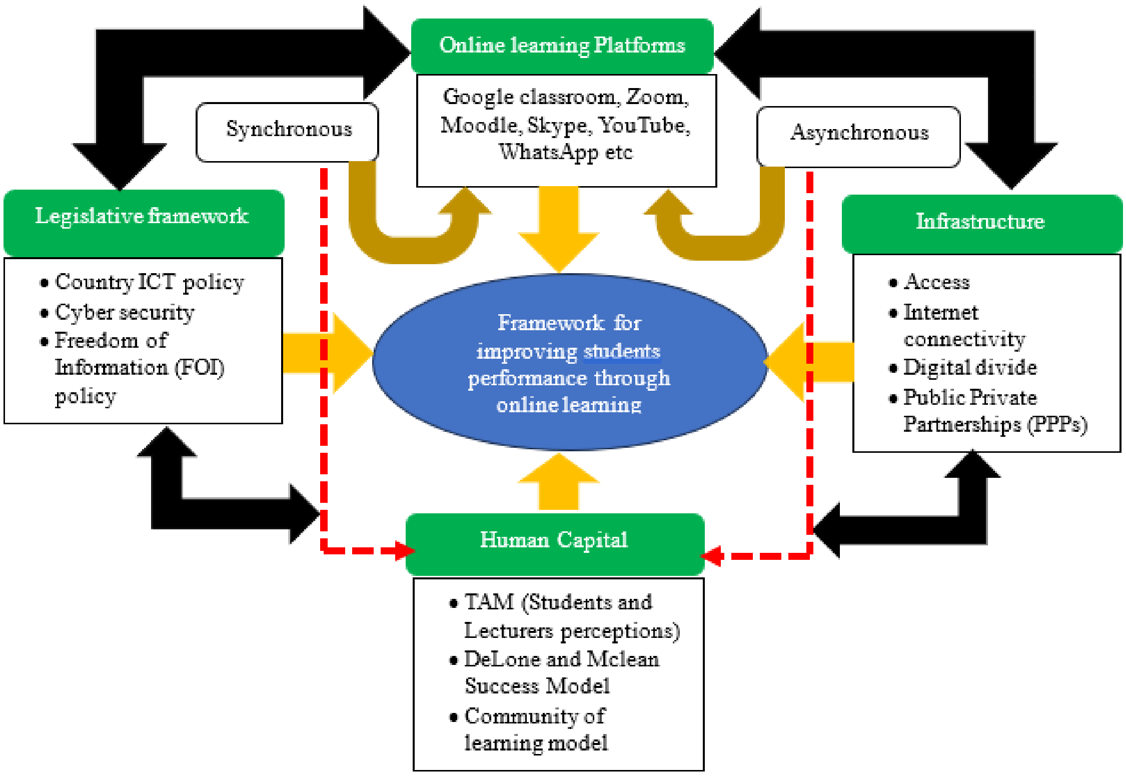

Figure 5. Framework for online learning

Platforms for Online Learning – Student performance

There are enormous numbers of online class tools available in the market. Some of the tools are free which are commonly used in emerging economies, and some of the tools are premium (Kulal & Nayak, 2020). From the literature review, the many popular online tools available is Google classroom is the most used and preferred tools for an online class. Zoom App is considered the second most popular and preferred tool for an online class. Even though Skype is the most popular online tool for communication, but here it is considered least using tools. Here the interesting fact is that many academicians are using social network tools (WhatsApp) for online classes. This review therefore recommends that universities in emerging economies free tools such as google classroom and Zoom so that both the institutions and the students can be able to such such platforms to improve their performance.

Synchronous and Asynchronous

Teachers and students join together in a common place in a real-time situation, which is known as synchronous learning. Moreover, Salmon (2013) says that synchronous learning is bounded with real-time interaction, which is collaborative. In addition, Teng et al. (2012) state that the synchronous learning is also facilitated on the virtual platform where collaborative learning takes place. The instructors interact with students through teleconferencing, live streaming, video conferencing, live chatting and so on. Development of software in recent days with new features such as the chat-box window, polling questions, live feedback, survey and so on has been highly useful for the faculty members and the student community (Hrastinski, 2008b), Media supports synchronous e-learning and allows faculties and students to interact with each other, say Murphy et al. (2011); Park and Bonk (2007). The advantages of synchronous learning are that students can ask questions, seek answers, get immediate feedback and share opinions and ideas in the class as the session proceeding will be real time. The few disadvantages of synchronous learning are it is stressful due to the rigid schedule and may be continuous where students will be seated before the computers for long hours (Pappas, 2015; Perveen, 2016). The synchronous learning may be disrupted due to low network, unstable Internet connection and may not help the students learn continuously. The instructor sets the learning path for the learners to acquire knowledge at their own pace and time, which sometimes may not be up to the expectations of the students.

Henceforth, to get involved in synchronous learning, students and teachers must devote time and coordinate with each other. In addition, synchronous learning is sometimes not flexible (Teng et al., 2012; Perveen, 2016). Asynchronous learning style has been widely followed to avoid these issues and provide education in a flexible mode. The standard method used in asynchronous learning is through the prerecorded session, virtual library, social media platforms, online forums and so on (Malamed, 2011; Lin et al., 2012). The benefits of asynchronous learning are it offers a lot of flexibility for the learner to progress in their learning at their own pace and can access learning from any place and time. In support of this, Wind Kofoed (2020) says that asynchronous learning enables students to lean with flexibility in their own comfort zone. Moreover, students get an opportunity to learn with freedom and wisdom and do not have to completely depend on the instructor (Trach, 2018). Asynchronous learning is cost effective, where it does not require daily attention from the instructors (Lawless, 2020; Tucker, 2020). Since it is a self-guided module, students can work on the content themselves and avail their education at a minimal cost. Few demerits of asynchronous learning are students feel less connected to the instructors and create a sense of loneliness due to a lack of conversation with the instructors and peers. It would make students procrastinate their work due to a lack of supervision. Sometimes, students forget to complete their asynchronous activities assigned to them by the faculty members. In addition, faculty members have to send gentle reminders to the students and remind them to finish the work and submit the same for evaluation. The study findings show that synchronous learning is sometimes stressful, placing more responsibility on students mainly because of the increased screen time. At the same time, asynchronous learning allows the students to self-explore and research the topics assigned to them. Students also felt that asynchronous activities create a burden because of many written assignments to be submitted within a short period (Fernandez et al., 2022). This review therefore recommends that a blended approach should be used to accommodate those students and lecturers who are not comfortable with synchronous learning or Asynchronous learning.

Legislative Framework and Infrastructure

In order to promote the uptake and usage of online learning by university students in emerging economies, sufficient government budgetary allocation should be made to universities to enable the acquisition of necessary equipment for online education. The students should be given more access to laptops, android phones, constant power supplies and internet access. The price of data from network providers should be subsidized to enable students to afford it. The lecturers should be adequately remunerated so as to motivate them to give their best towards the effectiveness of online education in universities for emerging economies (Ajibo & Ene, 2023).

This review also recommends that strengthening infrastructure facilities should include improvement in Internet connectivity (access), development of rural areas to bridge the digital divide, bringing changes in the attitude of students and teachers, etc. Colleges and other educational institutions are required to provide excellent training and support to both student and lecturers regarding the usage of online classes that helps in increasing their comfortability (Kulal & Nayak, 2020). This review therefore recommends that Public Private Partnerships (PPPs) should be promoted to put proper infrastructure that can promote online learning to improve students' performance. On their own universities in emerging economies can afford to provide the necessary infrastructure but their effort should be complemented by other players such as various telecommunication companies, government, and other internet services providers.

Human Capital

Human capital plays an important role in the development of a nation. It is the quality of the human beings of a country which helps in accelerating the pace of development. However, the fact is that human capital can be ensured through proper education only. Educated people are generally more productive workers because they can use the capital more effectively, can adopt new technologies, and learn from previous mistakes (Bordoloi, 2018). Therefore, this review recommends that the concept of human capital should be linked with the growth and development of a nation, and education should play an important role in producing the human capital for both the present and the future developments (Bordoloi, 2018). This can be achieved by students and lectures having a positive perception of online learning as indicated in the Technology Accepance Model (TAM), DeLenone and Mclean success model, and community learning model. It is students whose opinion matters most in the education system. Online classes may become a chunk of the future education system, but it cannot be carried for the future unless students accept it (Kulal & Nayak, 2020). The findings of the study indicate that the students had favorable perceptions of online learning. Despite the students' positive perceptions, the results of the study showed that the practice of online learning in the universities was limited; especially the practice of synchronous online learning was low (Endris & Molla, 2023). This review therefore recommends that practice of online learning in universities should not be limited once the above proposed framework in Figure 7 above is implemented by various countries in emerging economies.

Practical implications

Higher education has undergone multiple transformations in a short period (2020, 2021 and beyond). Educational institutions underwent a rapid transition in remote teaching and learning in the initial stages. This study discusses how perceptions of overperformance and underperformance in terms of perceived preparedness and threat can be formed (Nam, 2019). As time progressed, educational institutions did course navigation where they relooked into their course plans, syllabus and brought a structural change to match the pandemic requirements. Meanwhile, educational institutions slowly equipped themselves with infrastructure facilities to bring academic integrity. At present, educational institutions are ready to face the new normality without disrupting services to society (Fernandez et al., 2022). The theoretical findings of this study therefore provide some insights to policy implications for online learning practitioners and policymakers on how it can improve university students' performance in emerging economies.

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Investigation of Secondary School Students' Self-Regulation Strategies, Motivational Beliefs and Science Related Inquiry Learning Skills Perception

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Abstract

The aim of this study is to identify secondary school students' self-regulation strategies, motivational beliefs and science related inquiry learning skills perception levels, to reveal the relationship between them and to examine them regarding different variables. In this study, a quantitative research method was used. The study included 1127 students from secondary schools in Istanbul, Turkey. "Personal Information Form" developed by researchers, Pintrinch and De Groot (1990) produced the "Motivated Strategies for Learning Questionnaire," which Üredi adapted to Turkish (2005) and Balım and Taşkoyan (2007) established the "Science Related Inquiry Learning Skills Perception" scale (2007)" was used in study. The data were analyzed with SPSS 16. Independent Sample t-Test, ANOVA and Pearson Correlation technique was used in data analysis. It was concluded that the secondary school students' self-regulation skills, motivational beliefs and science related inquiry learning skills perception levels were high, there was a medium positive relationship between them, and It has been determined that the gender variable is in favor of female students, the class variable is in favor of lower-level classes, and the planning variable is in favor of students who like planning. Activities to increase students' self-regulation and motivational belief and science related inquiry learning skills perception levels are recommended. or tap here to enter text.

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Introduction

In today’s world, where developments in science and technology are increasing day by day, it’s apparent that improvement studies are carried out in education systems in many countries, including Turkey. With the new trends in education, learning has become an active process; It has become important to raise individuals who can inquiry, has critical and creative thinking skills, takes responsibility, be planned and are self-confident. There can be many factors that affect the learning process. In recent years, it has become known that besides mental factors, affective factors also affect learning (Zimmerman, 2000). In many studies on education, it’s apparent that self-regulation strategies, motivations, and inquiry learning skills are effective in students’ learning. The fact that the learner takes an active role at all stages of the learning process has highlighted the emphasis on such concepts as ‘learning to learn’ and ‘self-regulation’. Zimmerman (2002) defines self-regulation as a process. This process necessitates more than just metacognitive skills and knowledge. It also involves emotional and behavioral processes, as well as the ability to control them with a flexible sense of self-efficacy.

Pintrich (2000) defined self-regulation as an active and usable process in which students establish their own learning aims and try to organize their cognition, motivation, and behavior. In this context, self-regulation can be expressed as the synthesis of emotions, thoughts, and actions that individuals create to move from their current state to the desired state. Two factors affect the self-regulated learning process. These factors are self-regulation strategies and motivational beliefs. Self-regulation strategies: they cover the metacognitive strategies for planning, monitoring, and changing students’ cognitions, as well as controlling the effort spent on performing a task in the learning-teaching process and the strategies they use to learn, remember, and understand the material (Pintrich & De Groot 1990). The practice of self-regulation strategies significantly affects learning and academic performance (Sağırlı et al., 2010).

Another concept that is thought to be effective in learning is motivational beliefs that help encourage and maintain self-regulated learning (Pintrich, 1999). Motivational beliefs are expressed as students’ opinions, judgments, and values about objects, events, or subject areas (Boekaerts, 2002). That’s why it’s important to identify the factors affecting student motivation and to make learning-teaching processes more effective. Self-regulated learning is developed and sustained by interdependent factors, and in this context, student motivation is a critical component (Zumbrunn et al., 2011). Considering this information, it can be expected that students’ motivational beliefs and self-regulation skills are related to each other.

Another of the concepts discussed within the scope of the study is science related inquiry learning skills perception. The vision of science education is to raise individuals who research and inquiry, produce information and use it appropriately in life, make effective decisions, solve problems, be open to cooperation, have communication skills, self-confident, and learn lifelong (MEB, 2018). One of the methods applied to realize this vision is inquiry-based learning. In this context, contemporary Science Teaching programs (MOE, 2018 & NGSS, 2013) suggest and use inquiry-based learning methods. Inquiry-based learning is the process of solving problems by asking questions, researching, and analyzing information. Newly gained knowledge is transformed into useful information in this process (Perry & Richardson 2001). Thus, students are allowed to express and explore their strategies and concepts.

"Inquiry learning skills", on the other hand, are expressed by John Dewey as asking questions about the subject to be learned, searching for answers, producing, and creating new information while collecting information about any subject, discussing the foundation and experiences, and reflecting on the newly obtained information (Taşkoyan, 2008). Inquiry skills, such as self-regulation and motivation, can also give clues about the students in the learning process. The inquiry learning skill increases the student's motivation and creativity, improves analytical and critical thinking skills, and facilitates the comprehension of questions as a whole in the context of cause and effect (Öztürk et al., 2017). In this respect, it is important to examine students' science related inquiry skills perceptions.

In the literature, secondary school (Harrison & Prain, 2009; Pintrich & De Groot, 1990), high school (Affuso et al., 2022; Van Grinsven & Tillema, 2006) and university (Liebeendörferet et al., 2022) studies investigating students' self-regulation strategies and motivational beliefs are available. In addition, secondary school (Işık & Yenice, 2013; Öner & Özdem Yılmaz, 2019; Williams et al., 2017), high school (Harrison, 2014) and university (Vajoczki et al., 2011) studies investigating the inquiry learning skills of students are available. When reviewing the research in the literature, it's been established that the studies on self-regulation and motivational beliefs are mostly related to the mathematics lesson, are associated with achievement, and are mostly conducted with high school and university students.

Only a few studies have been carried out to determine the self-regulation, motivational beliefs of secondary school students. On the other hand, in the studies on science related inquiry learning skills perception carried out with secondary school students; It's apparent that he focuses on the inquiry learning skill or perception, and the effects of the methods, techniques, and strategies discussed in the teaching process. However, it has been observed that studies mostly examine the relationship between inquiry learning skills and learning styles, problem-solving, perception, motivation, and attitude, and only one study was found in which the science related inquiry learning skills perception of secondary school students was determined. No study was found in which the relationship between "self-regulation strategies", "motivational beliefs" and "science related inquiry learning skills perception" was examined together. Thus, it is considered that this work will contribute to the literature relating to examining the self-regulation and motivational beliefs studies, mostly related to the mathematics lesson, relating to different variables and by adding the inquiry learning skills dimension for the Science lesson.

This study aims to determine secondary school students' self-regulation strategies, motivational beliefs, and science related inquiry learning skills perception levels, reveal the relationship between them and examine them relating to different variables, based on the question of how there is a relationship between motivation, self-regulation strategies, and science related inquiry learning skills perception to learning. For this purpose, answers were sought to the following questions:

1. What are secondary school students' self-regulation strategies, motivational beliefs, and science-related inquiry learning skills perception levels?
2. Is there a significant relationship between secondary school students' self-regulation strategies, motivational beliefs, and science-related inquiry learning skills perception levels?
3. Do secondary school students' self-regulation strategies, motivational beliefs, and science-related inquiry learning skills perception levels differ significantly according to the gender variable?
4. Do secondary school students' self-regulation strategies, motivational beliefs, and science-related inquiry learning skills perception levels differ significantly according to the grade variable?
5. Do secondary school students' self-regulation strategies, motivational beliefs and science-related inquiry learning skills perception levels differ significantly according to the variable of liking to plan?

Method

Research Model

This research is a quantitative study designed in the relational screening model for the comparison of secondary school students' self-regulation strategies, motivational beliefs, and science-related inquiry learning skills perceptions (Karasar, 2008).

Research Sample

The participants of the research are 6th, 7th, and 8th grade students who are studying at five different public secondary schools in Istanbul, Turkey and have low socio-economic level living conditions. Participants were chosen by a simple random sampling method. In this regard, participants in the research consisted of 287 (25.5%) 6th grade, 385 (34.2%) 7th grade, and 455 (40.4%) 8th-grade students, with 549 (48.7%) females and 578 (51.3%) males, for a total number of 1127 students.

Data Collection Tools

The first of these data collection instruments is the "Personal Information Form," which was developed by the researchers after consulting with science education experts. This form is made up of secondary school students' data on the demographic such as "gender", "grade" and the question "whether they like to plan or not". The second data collection instrument in the study is the "Motivated Strategies for Learning Questionnaire" (MSFLQ), consisting of 44 items, developed by Pintrinch and De Groot (1990) and adapted into Turkish by Üredi (2005), was used. The measurement instrument consists of two dimensions: "Self-regulation strategies" (SRS) and "Motivational beliefs" (MB). Self-regulation strategies measurement instrument; scientific strategy use (13 items) and self-regulation (9 items); motivational beliefs measurement instrument; It consists of three sub-dimensions: self-efficacy (9 items), intrinsic value (9 items), and exam anxiety (4 items). Cronbach alpha values for the sub-dimensions of scientific strategy use were 0.82 in the study of adapting the measurement instrument to Turkish, 0.84 in self-regulation, 0.92 in self-efficacy, 0.88 in intrinsic value, and 0.81 in exam anxiety (Üredi, 2005). The Cronbach alpha Coefficient obtained from the analysis of the data within the scope of this study of the measurement instrument was calculated as 0.83 for the Self-Regulation Strategies (SRS) scale and 0.81 for the Motivational Beliefs (MB) scale.

Another data collection instrument used is the "Science Related Inquiry Learning Skills Perception" scale (SRILSP) developed by Balım and Taşkoyan (2007). The measurement instrument consists of 22 items in total, including 3 sub-dimensions: positive perceptions, negative perceptions, and perceptions of questioning the accuracy. The reliability of the factors belonging to the scale is 0.73, 0.67, and 0.71, respectively. Cronbach's alpha reliability for the entire scale is 0.84. The scale's Cronbach's alpha reliability coefficient was found to be 0.77 in this investigation.

Data Analysis

Statistical solutions for measuring instruments were made with the SPSS 16.0 package program. Before starting the analysis, the Kolmogorov-Smirnov test was used to determine the normality of the distribution of the data, and the skewness and kurtosis values of the scores were checked at the same time. According to the result of the Kolmogorov-Smirnov test, it was observed that the data provided a normal distribution since the significance value was less than .05, but the skewness and kurtosis values were between +2.0 and -2.0, according to George and Mallery (2010). In this context, parametric tests were utilized. Accordingly, in the analysis of the data, the Independent Sample t-Test for gender, One-Way Analysis of Variance (ANOVA) according to grade levels, and the Pearson Correlation Coefficient technique to reveal the relationship between dependent variables were calculated.

Ethical

Voluntary participation and informed consent were provided for all participants during the study process, and there was no manipulation in the study.

Results

The findings of the 1st sub-problem "What are secondary school students' "SRS," "MB," and "SRILSP" levels?" are indicated in Table 1.

Table 1. "SRS", "MB" and "SRILSP" Average scores

Scales/Dimensions and Sub-Dimensions	N	$\bar{X}$	Sd	SH_x	Min.	Max.
Scientific strategy use	1127	5.38	0.99	0.03	1.00	7.00
Self-regulation	1127	4.77	0.91	0.03	1.00	7.00
SRS	1127	5.08	0.86	0.03	1.00	7.00
Self-efficacy	1127	5.50	1.12	0.03	1.67	7.00
Intrinsic value	1127	5.70	0.90	0.03	1.56	7.00
Exam anxiety	1127	4.00	1.75	0.05	1.00	7.00
MB	1127	5.07	0.78	0.02	1.41	7.00
Positive perceptions	1127	3.98	0.72	0.02	1.00	5.00
Negative perceptions	1127	2.44	0.90	0.03	1.00	5.00
Perceptions of questioning the accuracy	1127	3.86	0.82	0.02	1.00	5.00
SRILSP	1127	3.52	0.51	0.02	1.00	5.00

When the findings in Table 1 are viewed, it's apparent that the "SRS" scores of secondary school students ($\bar{X}$=5.08) are at a high level. When the sub-dimensions of the "SRS" were studied, it was discovered that students had a high level of "Scientific strategy use" ($\bar{X}$=5.38) and "Self-regulation" ($\bar{X}$=4.77). The "MB" scores of secondary school students ($\bar{X}$=5.07) are extremely high. When the sub-dimensions of "MB" were examined, it was determined that the students had a high level of "Self-efficacy" ($\bar{X}$=5.50) "Intrinsic values" ($\bar{X}$=5.70) and moderate "Exam anxiety" ($\bar{X}$=4.00). The "SRILSP" scores of secondary school students ($\bar{X}$=3.52) are at a high level. When the sub-dimensions of "SRILSP" were examined, it was determined that the students had a high level of "Positive perceptions" ($\bar{X}$=3.98) and "Perception of questioning their accuracy" ($\bar{X}$=3.86) and they had a low level of "Negative perception" ($\bar{X}$=2.44).

The findings of the 2nd sub-problem as "Is there a significant relationship between secondary school students "SRS," "MB" and "SRILSP" levels?" are indicated in Table 2.

Table 2. The relationship between "SRS", "MB", "SRILSP" scores

Variables	N	r	p
SRS MB	1127	.624**	.000
SRS SRILSP	1127	.409**	.000
MB SRILSP	1127	.349**	.000

When the findings in Table 2 are viewed, it's apparent that there are a moderately positive and significant relationship secondary school students' between "SRS" and "MB" scores (r=.624; p<.01); between "SRS" and "SRILSP" scores (r=.409; p<.01) and between "MB" and "SRILSP" scores (r=.349; p<.01).

The findings of the 3rd sub-problem as "Do secondary school students' "SRS," "MB" and "SRILSP" levels differ significantly according to the gender variable?" are indicated in Table 3 and Table 5.

Table 3. Independent sample t-test results of "SRS" scores by gender variable

Scale and Sub-Dimensions	Gender	N	$\bar{X}$	Sd	SH_x	t-Test		
						t	Sd	p
Scientific strategy use	Female	549	5.51	0.90	0.04	4.32	1125	.000
	Male	578	5.26	1.05	0.04			
Self-regulation	Female	549	4.82	0.85	0.04	1.50	1125	.132
	Male	578	4.74	0.96	0.04			
SRS	Female	549	5.16	0.79	0.03	3.26	1125	.001
	Male	578	5.00	0.92	0.04			

When the findings in Table 3 are viewed, it's apparent that there is a statistically significant difference between the average "SRS" total scores of secondary school students according to the gender variable ($t_{(1125)}$=3.26; p<.05). When the sub-dimensions of the "SRS" were studied, the average scores of secondary school students related to the sub-dimension of "Scientific strategy use" show a statistically significant difference ($t_{(1125)}$=4.32; p<.05). This difference has been determined to be in favor of female secondary school students. In addition, there is no significant difference in the sub-dimension "Self-regulation" ($t_{(1125)}$=1.50; p>05). Although no significant difference was detected, it was observed that the average scores of female secondary school students were higher than those of male students in the "Self-regulation" sub-dimension (Female=4.82; Male=4.74).

Table 4. Independent sample t-test results of “MB” scores by gender variable

Scale and Sub-Dimensions	Gender	N	$\bar{X}$	Sd	SH_x	t-Test		
						t	Sd	p
Self-efficacy	Female	549	5.59	1.10	0.05	2.546	1125	.011
	Male	578	5.41	1.14	0.05			
Intrinsic value	Female	549	5.81	0.84	0.04	3.946	1125	.000
	Male	578	5.60	0.94	0.04			
Exam anxiety	Female	549	3.99	1.78	0.08	0.185	1125	.853
	Male	578	4.01	1.71	0.07			
MB	Female	549	5.13	0.72	0.03	2.572	1125	.010
	Male	578	5.01	0.84	0.04			

When the findings in Table 4 are viewed; It’s apparent that to be a statistically significant difference between secondary school students’ total average scores of “MB” according to the gender variable ($t_{(1125)}$=2.572; p<.05). When the sub-dimensions of the “MB” were studied, the average scores of secondary school students related to the sub-dimensions of “Self-efficacy” ($t_{(1125)}$=2.546; p<.05) and “Intrinsic value” ($t_{(1125)}$=3.946; p <.05) show a statistically significant difference. This difference has been determined to be in favor of female secondary school students. Furthermore, there is no noticeable difference in the sub-dimension “Exam anxiety” ($t_{(1125)}$=0.185; p >05).

Table 5. Independent sample t-test results of “SRILSP” scores by gender variable

Scale and Sub-Dimensions	Gender	N	$\bar{X}$	Sd	SH_x	t-Test		
						t	Sd	p
Positive perceptions	Female	549	4.08	0.69	0.30	4.508	1125	.000
	Male	578	3.88	0.73	0.30			
Negative perceptions	Female	549	2.36	0.89	0.04	2.928	1125	.003
	Male	578	2.52	0.90	0.04			
Perceptions of questioning the accuracy	Female	549	3.95	0.81	0.03	3.860	1125	.000
	Male	578	3.76	0.81	0.03			
SRILSP	Female	549	3.56	0.49	0.02	3.151	1125	.002
	Male	578	3.47	0.51	0.02			

When the findings in Table 5 are viewed, It’s apparent that there is a statistically significant difference between the “SRILSP” total average scores of secondary school students according to the gender variable ($t_{(1125)}$=3.151; p<.05). When the sub-dimensions of the “SRILSP” were studied, it was discovered that; Similarly, secondary school students’ “Positive perceptions” ($t_{(1125)}$=4.508; p<.05), “Negative perceptions” ($t_{(1125)}$=2.928; p<.05) and “Perceptions of questioning the accuracy” ($t_{(1125)}$=3.860; p<.05) the average scores of the sub-dimensions show that there is a statistically significant difference between them. It was determined that this difference was in favor of female secondary school students in “SRILSP”, “Positive perceptions” and "Perceptions of questioning the accuracy", and in favor of male students in "Negative perceptions" scores.

The findings of the 4th sub-problem as "Do secondary school students' "SRS," "MB" and "SRILSP" levels differ significantly according to the grade variable?" are indicated in Table 6 and Table 8.

Table 6. ANOVA Results of "SRS" scores by grade level

	N, X and SD Values				**ANOVA Results**				
Scale and Sub-Dimension	**Group**	**N**	**X̄**	**Sd**	**Var. K.**	**K.T.**	**K.O.**	**F**	**p**
Scientific strategy use	6.Grade	287	5.59	.95	Between	28.614	14.307	14.912	.000
	7.Grade	385	5.44	.96	Within	1078.377	.959		
	8.Grade	455	5.20	1.01	Total	1106.991			
	Total	1127	5.38	.99					
Self-regulation	6.Grade	287	4.92	.87	Between	13.447	6.723	8.287	.000
	7.Grade	385	4.81	.93	Within	911.914	.811		
	8.Grade	455	4.66	.90	Total	925.361			
	Total	1127	4.77	.91					
SRS	6.Grade	287	5.26	.822	Between	20.323	10.12	13.922	.000
	7.Grade	385	5.12	.859	Within	820.402	.730		
	8.Grade	455	4.92	.870	Total	840.725			
	Total	1127	5.08	.864					

When the findings in Table 6 are viewed, there is seen that to be a statistically significant difference between the "SRS" total average scores of secondary school students according to the grade variable [F(2-1124) = 13.922; p<.05]. When the sub-dimensions of the "SRS "were studied, it was discovered that; Similarly, secondary school students' average scores on the sub-dimensions of "Scientific strategy use" [F(2-1124) = 14.912; p<.05] and "Self-regulation" [F(2-1124)=8.287; p<.05] it can be seen that the difference between them is statistically significant.

According to the results of Levene's test applied to determine between which groups the difference is; Since the average group variances of total SRS (L=.641; p>.05) and sub-dimensions (L=2.755; L=1.191; p>.05) were found to be homogeneous, the Tukey HSD test, one of the post-hoc analysis techniques, was used. The results of the post-hoc analysis show that it was determined that the "SRS" and its sub-dimensions "Scientific strategy use" and "self-regulation" scores of the 6th and 7th grade secondary school students were significantly higher than the scores of the 8th-grade students.

Table 7. ANOVA Results of “MB” scores by grade level

N, X and SD Values					ANOVA Results				
Scale and Sub-Dimensions	**Group**	**N**	**$\bar{X}$**	**Sd**	**Var. K.**	**K.T.**	**K.O.**	**F**	**p**
Self-efficacy	6.Grade	287	5.68	1.02	Between	12.051	6.025	4.812	.008
	7.Grade	385	5.42	1.17	Within	1407.527	1.252		
	8.Grade	455	5.46	1.13	Total	1419.577			
	Total	1127	5.50	1.12					
Intrinsic value	6.Grade	287	5.89	.78	Between	23.736	11.868	14.973	.000
	7.Grade	385	5.77	.92	Within	890.923	.793		
	8.Grade	455	5.53	.94	Total	914.660			
	Total	1127	5.70	.90					
Exam anxiety	6.Grade	287	4.00	1.70	Between	.359	.180	.059	.943
	7.Grade	385	3.98	1.82	Within	3436.859	3.058		
	8.Grade	455	4.02	1.72	Total	3437.28			
	Total	1127	4.00	1.74					
MB	6.Grade	287	5.19	.73	Between	6.074	3.037	4.926	.007
	7.Grade	385	5.06	.81	Within	692.863	.616		
	8.Grade	455	5.06	.80	Total	698.937			
	Total	1127	5.07	.79					

When the findings in Table 7 are viewed, there is determined to be a statistically significant difference between secondary school students’ “MB” total average scores according to the grade variable [F(2-1124)=4.926; p<.05]. When the sub-dimensions of the “MB” were studied, it was discovered that; Similarly, secondary school students’ average scores on the sub-dimensions of “Self-efficacy” [F(2–124)=4.812; p<.05] and “Intrinsic Value” [F(2–124)=14.973; p<.05] It’s apparent that there is a statistically significant difference, in “Exam anxiety” [F(1-124)=.059; p>.05] sub-dimensions, but there is no statistically significant difference. According to the results of Levene’s test applied to determine between which groups the difference is; Since the average group variances of total MB (L=2.493; p>.05) were determined to be homogeneous, the Tukey HSD test, one of the post-hoc analysis techniques, and Since the average group variances of “Self-efficacy” (L=3.453; p<.05) and “Intrinsic Value” (L=8.145; p<.05) were not determined homogeneously, Tamhane test one of the post-hoc analysis techniques were used. According to the results of post-hoc analysis; it was determined that the “MB” scores of the students studying in the 6th grade of secondary school were significantly higher than the scores of the students studying in the 8th grade, and the “Self-efficacy” scores of the students studying in the 7th and 8th grades were significantly higher. Furthermore, the “Intrinsic Value” scores of 6th and 7th grade secondary school students were found to be much higher than the results of 8th grade students.

Table 8. ANOVA Results of “SRILSP” scores by grade level

N, X and SD Values					ANOVA Results				
Scale and Sub-Dimensions	**Group**	**N**	**X̄**	**Sd**	**Var. K.**	**K.T.**	**K.O.**	**F**	**p**
Positive perceptions	6.Grade	287	4.10	.75	Between	5.665	2.833	5.485	.004
	7.Grade	385	3.96	.70	Within	580.456	.516		
	8.Grade	455	3.92	.71	Total	586.122			
	Total	1127	3.98	.72					
Negative perceptions	6.Grade	287	2.39	.98	Between	1.327	.663	.813	.444
	7.Grade	385	2.46	.90	Within	917.161	.816		
	8.Grade	455	2.48	.86	Total	918.487			
	Total	1127	2.39	.86					
Perceptions of questioning the accuracy	6.Grade	287	3.99	.74	Between	12.112	6.056	9.145	.000
	7.Grade	385	3.89	.84	Within	744.354	.662		
	8.Grade	455	3.74	.82	Total	756.466			
	Total	1127	3.86	.56					
SRILSP	6.Grade	287	3.60	.47	Between	2.933	1.466	5.682	.004
	7.Grade	385	3.53	.51	Within	290.077	.258		
	8.Grade	455	3.47	.51	Total	293.010			
	Total	1127	3.52	.98					

When the findings in Table 8 are viewed, it is determined to be a statistically significant difference between secondary school students’ “SRILSP” average scores according to the grade variable [F(2-1124)=5.682; p<.05]. When the sub-dimensions of the “SRILSP “were studied, it was discovered that; Similarly, the average scores of secondary school students in the sub-dimensions of “Positive perceptions” [F(2-1124)=5.485; p<.05] and “Perceptions of questioning the accuracy” [F(2-1124)=9.145; p<.05] It’s apparent that there is a statistically significant difference. “Negative perceptions” [F(2-1124)=.813; p>.05] sub-dimensions, however, the difference is not statistically significant. According to the results of Levene’s test applied to determine between which groups the difference is; Since the average group variances of total “SRILSP” (L=2.434; p>.05) and “Positive perceptions” (L=.480; p>.05) were determined to be homogeneous, the Tukey HSD test, one of the post-hoc analysis techniques, and since the average group variances of “Perceptions of questioning the accuracy” (L=3.325; p<.05) were not determined homogeneously, the Tamhane test, one of the post-hoc analysis techniques, were performed. It was determined that the “SRILSP “scores of the 6th grade secondary school students were significantly higher than the 8th grade students’ scores, and the “Positive Perceptions” scores were significantly higher than the 7th and 8th grade students’ scores. Furthermore, it was found that 6th and 7th grade secondary school students “perceptions of questioning the accuracy” were significantly higher than the scores of 8th grade students.

The findings of the 5th sub-problem as “Do secondary school students’ “SRS,” “MB” and “SRILSP” levels differ significantly according to the variable of liking to plan?” are indicated in Table 9 and Table 11.

Table 9. Independent sample t-test results of "SRS" scores according to the variable like to plan

Scale and Sub-Dimensions	**Group**	**N**	**X̄**	**Sd**	**SHₓ**	**t-Test**		
						t	**Sd**	**p**
Scientific strategy use	Yes	908	5.53	0.92	0.03	10.57	1125	.000
	No	219	4.78	1.05	0.07			
Self-regulation	Yes	908	4.88	0.86	0.03	7.78	1125	.000
	No	219	4.36	0.98	0.07			
SRS	Yes	908	5.20	0.80	0.03	10.20	1125	.00
	No	219	4.57	0.92	0.06			

When the findings in Table 9 are viewed; It is determined to be a statistically significant difference between the "SRS" total average scores of secondary school students according to the variable of liking to plan ($t_{(1125)}$=10.20; p<.05). When the sub-dimensions of the "SRS "were studied, it was discovered that, similarly, the average scores of the secondary school students in the sub-dimensions of "Scientific strategy use" ($t_{(1125)}$=10.57; p<.05) and "Self-regulation" ($t_{(1125)}$=7.78; p>05) there is a statistically significant difference between them. It has been determined that this difference is in favor of those who like to plan.

Table 10. Independent sample t-test results of "MB" Scores according to the variable like to plan

Scale and Sub-Dimensions	**Group**	**N**	**X̄**	**Sd**	**SHₓ**	**t-Test**		
						t	**Sd**	**p**
Self-efficacy	Yes	908	5.63	1.06	0.04	8.271	1125	.000
	No	219	4.95	1.20	0.08			
Intrinsic value	Yes	908	5.87	0.79	0.03	13.093	1125	.000
	No	219	5.04	1.02	0.07			
Exam anxiety	Yes	908	3.93	1.76	0.06	-2.878	1125	.004
	No	219	4.30	1.66	0.11			
MB	Yes	908	5.14	0.75	0.02	6.462	1125	.000
	No	219	4.76	0.88	0.06			

When the findings in Table 10 are viewed; It is determined to be a statistically significant difference between "MB" total average scores of secondary school students according to the variable of liking to plan ($t_{(1125)}$=6.462; p<.05). When the sub-dimensions of the "MB" were studied, it was discovered that, similarly, secondary school students' "Self-efficacy" ($t_{(1125)}$=8.271; p<.05), "Intrinsic value" ($t_{(1125)}$=13.093; p<.05) and "Exam anxiety" ($t_{(1125)}$=-2.878; p<.05) the average scores of the sub-dimensions show that there is a statistically significant difference between them. It has been determined that this difference is in favor of secondary school students who like to plan in the "MB" total average scores, "Self-efficacy" and "Intrinsic value". In addition, it's apparent that the average score of "Exam anxiety" is in favor of secondary school students who do not like to plan.

Table 11. Independent sample t-test results of "SRILSP" scores according to the variable of likes to plan

Scale and Sub-Dimensions	Group	N	$\bar{X}$	Sd	SH_x	t-Test		
						t	Sd	p
Positive perceptions	Yes	908	4.06	0.69	0.02	7.877	1125	.000
	No	219	3.64	0.77	0.05			
Negative perceptions	Yes	908	2.37	0.91	0.03	-5.295	1125	.000
	No	219	2.73	0.82	0.06			
Perceptions of questioning the accuracy	Yes	908	3.96	0.77	0.03	9.229	1125	.000
	No	219	3.41	0.88	0.06			
SRILSP	Yes	908	3.57	0.48	0.02	6.584	1125	.000
	No	219	3.32	0.58	0.04			

When the findings in Table 11 are viewed; It is determined to be a statistically significant difference between secondary school students' "SRILSP" total average scores according to the variable of liking to plan ($t_{(1125)}$= 6.584; p<.05). When the sub-dimensions of the "SRILSP" were studied, it was discovered that; Similarly, secondary school students' "Positive perceptions" ($t_{(1125)}$=7.877; p<.05), "Negative perceptions" ($t_{(1125)}$=5.295; p<.05) and "Perceptions of questioning the accuracy" ($t_{(1125)}$)=9.229; p<.05) the average scores of the sub-dimensions show that there is a statistically significant difference between them. It has been determined that this difference is in favor of secondary school students who like to plan in the "SRILSP" total scores, "Positive perceptions" and "Perceptions of questioning the accuracy", and in favor of the students who do not like to plan in the "Negative perceptions" scores.

Discussion and Conclusion

In this study, regarding the first sub-problem, it's apparent that secondary school students get high scores in both the 'Scientific strategy use' and 'Self-regulation' sub-dimensions of the "SRS." Similarly, it was seen that they got high scores in both the 'Self-efficacy' and 'Intrinsic Value" sub-dimensions of the "MB" scale, and they got moderate scores in the 'Exam anxiety' dimension. When both scales are evaluated in general, it's possible to say secondary school students have high self-regulation skills and motivational beliefs. In many studies conducted, results similar to the findings of the research were obtained (Mutweleli, 2014). In the study carried out, it is thought that the use of new teaching methods and techniques applied in the developing and changing world conditions causes the students' self-regulation skills to be high. Studies investigating the effectiveness of different teaching methods and techniques on self-regulation skills support this view (Schraw et al., 2006; Sletten, 2017). The fact that secondary school students have high self-regulation skills may suggest that they can easily apply cognitive strategies such as remembering, summarizing, and categorizing the information they have learned. Zimmerman and Schunk (2007) stated that students with self-regulation skills can repeat, elaborate, organize, know how to plan, and direct their mental processes, are willing to participate in academic studies, conduct their studies by focusing on processes, make evaluations, and thus prepare for a better learning environment. In the learning process, students should be motivated to use cognitive and metacognitive strategies as well as to practice these strategies. Zimmerman (2002) stated that it is possible to improve motivation if the individual can use a high level of self-regulation strategy. For this reason, the high “MB” scores of the students obtained as a result of the study; can be considered that motivational beliefs are related to self-regulation skills, and it suggests that students come to the lessons with interest and enthusiasm. The fact that students have a high level of self-efficacy, according to the study’s findings, and intrinsic value orientation indicates that these students have self-confidence in what they can achieve and are interested in the lesson. It can be said that students’ having high motivational beliefs is an important factor in coping with negativities such as exam anxiety. The learning process is greatly influenced by motivation and the success achieved at the end of this process (Linnenbrink & Pintrich, 2002).

Studies have determined that there are positive and significant relationships between self-regulation and motivational beliefs and academic achievement (Malpass et al., 1999; Pintrich & De Groot, 1990). For this reason, it can be said that the high self-regulation skills and motivational beliefs of students are very important in the learning process. When the scores of secondary school students from the “SRILSP” scale are examined, it’s apparent that they got high scores in both of the sub-dimensions of ‘Positive perceptions’ and ‘Perceptions of Questioning the Accuracy” and low scores in the sub-dimension of ‘Negative perceptions’. When the scale is evaluated in general, it can be said that secondary school students’ inquiry learning skills perception of science is high. Studies were conducted in which the effects of students’ science related inquiry skills and perception levels on different variables were examined (Işık & Yenice, 2013). In the study carried out, the reason why middle school students have a high perception of science related skills is that, with the Science Curriculum that came into effect in 2018, the activities that will improve the inquiry learning skills of secondary school students are given enough space.

Regarding the second sub-problem, it was discovered that the overall scores of secondary school students “SRS,” “MB,” and “SRILSP” have a moderately positive and significant relationship. In line with these results, it can be said that there is a significant relationship in the same direction between the “SRS”, “MB”, and “SRILSP” scores of secondary school students. This may suggest that secondary school students with self-regulation skills increase their motivation for the lesson along with their questioning skills. This finding supports the statement by Zimmerman (1990) that learners with developed self-regulation skills approach educational tasks by questioning and researching, unlike their passive classmates, with confidence, motivation, and a sense of readiness. In another study, Wolters (1999) investigated the relationship between students’ self-regulation skills, motivational strategies, and academic achievement in a group of 88 secondary school students. The study showed that student motivation is a key role in self-regulated learning practices. The research suggests that there is a positive relationship between students’ self-regulation strategies and their motivational beliefs and science related inquiry learning skills. It is thought that students who have developed self-regulation skills and can set their own learning goals will be interested, willing, and highly motivated toward the lesson, and these students will be inclined to research, question, and learn new things. As a result, it is important to positively improve students’ self-regulation and inquiry learning skills during the educational and training process.

Regarding the third sub-problem, female students scored higher than male students on the "SRS" scale, as well as the "Scientific strategy use" and "Self-regulation" sub-dimensions. Similarly, in both the "Self-efficacy" and "Intrinsic Value" sub-dimensions of the "MB" scale, female students scored higher than male students, and they did not get different scores in the 'Exam anxiety' dimension. When the scores they got from the "SRILSP" scale were examined, it was seen that female student scored higher than male students in both the 'Positive perceptions' and 'Perceptions of Questioning the Accuracy" sub-dimensions and lower scores in the 'Negative perceptions' sub-dimension. When all three scales are evaluated in general, it can be said that female secondary school students have higher "SRS", "MB", and "SRILSP" scores than male students. According to studies, female students have more self-control strategies and motivational beliefs than male students (Dadlı, 2015; Erdoğan & Şengül, 2014; Peklaj & Pecjak, 2002) and inquiry learning skills than male students (Işık & Yenice, 2013). Similar to the findings obtained from the study, in the study conducted by Peklaj and Pecjak (2002) with 181 secondary school students, it was determined that self-regulation strategies and motivational beliefs had a significant difference in favor of female students. In addition, in the study conducted by Işık and Yenice (2013), it was determined that there were significant differences in favor of female students between gender and inquiry skill scores of secondary school students.

Unlike the findings, in another study, Mutweleli (2014) determined that self-regulation strategies and motivational beliefs were in favor of male students. Contrary to the findings obtained from the study, there are also studies in the literature stating that there is no difference between male and female students relating to motivational beliefs (Almarashdeh, 2012). In his study, Martin (2003) states that female students value school more than male students, they focus more on learning, they are more successful and patient in planning, implementing, and managing work. To be able to question the learning process, students need to express their views boldly and confidently and be motivated to learn. In this context, the fact that female students are more planned and programmed, organized, communicate more easily, are more interested in science and more willing to question than male students, have higher self-regulation strategies, motivational beliefs and inquiry learning skills than male students can be considered as the reason.

Regarding the fourth sub-problem, it's apparent that secondary school students get lower scores as their grade level increases in both the "SRS" scale's 'Scientific strategy use' and 'Self-regulation' sub-dimensions. Similarly, students get lower scores the higher their grade level in both the 'Self-efficacy' and 'Intrinsic Value" sub-dimensions of the "MB" scale. In the 'exam anxiety' dimension, it was determined that there was no difference between their scores, but they had moderate test anxiety at all grade levels. When the scores they got from the "SRILSP" scale were examined, it's apparent that in both the 'Positive perceptions' and 'Perceptions of questioning the accuracy' sub-dimensions, the students get lower scores as the grade level increases, while there is no difference between their scores in the 'Negative perceptions' sub-dimension. When all three scales are evaluated in general, it can be said that as the grade level of secondary school students increases, their "SRS", "MB" and "SRILSP" scores decrease. In parallel with the findings, there are studies in the literature showing that as the grade level increases, students' self-regulation strategies and motivational beliefs (Erdoğan & Şengül, 2014) and inquiry learning skills (Işık & Yenice, 2013) decrease. In line with the results obtained from the study, Erdoğan and Şengül (2014) reported in their research with secondary school students that as the grade level increases, their metacognitive self-regulated learning skills decrease. In contrast to the findings of the study, there are studies in the literature that indicate there is no significant difference in self-regulation skills between grade levels (Almarashdeh, 2012; Zimmerman & Martinez Pons, 1990). In their study, Zimmerman and Martinez Pons (1990) revealed that 11th-grade students who attend different grade levels use self-regulation strategies more effectively than 8th-grade students. In our country, students are preparing for the high school entrance examination in 8th grade. Because they mostly focus on test techniques while preparing for the exam, their time to do research, conduct experiments in which they actively participate in the process, and participate in environments where they can make inquiries is limited. For this reason, students' self-regulation, inquiry learning skills, and motivation are negatively affected by exam anxiety. In addition, as the grade levels of the students increase, the expectations of the students about the learning process increase, and they are expected to switch from concrete concepts to abstract concepts. It is thought that students have difficulty questioning abstract concepts to concrete concepts. For these reasons, it is thought that the result of the study was that the students' self-regulation strategies, motivational beliefs, and inquiry learning skills decreased as the grade levels progressed.

Regarding the fifth sub-problem, it's apparent that secondary school students get high scores in favor of those who like to plan in both sub-dimensions of the "SRS" scale: 'Scientific strategy use' and "Self-regulation'. Similarly, it's apparent that students get high points in favor of those who like to plan in both the 'Self-efficacy' and 'Intrinsic Value" sub-dimensions of the "MB" scale, and high points in favor of those who do not like to plan in the 'Exam anxiety' dimension. When the scores they got from the "SRILSP" scale were examined; It's apparent that in both the 'Positive perceptions' and 'Perceptions of questioning the accuracy' sub-dimensions, the students got high scores in favor of those who like to plan, and in the 'Negative perceptions' sub-dimension, they got high scores in favor of those who do not like to plan. When all three scales are evaluated in general, it can be said that secondary school students who like to plan have high "SRS", "MB" and "SRILSP" scores. Although there was no study like the study carried out, it was determined in the literature that planning is related to students' self-regulation strategies and motivational beliefs (Martin, 2003; Pintrich, 2000; Uykun, 2021; Zimmerman, 2002) and their level of inquiry learning skills (Erkol & Şahintepe, 2020) is indicated. In his study in which he identified the "factors affecting the learning motivation of secondary school students" Uykun (2021), determined that the ability of students to make their plans is one of the factors under the theme of self-regulation that affects their learning motivation.

Zimmerman (2002) states that one of the main stages of the self-regulated learning model is planning. It is stated in the literature that individuals with self-regulation skills can set their own goals, be active in the learning process, control and regulate their motivation, and plan time and resources (Pintrich, 2000). Erkol and Şahintepe (2020) observed that students were able to plan better with inquiry-based learning activities. It can be said that this result of our study is due to the high self-regulation skills of the students who know and love to plan, the parallel increase in their motivation for learning, and the fact that they perform all these skills by questioning in learning environments.

Recommendations

In line with the findings obtained from the study, the following recommendations are presented:

- To determine which characteristics of students, affect their self-regulation skills, motivational beliefs, and inquiry learning skills perception for science, a multidimensional perspective can be gained by making use of qualitative data such as observation and interviews, as well as quantitative data.
- Qualitative research on why and how gender affects students' self-regulation skills, motivational beliefs, and inquiry learning skills perception for science can be conducted and the results discussed.
- Students learning levels can be increased by enabling them to participate more in activities aimed at increasing their self-regulation, motivational belief, and inquiry levels.
- In addition to planning, the effects of different variables on self-regulation skills, motivational beliefs, and inquiry learning skills perception for science can be investigated.

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Understanding Students' Misconceptions about Chemical Formula Writing and Naming Ionic Compounds

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Abstract

Difficulties in the competency of chemical formula writing and naming ionic compounds are common to General Chemistry 1 learners. Hence, this study is formulated to understand 34 General Chemistry 1 learners' misconceptions about chemical formula writing and naming ionic compounds. This descriptive case study research used a two-tier test and interview questionnaire as the main data-gathering instruments. From the conducted study, analysis shows that in terms of chemical formula writing, the learners misrepresent ionic compounds as charged species, show a lack of understanding of valency and the use of the cross-charge method, and mispresent radicals. In naming ionic compounds, the learners generally misname some of the elements found in binary ionic compounds and misname metal ions with more than 1 charge and polyatomic ions. These misconceptions were validated by the difficulties experienced by the learners in answering the two-tier test, as mentioned in their interviews. Despite the misconceptions and difficulties of the learners in chemical formula writing and naming ionic compounds, they mentioned several ways of addressing them.

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Introduction

The Senior High School of the K to 12 program started in the Philippines in the year 2016 as prescribed in the Enhanced Education Act of 2013. It is a specialized upper secondary education program taken for two years (Grades 11 and 12) and each learner can choose from three tracks based on aptitude, interest, and school capability. Science, Technology, Engineering, and Mathematics (STEM) is one of the strands a Senior High School learner may take in the program's Academic Track. One of the specialized subjects taken by STEM learners is General Chemistry 1 and as stated in the General Chemistry 1 and 2 Curriculum Guide, the subject focuses on composition, structure, and properties of matter; quantitative principles, kinetics, and energetics of transformations of matter; and fundamental concept of organic chemistry (DepEd, 2016). It can be noted in the subject description that General Chemistry 1 and 2 are made up of topics that are taught at macroscopic, microscopic, and symbolic levels. These levels of teaching Chemistry are important to meaningfully understand the subject (Hinton & Nakhleh, 1999; Johnstone, 1993). In addition, understanding their interactions and distinctions is crucial in learning Chemistry and if a difficulty arises from one level, other levels will be affected (Sirhan, 2007).

Shapes that are pictorial, algebraic, physical, and computational are used to depict the symbolic level. At this level, teachers can employ equations in chemistry, graphs, reaction mechanisms, symbols, formulas, analogies, model kits, and numbers (Tüysüz et al., 2011). For instance, the ionic compound Sodium Chloride commonly known as the table salt, can be shown in the symbolic level as NaCl. The formation of the said inorganic compound can also be represented at the symbolic level as $2Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$. Chemistry as taught at the symbolic level makes it challenging for students to understand it. As communicated by Taber (2019), Chemistry uses a significant quantity of abstract ideas based on theoretical information and these are frequently addressed and taught mostly in terms of theoretical, non-observable phenomena. As cited by Fitriani et al. (2021), Fitriani et al. (2017) further mentioned that studying Chemistry is one of the science classes that is considered difficult. Learners dislike Chemistry classes because they are generally abstract and complicated.

One of the symbolic lessons in Chemistry is chemical nomenclature and chemical formula writing. To show or represent the composition of a certain compound, a chemical formula which is made up of element symbols and subscripts is used. In a chemical formula, the element symbols and subscripts will tell the elements and number of atoms present in the compound. For example, the compound Hydrogen peroxide is represented by the chemical formula H_2O_2, where the element symbols H and O and the number 2 as subscripts tell that the compound is made up of two atoms of Hydrogen and two atoms of Oxygen. On the other hand, chemical nomenclature entails the use of sets of rules in naming compounds. The rules are being set by the International Union of Pure and Applied Chemistry (IUPAC). Many students find naming chemical compounds challenging, but it is a critical aspect of chemistry (Wood & Donnelly-Hermosillo, 2019). This is because students need to learn how to use the set rules of IUPAC in naming elements and compounds that are at the symbolic level. Chemical nomenclature and chemical formula writing are two basic skills that students use in their entire exploration of Chemistry. Baah and Krueger (2012) further posit that the student's ability to write the names of compounds following the rules set by IUPAC is fundamental to learning and understanding chemistry – all other topics are connected to correctly naming and writing a chemical formula.

Recurring yearly, it was observed that General Chemistry 1 learners have difficulty in the competency of formula writing and naming ionic compounds. Although some can follow the rules in ionic compound formula writing and naming, some learners cannot still write properly the symbolic representations of the ionic compounds – some write the charges of ions but do not do the cross-charge method and if others do the cross-charge method, the learners tend not to reduce the subscripts into simplest form or ratio. In terms of naming the ionic compounds, some students are confused about how to use the Stock and Classical systems. For instance, the compound $CaCl_2$ is properly named as calcium chloride, but some would name it using the stock system as calcium (II) chloride. Generally, General Chemistry 1 learners cannot properly name ionic compounds with polyatomic ions. Since they are struggling at the symbolic level, it may also result in their difficulties in understanding the microscopic and macroscopic levels of Chemistry and higher-level lessons. It is therefore important to invest time and explore their conceptions to plan for better instruction and remediation. As also built up earlier, Chemistry is one of the most conceptually challenging subjects. Hence, it is essential for anyone who teaches it to have a good understanding of the challenging areas (Dula, 2018).

In the past years, it has been noted in different related research that learners have difficulty understanding chemical nomenclature and chemical formula writing. In the investigations done by Savoy (1988) and Hines (1990), it was shown that learners struggle to write chemical formulae. If learners are not able to fully understand chemical formula writing and naming, the tendency is that they will be hard up in learning concepts related to stoichiometry, chemical reactions, and balancing equations among others. This is supported by the findings of Lazonby, Morris, and Waddington (1982) in their research that learners' failure to accurately write chemical formulae is linked to their ongoing struggles in solving problems concerning stoichiometric calculations. This was also observed in the study of Galacer et al. (2013) that students failed stoichiometry due to a lack of fundamental chemical knowledge, including compound nomenclature.

Furthermore, in the series of tests conducted by the West African Examination Council (WAEC), the association responsible for establishing examinations in West Africa, it was revealed that many of the test takers in 1995 and 1999 had problems in naming inorganic compounds systematically and generally cannot give the IUPAC names of selected ionic compounds (WAEC, 1995 & 1999). Since learners have issues with naming inorganic compounds, this has led to their incapability to accurately write chemical formulae (WAEC, 1994; WAEC, 2001; WAEC, 2004; & WAEC, 2005). Similarly, Baah and Krueger (2012) tested 334 senior high school students in terms of their ability to name and write the chemical formula of ionic compounds. Their study determined that students have trouble in naming and chemical formula writing and that they lack understanding of the meaning of the Roman Numeral in brackets and the role of valency in writing chemical formulae. Glažar and Devetak (2002) also recorded some problems of students with chemical language. In their investigation, they saw that: (1) students do not understand the connection between a compound's name and its formula; (2) they don't possess a mastery of using suffixes; (3) they don't correlate the use of oxidation numbers of elements in naming substances; and (4) occasionally, they use incorrect symbols of elements.

According to Taskin and Bernholt (2014), these difficulties in chemical nomenclature are generally linked to language (meaning, function, and syntax of formula) and conceptual (links between macroscopic, microscopic, and symbolic levels) difficulties.

In addition, Naah and Sanger (2012) explored learners' alternative conceptions of stoichiometric equations for electrolyte solutions. One of the results of the study shows that among the 37 college students who participated in the semi-structured interview, there were students who exhibited confusion on how to properly use subscripts and coefficients. Confusion about the use of subscripts concerning simple compounds containing polyatomic ions was also documented by Habiddin (2014). Related to this, Habiddin (2014) also noted that learners tend to misname compounds with radicals because they fail to memorize the names of polyatomic ions. Espinosa et al. (2016) also recorded a misconception among learners in writing chemical formulae regarding putting charges to supposed neutral species. While students show difficulties in naming compounds and chemical formula writing, it is also good to point out that one of the results from the study of Amazona, Jr., and Vallejo (2020) shows that the student's performance in writing formulae is categorized as "nearly proficient". It appears that the students quite easily remember how to write chemical formulae.

Given the past and recent studies, it is important to note that students have difficulties in chemical formula writing and naming ionic compounds. If these difficulties are not determined and not taken action upon, these may result in other conceptual problems and challenges in understanding higher-level topics in Chemistry. Thus, this study is formulated to understand the misconceptions related to the difficulties of General Chemistry 1 learners in formula writing and naming ionic compounds. This present study is also considered worthwhile because it appears that little research has been done in this area and findings can be used for proper remediation and planning for instructional activities. The following questions are used in conducting the study: (1) What are the students' misconceptions about formula writing and naming ionic compounds?; and (2) What are the challenges of the students in formula writing and naming ionic compounds and how do they address these challenges?

Method

Research Design

In this study, the misconceptions of General Chemistry 1 learners on formula writing and naming ionic compounds were investigated. To accomplish this, a descriptive case study research design was used. This type of case study illuminates the intricacies of an experience (Stake, 1995). The descriptive case study was chosen to understand the misconceptions and difficulties experienced by the learners in chemical formula writing and naming ionic compounds. The descriptions of the misconceptions observed in the study will help to correct and avoid alternative conceptions.

The study utilized a two-tier test to gauge the performance and misconceptions of the Grade 11 learners in formula writing and naming ionic compounds. The top 10 and bottom 10 learners have undergone an interview to dig deeper into their reasons or conceptions for answering the questions in the test. The students were asked about their challenges or difficulties in answering the test and how they addressed them. The interview followed the interview protocol prescribed by Creswell (2009). After the collection of data, the gathered sets of information are summarized, taking into consideration the students' misconceptions, reasons, and processes to systematically interpret the results and understand misconceptions of students on formula writing and naming ionic compounds.

Participants

A total of 34 Grade 11, General Chemistry 1 learners for the academic year 2022 - 2023 were taken as the source of data for this study. Twenty students were purposively selected from the 34 General Chemistry 1 learners based on their scores or performance from the two-tier test and were subjected to an interview. For ethical considerations, the respondents were made aware of the purpose of the study before participating. The necessary data collected from the participants were only used to shed light on the posted research questions. The identity of the school and the learners was not disclosed in presenting data.

Research Instruments

To avoid deception in data gathering, the researcher made a graded two-tier test to gauge the General Chemistry 1 learners' conceptions and possible alternative conceptions of formula writing and naming ionic compounds. The formula writing and naming ionic compounds questionnaire was content and face-validated by chemistry and chemistry education experts.

The test covered 3 items of formula writing and 3 items of naming ionic compounds. The content of the two-tier test was taken from JCE Software: Inorganic Nomenclature by David Shaw and adapted for the web by Laura Yindra which is a web page for a tutorial on naming and writing chemical formulae of simple inorganic compounds (Shaw & Yindra, 2003). The questions are arranged in increasing difficulty. In the first part of the test, the learners need to write the chemical formula given the names of the inorganic compounds on the blank spaces provided. Below the blank spaces are boxes where the learners need to write their explanations on how they come up with their answers. The same process was done on the second part of the test but learners need to write the name of the inorganic compounds given their chemical formulae instead and explain how they arrived at their answers inside the boxes.

After the two-tier test, the top 10 and bottom 10 went to an interview to probe into their challenges in chemical formula writing and naming ionic compounds and how they address them.

Procedure

Validation of the two-tier test and securing approval to conduct research from chemistry education experts and the Dean of the College are done before the collection of data. Subsequently, after several lessons in chemical formula writing and naming ionic compounds, the researcher gave the graded two-tier test to the learners. After the test, the top 10 and bottom 10 were identified by the researcher. The 20 purposively selected learners went into an interview with the researcher following the interview protocol set by Creswell (2009) to dig deeper into their difficulties in answering the test. Their ways on how they address their problems in chemical formula writing and naming ionic compounds were also asked. Data analysis followed after the collection of needed information.

Data Analysis

The number of correct responses of the learners in the two-tier test was tabulated and presented in frequency and percentages to know their performance. Furthermore, their written responses and their reasons for their answers in each item were grouped according to common errors. From these responses, the common misconceptions about chemical formula writing and naming ionic compounds were derived and described. The common difficulties in answering the test items were audio-recorded in an interview, transcribed, and grouped to further validate and understand the misconceptions on chemical formula writing and naming ionic compounds. In the same manner, the responses of the participants in the interview on how they addressed their difficulties were audio-recorded, transcribed, and grouped.

According to how they address their difficulties, the learners were categorized using the VARK model of learning styles. As discussed in the study of Sintia et al. (2019), learners can be classified using the VARK model of learning styles developed by Fleming. Visual learners acquire and process information with the use of visuals like photos, graphs, and charts; the aural learners, on the other hand, like listening to discussions and tutorials; read/write learners tend to like to see and read printed or written texts and to take down notes then reread them; lastly, the kinesthetics learners like it the most to learn by doing or experiencing things that are with connection to real-life situations. Sintia et al. (2019) also noted that learners with more than one preference for learning can be considered “multimodal”.

Results and Discussion

Data were gathered during the first grading period of the first semester of the academic year 2022-2023 in a certain school in La Union, Philippines. The two-tier test on formula writing and naming ionic compounds was administered to Grade 11 learners enrolled in General Chemistry 1. After the checking of the test, the identified top 10 and bottom 10 have undergone an interview. Table 1 summarizes the performance of the learners in chemical formula writing and naming ionic compounds.

Table 1. Percentage of correct response

Test Items	Correct Response (N = 34)	Percentage (%)
Part I. Chemical Formula Writing	23	68
	20	59
	3	9
Part II. Naming Ionic Compounds	31	91
	17	50
	3	9

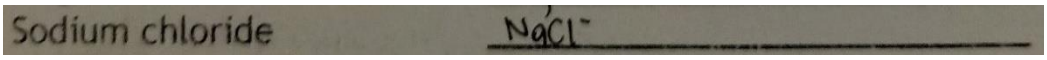
It is deemed in Table 1 that students' performance in chemical formula writing and naming ionic compounds are both decreasing following the increasing difficulty of questions. Although there are students who can answer the questions in formula writing and naming ionic compounds correctly, the low and decreasing number of correct responses in the administered test tells that the students still experience difficulties and might have possible misconceptions about the topics.

Misconceptions in Chemical Formula Writing

From the written answers of the learners in the two-tier test, several common alternative conceptions in chemical formula writing are listed. These misconceptions are summarized in the following themes.

Misrepresentation of ionic compounds as charged species.

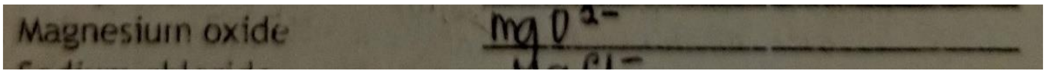
It is noted from the answers of the respondents that they are misrepresenting the chemical formula of ionic compounds as charged species. Instead of being neutral, the learners are putting charges in the chemical formula. For instance, in writing the chemical formula of Sodium chloride, the learners retained the charge of the Chloride ion in the written chemical formula of the compound. A sample unedited answer and explanation are shown in Figure 1.



"I input the chemical symbol of the 2 [ions]: Na for sodium and Cl for chloride. There's a negative [charge] in chloride since it's a non-metal."

Figure 1. The answer of learner 5 to item I.1

In the case of writing the formula of Magnesium Oxide, learner 34 has written correctly the element symbols for Magnesium and Oxygen in the chemical formula but a charge of two negative (2-) is written after the symbol of Oxygen, making the species not neutral. When asked about the reason, the learner recalled the rule of representing non-metal ions in symbols. It is seen that the learners can represent the monoatomic ions in symbols, but they are confused about using these symbols to represent the chemical formula of ionic compounds. The unedited response of Learner 34 is given in Figure 2.



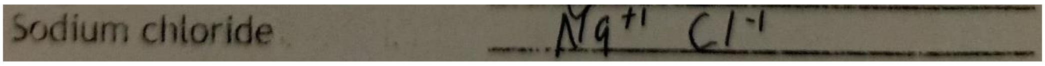
"Magnesium is Mg and Oxide is O negative because oxide has -ide."

Figure 2. The answer of learner 35 to item I.2

This misconception is also seen in the study of Espinosa et al. (2016) in their investigation of pre-service Chemistry teachers' problem-solving strategies where some students also put a negative (-) sign at the end of a chemical formula of a compound.

Lack of Understanding of Valency and Cross-Charge Method

To attain the chemical formula of an ionic compound, charges should be identified correctly and the cross-charge method should be done properly. In the case of the General Chemistry 1 learners, it is common that they are confused about how to represent the charges of the ions involved in making the compound – they often misrepresent it as oxidation numbers. Others made the representation of the ions correct but it is noticeable that the cross-charge method to get the chemical formula of the compound is not done. Below are Figures 3 and 4 showing the unedited responses from the learners.



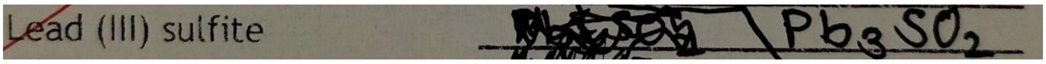
"I got my answer by identifying the chemical symbol of the following and putting a negative or positive sign if it is an anion or cation."

Figure 3. The answer of learner 16 to item I.1

"I first looked at the names of the elements in the periodic table then I wrote the symbols of each element and put a positive sign on the metal and a negative sign on the nonmetal."

Figure 4. The answer of learner 32 to item I.1

In addition, when prompted to write the chemical formula of Lead (III) sulfite, the learners show misconception about the use of the Roman numeral found in the name. Supposed to be, the Roman numeral represents the charge of the metal ion but the learners are making it as the subscript of the metal ion when the compound's chemical formula is written. As written by learner 17 in the two-tier test (Figure 5), the Roman numeral beside the lead is converted as its subscript. The cross-charge method is not used in this process.



"I wrote the chemical symbol of lead (Pb) with the numerical number (3), then the chemical symbol of sulfite (SO) because it contains oxygen, then I wrote (2) because I was basing on these examples: hyposulfite (1), sulfite (2), sulfate (3), persulfate (4)."

Figure 5. The answer learner 17 to item I.3

On the other hand, other learners can represent the charges of ions properly and attempted to do the cross-charge method but failed to simplify the subscripts. Like for example, learner 4 has written the chemical formula of magnesium oxide as MgO_2. The learner recognized that Magnesium and Oxide ions have charges of 2+ and 2- respectively but failed to carry out the cross-charge method and retained 2 as a subscript for oxygen in the chemical formula. When asked about his/her reason, since both ions have the same opposite charges, the whole compound takes 2 as a subscript. Below is the sample unedited answer of learner 4 (Figure 6).

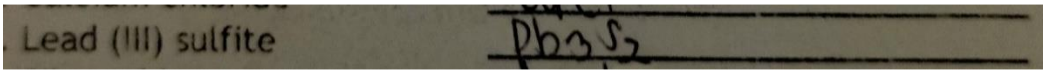
"Magnesium oxide is made up of Mg^{2+} and O^{2-} ions and are connected to each other by an ionic bond. However, they have both 2 ions that's why I put 2 in the chemical formula, therefore the formula of magnesium oxide is MgO_2."

Figure 6. The answer of learner 4 to item I.2

Problems with valency and the use of the cross-charge method were also reported in some studies. Baah and Krueger (2009) made senior high school students write the chemical formulae of some ionic compounds and concluded that they lacked knowledge of valency and its importance in writing the chemical formula of ionic compounds. In the examination of the secondary school students' ability to transform among representation levels, Celikkiran (2020) noticed that most of the incorrect responses were made in the subscripts of chemical formulae. Even if these studies were done almost a decade apart, the problem of valency and the correct usage of the cross-charge method is still evident.

Misrepresentation of Radicals

Of the three items in the chemical formula writing part of the two-tier test, only Lead (III) sulfite contains a radical or a polyatomic ion. In item number three of chemical formula writing, only 3 learners are able to write the chemical formula of Lead (III) sulfite correctly. All those who did not get the chemical formula for Lead (III) sulfite correctly do not know how to represent the sulfite ion in a symbol. It can be noted that they have difficulty following rules in writing the symbol of a polyatomic ion or oxyanion. The learners know the symbol for lead as Pb but it is evident from their answers that they have misconceptions on what to do with the given charge of the metal element which is enclosed in a parenthesis. For instance, learner 33, made the charge of lead as its subscript and mistakenly took the symbol for sulfur (S) as sulfite because of the suffix -ite, in which sulfur when in ion form should be in -ide suffix. Learner number 33 has written the subscript of the supposed sulfite in the compound from the charge of the sulfide ion. The answer of learner 33 is shown in Figure 7.



"Lead III sulfite because lead is Pb3 and the sulfite is 2 because it has -ite."

Figure 7. The answer of learner 33 to item I.3

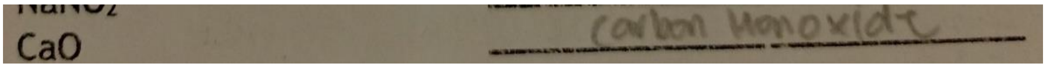
This finding corroborates with one of the findings of Habiddin (2014) that first-year chemistry undergraduate students have difficulty writing the chemical formula of ionic compounds containing polyatomic ions. For the compound Iron (III) sulfate, Habiddin (2014) noted answers such as Fe_2S_3 and Fe_3S similar to what was observed in this present study.

Misconceptions in Naming Ionic Compounds

Several misconceptions in naming ionic compounds are noted in this study. Most of the misconceptions are related to naming ionic compounds with polyatomic ions. The following themes summarized these misconceptions.

Misnaming Metal and Non-Metal Elements in Ionic Compounds

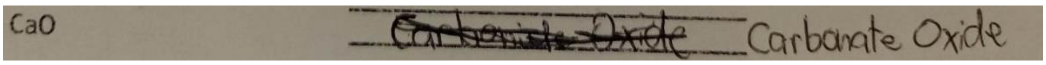
Based on Table 1, 31 learners or 91% of the total population have written the name of CaO correctly. Although almost all correctly named CaO, some misconceptions are still noted. Learner number 4 is not familiar with the symbol and name of the element calcium – he/she named Ca as carbon. Aside from being unfamiliar with the element symbol, learner number 4 was also confused about what rules to use in naming the oxide ion; the learner used the rules in naming molecular compounds. Shown in Figure 8 is the original answer of learner 4.



"I identified Ca as an element named Carbon and O for Oxygen then I put mono because the atom of Oxygen is 1."

Figure 8. The answer of learner 4 to item II.1

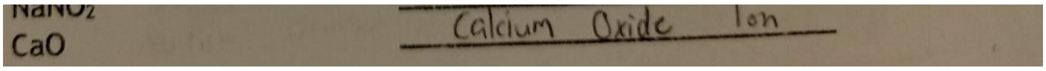
Similar to learner 4, learner 31 is also not familiar with the name of the given metal in the chemical formula. Instead of naming it calcium, learner 31 named it carbonate. He/she named the non-metal ion in the chemical formula correctly (Figure 9).



"I have answered carbonate oxide because Ca is Carbon and O is oxide. I just guessed the suffix of carbon to be -ate because I don't know what to use between -ate and -ite."

Figure 9. The answer of learner 31 to item II.1

On the contrary, learner 30 had the correct process of naming the ionic compound but he/she forgot to remove the word "ion" from the ion name of oxygen (Figure 10).



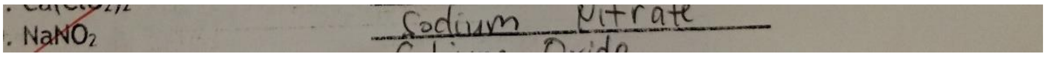
"[I arrived at my answer] by identifying the name of the symbol and putting "ide" at the end of the root word for the non-metal [ion]."

Figure 10. The answer of learner 30 to item II.1

Baah and Krueger (2012) also detected the same problem. The learners cannot name some elements found in the inorganic compounds. For instance, in the compound H_2S, learners believed that S is named sulfur instead of sulfide.

Misnaming Radicals

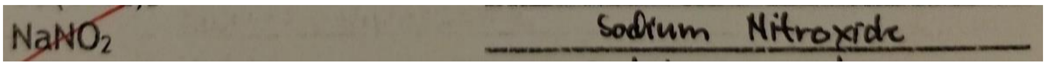
Under the ionic compound naming part of the two-tier test, $NaNO_2$ is the only compound containing a radical or polyatomic ion. Only half of the General Chemistry 1 learners were able to name $NaNO_2$ as sodium nitrite. It is evident from the answers of the learners that they have difficulties naming ionic compounds containing radicals. There are several misconceptions listed regarding the naming of $NaNO_2$. One misconception seen is that the learners tend to be confused about the rules on naming oxyanions. Instead of naming NO_2- ¬ion in the compound as nitrite because it contains two oxygen atoms, the learners named it as nitrate which is supposed to be used if the number of oxygen atoms is three. A sample unedited answer from learner 25 is shown in Figure 11.



"I used the element name of Na (Sodium) and NO is an oxyanion which consists of nitrogen and oxygen so I used the root word of Nitrogen and added the suffix "-ate" because nitrate is NO_2 making it Sodium Nitrate."

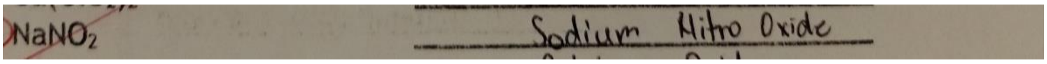
Figure 11. The answer of learner 25 to item II.2

In addition, learner 28 thought that N and O in the given chemical formula of $NaNO_2$ are not taken as a polyatomic ion, instead, he/she combined the root words of Nitrogen ion and Oxygen ion and then added the suffix -ide (Figure 12). The same misconception is seen from learner 2 who explained it as naming simple covalent compounds (Figure 13).



"I just find the element symbol on the periodic table, then copied their names."

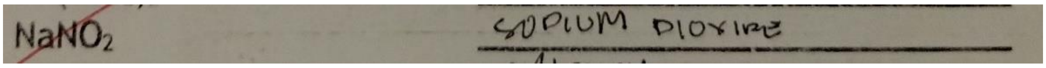
Figure 12. The answer of learner 28 to item II.3



"Basing on the periodic table: Na (Sodium) and N (Nitrogen). For my answer, after I got [the names of] the elements, I wrote them together. I answered it by using the rules of naming simple covalent compounds. That's why I got Sodium Nitro Oxide."

Figure 13. The answer of learner 2 to item II.2

In other answers, the learners still do not recognize that there is a polyatomic (oxyanion) in the given chemical formula. The learners dropped the nitrogen and disregarded the number of oxygen atoms from the oxyanion NO_2- when they named the whole compound, resulting in an answer of Sodium oxide. Others considered the subscript of Oxygen and named it using the rules in naming simple covalent compounds. Figure 14 shows a sample answer from learner 4.



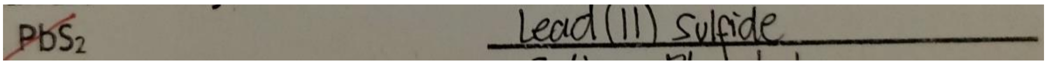
"I simply named the chemical formula. I used "di" in oxide since there are 2 ions in it."

Figure 14. The answer of learner 4 to item II.2

Naming ionic compounds that contain polyatomic ions is somewhat more difficult for the learners to answer since they show the inability to correctly name radicals (Baah & Krueger, 2012; Habiddin, 2014). Although Habiddin (2014) mentioned that this difficulty result from failing to memorize the names of polyatomic ions, the learners in the study are generally just confused about what set of rules in naming compounds should be followed.

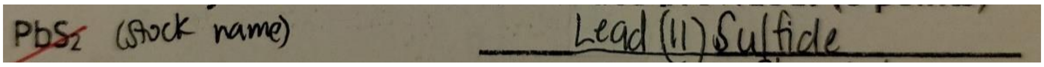
Misnaming transition metal ions with reduced subscripts of non-metal ions

Item number three is considered the most difficult question in naming ionic compounds part of the two-tier test as evidenced by the low percentage of students who named it correctly – 9%. The noted misconception is how to identify the charge of the metal ion in the compound. Since lead is found in Family B metals, it can make ions of different charges, in the case of PbS_2, the charge of the lead ion is 4+ as evidenced by the reduced subscript of sulfur in the chemical formula. The majority of students recognize that from the cross-charge method, the subscripts are the interchanged charges of the ions involved in the chemical formula but the learners were not able to analyze that the subscript found in Sulfur is already reduced into simplest form, thus their answer is Lead (II) sulfide. About this misconception, Figures 15 and 16 show unedited answers from learners 14 and 6 respectively.



"Using the stock method, I identified the cation first and then the anion, and given the formula PbS_2, we See that sulfur has a subscript of 2 so the lead will have a charge of 2."

Figure 15. The answer of learner 14 to item II.3



"I've come up with the answer by the process of Naming Ionic Binary Compounds- Stock Systems of naming. The first step I did is to write the Roman Numeral indicating the charge of the element written in parentheses after the English name of the metal. Then, the non-metal with the suffix-ide."

Figure 16. The answer of learner 6 to item II.3

Difficulties Encountered in Chemical Formula Writing and Naming Ionic Compounds

From the results of the two-tier test, it can be seen that the General Chemistry 1 learners have difficulties and misconceptions about chemical formula writing and naming ionic compounds. These difficulties observed in their answers were further probed and confirmed from the interview.

Generally, the learners find it difficult to look for the element symbols in the periodic table since they claim that they are not familiar with all of the element symbols. This explains why learners tend to misname some of the elements that are seen in the chemical formula of ionic compounds. For instance, learner 4 misnamed the element symbol Ca as carbon. Another common difficulty stated by the learners is that they are hard up in identifying what suffix to use in naming the concerned anions in the ionic compounds. Related to this, the usage of suffixes in naming polyatomic ions, especially oxyanions, was not followed correctly. When asked about their reasons, they said that they were confused about what rules on naming should be considered. Below is an excerpt from the interview of learner 8.

Learner 8: *"The methods in naming are confusing because there are too many methods that can be applied in naming."*

In addition, concerning the stock method of naming ionic compounds, the learners find it difficult to identify the charge of the involved transition metal ion when the chemical formula of the compound is given. They generally know that the subscripts in the chemical formula tell the charges of the ions but the learners are confused in identifying the charge of the transition metal ion, especially if the subscripts are already written in their simplest form.

Similar to naming ionic compounds, the learners also stated that their inability to recognize the symbols of elements present in the given IUPAC name of the compound makes it difficult for them to properly represent the compound in its chemical formula. Since they are not familiar with the element symbols and their names, they still need to inspect the periodic table of elements. Furthermore, the learners also mentioned that they find it difficult to identify the charges of ions if the only given is the IUPAC name of the ionic compound – the identification of the charges is important to correctly write the chemical formula, following the cross-charge method. It is also noted from the interview that the learners encountered difficulty in writing the subscripts found in the chemical formulae – they are having a hard time identifying where to put the subscript especially if the compound contains a polyatomic ion and they don't know what subscripts to be reduced in their simplest form. This confirms one of the results of the study conducted by Naah and Sanger (2012) that students exhibited confusion on how to properly use subscripts and coefficients in writing ionic compounds in a balanced chemical equation. Some excerpts from the interviews concerning these difficulties are as follows:

Learner 30: *"I am confused with the use of charges in the Criss Cross rule to write the subscripts and when to reduce them like reducing the subscript from 4 to 2."*

Learner 14: *"I am hard up in identifying the charges and writing subscripts of polyatomic ions to be enclosed in parenthesis."*

It is also important to note that learners experienced difficulty in writing the chemical formula of ionic compounds because there are too many rules to be followed and they are confused about what set of rules to use. This difficulty could be associated with what was described by Danili and Reid (2004) in their study on strategies to improve performance in school chemistry. They have mentioned that learning will fail if the working memory space is overloaded with information.

General Chemistry 1 Learners' Ways of Addressing Their Encountered Difficulties in Chemical Formula Writing and Naming Ionic Compounds

In the conducted interview, there are several ways in which the General Chemistry 1 learners tend to address in addressing their difficulties in chemical formula writing and naming ionic compounds. Based on their ways, the learners fit into some categories prescribed by the VARK model of learning styles. Most of the learners have said in their interview that one of their ways of addressing their noted difficulties is to reread the PowerPoint presentations related to the rules in chemical formula writing and naming ionic compounds. Aside from rereading the lectures in PowerPoint presentations, the learners also said that they go over their notes and try to memorize or familiarize themselves with the said rules and the table of common ions. With the mentioned ways of addressing their difficulties related to ionic compound nomenclature and chemical formula writing, these learners can be considered with a read/write learning style. Furthermore, other learners prefer to address their problems by listening to the lectures or review lessons given by the teacher. They often couple it with asking for some help from the teacher and/or from other learners in class for additional explanations, clarifications, and examples. These learners can be considered aural learners. Concerning their difficulty in identifying symbols of elements and their names, some students tried to employ visual learning by familiarizing the periodic table of elements. Lastly, some learners help themselves by watching video tutorials found on video-sharing websites that contain some visuals to explain how chemical formula writing and naming ionic compounds are done. In watching these videos, they are not only processing information with the use of the visuals but also with the use of the audio and text explanations embedded in the videos, hence they are employing multimodal ways of learning.

While there are several ways noted in addressing difficulties in chemical formula writing and naming ionic compounds, the are no recorded kinesthetic ways from the learners.

Conclusion

The study sought to understand the misconceptions of General Chemistry 1 learners on chemical formula writing and naming ionic compounds. In terms of chemical formula writing, the learners misrepresent ionic compounds as charged species, show a lack of understanding of valency and the use of the cross-charge method, and mispresent radicals. In naming ionic compounds, the learners generally misname not only some of the elements found in binary ionic compounds but also misname metal ions with more than 1 charge and polyatomic ions. These misconceptions were validated by the difficulties experienced by the learners in answering the two-tier test. The learners mentioned they experienced difficulty in naming some element symbols or representing the metal ions into symbols for they are unfamiliar with the periodic table. They are also hard up in naming the ionic compounds vis-à-vis representing them in chemical formulae because they are confused with the numerous rules to consider. Also, the learners mentioned that they are not quite sure how to identify the charges of the ions, where to put them as subscripts in the chemical formula, and when to reduce them in their simplest form. Despite the misconceptions and difficulties of the learners in chemical formula writing and naming ionic compounds, they mentioned several ways of addressing them. The following are their ways: (1) Visual learning – Familiarizing themselves with the periodic table of elements; (2) Aural learning – Listening to class discussions or reviews provided by the teacher and/or their co-learners; (3) Read/write learning – Reviewing PowerPoint presentations and their notes on chemical formula writing and naming ionic compounds; and (3) Multimodal learning – Watching video tutorials.

Recommendations

From this study's findings, the researcher recommends the following. For teachers of chemistry, it is recommended to fortify instruction of basic concepts in chemistry related to chemical formula writing and the nomenclature of compounds to avoid alternative conceptions. The periodic table should be maximized not only to make students familiarized with the names and symbols of elements but also to make students aware that the periodic table can also be used to identify charges of metal and non-metal ions. Before naming ionic compounds and writing their chemical formula, lessons on naming and representing ions and polyatomic ions in symbols should be taught properly. Visual representations of the cross-charge method can also be used to show how the subscripts are formed and how they are simplified in attaining the chemical formula of an ionic compound. The use of the Stock system in naming ionic compounds with transition metals should also be revisited. Furthermore, students' learning styles should be considered to effectively plan for instruction.

Information to be given should be chunked to avoid overloading of working memory space. For future researchers, it is recommended to conduct the study on college students taking General Chemistry courses to see if they have the same results. Since this research only dealt with understanding the misconceptions and difficulties of General Chemistry 1 learners related to chemical formula writing and naming ionic compounds and how they address them, it is therefore recommended that a study on a teaching strategy or intervention to improve performance is to be done.

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