POGIL Implementation in Middle School Chemistry

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Chapter I: Introduction

As time has gone on, the availability of information has become ever more readily available. There are numerous innovations such as laptops, tablets, and smartphones. All these devices can give people information at the press of a button. This has filtered into the classroom. With all of this information being available to students, it is harder to keep their attention. Students can look up information, call and send information to their friends, and even keep themselves entertained through all sorts of different applications. All of this stimulation for the students is at the palm of their hands and it is the educator's job to keep them engaged in a lesson while enhancing their problem-solving skills.

Science educators have the benefit of engaging activities being built into the fiber of the class. With laboratory activities being a prime example, students are asked to problem-solve to complete their lab. There are days, however when the teacher is not implementing a lab for that lesson. On those days, it is all about keeping the students engaged, so that they can gain the most from that lesson. Classrooms in the past have been based on the lecture, which is prone to having students drift off during the teaching. When teaching students of any age, it is important to keep them involved not so much, because they need to pay attention to the content but to give them some sort of ownership of their learning. If the students become disengaged with the content, they will not be able to develop a connection with it. It is harder to understand and learn content if there is no connection with the lesson.

One of those ways is to implement active learning strategies. Active learning strategies are designed to keep students engaged, rather than having the students listen to lectures on the content. In active learning classrooms, students are playing a more engaged role in the learning process and the teacher is not to be relied on for the majority of the instruction (Edwards, 2015). One study found that the active learning classroom format can promote active learning and student engagement, which can lead to better student performance and learning outcomes (Chacon-Diaz, 2020). Other examples that have been implemented include Problem-Based Learning (PBL) and Project-Based Learning (PjBL). Both of these student-centered approaches are used to stray away from the traditional lecture-based classroom. What the research shows is that PBL and PjBL promote higher levels of student motivation and engagement among all types of learners (Dole et al., 2017). The students also showed a preference for PBL and PjBL because of the autonomy and collaboration that these methods brought. This research showed themes of learning behaviors that increased motivation and engagement, creativity, perseverance, and divergent thinking.

All of these ideas have led to the conception of Process Oriented Guided Inquiry Learning (POGIL). Process-Oriented Guided Inquiry Learning is an instructional approach that emphasizes active learning, critical thinking, and collaboration among students (Moog et al., 2006). In POGIL, students work in small groups to explore a series of carefully designed activities that are meant to guide them toward developing conceptual understanding and problem-solving skills. Each group will have defined group roles for each student, including a facilitator, a recorder, a spokesperson, and a timekeeper. These roles should be clearly defined and explained to the students at the beginning of the semester and divided for each lesson. POGIL is based on constructivist learning theory, which suggests that learners construct their understanding of the world through their experiences and interactions with others. The instructors in the POGIL method serve as facilitators, providing guidance and support as needed, but allowing the students to take ownership of their learning. Instructors design and facilitate the activities, but also encourage students to take initiative and explore their interests and questions.

Significance of the Problem

With POGIL reducing the amount of time that the students are listening to me lecturing, it is increasing the time that they are interacting with the content. This increase in time with the content will allow them to develop connections with the content. The hope of implementing POGIL is not just so they increase their knowledge of the content, but to enhance other skills that they will need in life as well. Even if the students are not fully understanding the lesson, they will be working on other important skills like problem-solving, critical thinking, and working in collaboration.

Purpose of the Project

Introducing Process Oriented Guided Inquiry Learning (POGIL) to middle school physical science students can be a strategic and impactful approach within the context of a master's capstone project. The purpose of integrating POGIL into middle school physical science classrooms in this context is multifaceted and aligned with the goals of a comprehensive educational research endeavor.

The primary objective of incorporating POGIL into the middle school physical science curriculum for a master's capstone project is to enhance the overall learning experience for students. This active learning methodology diverges from traditional didactic approaches by emphasizing collaborative problem-solving, critical thinking, and inquiry-based exploration. By introducing POGIL, the capstone project aims to facilitate a more engaging and participatory classroom environment.

A crucial purpose of this approach is to investigate the impact of POGIL on student learning outcomes. Through meticulous research and data collection, the capstone project seeks to assess how POGIL activities influence students' comprehension of physical science concepts, their ability to apply knowledge in real-world scenarios, and their development of critical thinking skills. By doing so, the research contributes to the broader understanding of effective pedagogical strategies in middle school science education.

Moreover, establishing POGIL as part of a classroom can address the need for evidence-based instructional practices. By systematically analyzing the effectiveness of POGIL, the project endeavors to provide empirical data and insights that can inform future decisions regarding science education curriculum design and teaching methodologies.

Additionally, the capstone project recognizes the importance of nurturing high level science skills, such as communication and teamwork, among middle school students. POGIL's collaborative nature fosters these skills, which are essential not only for academic success but also for future career readiness. The purpose is to explore how POGIL impacts students' abilities to work together, articulate their ideas, and engage in meaningful scientific discourse.

Introducing POGIL to middle school physical science students within the framework of a master's capstone project serves a multifaceted purpose. It seeks to enhance the learning experience, contribute to the body of educational research, promote evidence-based instructional practices, and nurture essential skills for both academic and professional success. By accepting this venture, the aim is to make a meaningful and lasting impact on science education at the middle school level.

Chapter II: Literature Review

Education is a fundamental human right and a requirement for a healthy and flourishing society. It is essential for personal development and societal advancement and is one of the most important investments a community can make. Likewise, instructors can utilize Process Oriented Guided Inquiry Learning (POGIL) to ensure students acquire the best education. POGIL illustrates an educational approach that stresses the development of student-centered, cooperative learning tactics. Students are encouraged to collaborate and actively participate in the learning process using this teaching strategy, which leads to the growth of critical thinking, dialogue, and problem-solving abilities. POGIL activities aim to help students acquire a deeper understanding of the material while encouraging the development of crucial skills that they can use outside the classroom. Despite conflicting findings from previous research, POGIL activities assist in creating an environment that is conducive to learning, thus increasing student engagement and overall comprehension.

Overview of POGIL

Since POGIL is a student-centered instructional approach, learners collaborate in groups, with the teacher as a coordinator in a regular POGIL classroom or laboratory. Students engage in uniquely designed activities in a POGIL method, which usually follows a learning cycle model (Moog et al., 2006). These tasks have three distinct characteristics. They work effectively for self-managed teams, with the instructor facilitating learning rather than providing information. They guide the students through an investigation to deepen comprehension. They also use discipline-specific content to aid students in developing essential process abilities like advanced reasoning and applying knowledge in new contexts. These tasks allow students to understand the material by explaining and using concepts comprehensively. Therefore, POGIL is a student-centered teaching strategy.

Origin of POGIL

Instructors have utilized the POGIL method in many disciplines, including chemistry, biology, physics, engineering, mathematics, and psychology. Douglas and Chiu (2013) supposed that POGIL began in college chemistry departments in 1994. The National Science Foundation (NSF) quickly funded the POGIL approach, which US chemistry departments have extensively adopted, with adoption expanding to other sciences and engineering disciplines. The POGIL project started as a method devised by chemistry teachers to assist their students in better understanding general chemistry concepts. Since then, the POGIL project has developed into a vibrant community of dedicated teachers who support one another in transforming classrooms, enhancing student achievement, and creating curricula to facilitate these changes. POGIL enables researchers to expand their knowledge about learning and teaching and provides professional development and collaboration. Thus, with the invention of POGIL, instructors can now take a multi-concept strategy to teach their students.

Key Principles of POGIL

Student-Centered

Due to its emphasis on fostering higher-order thinking and critical analytical abilities, the POGIL approach is student-centered. POGIL has its basis in the notion that pupils learn most effectively when actively involved in the learning process (Boda & Weiser, 2018). It encourages students to take an active role in their education rather than instructors simply giving information and expecting learners to remember it. Teachers use the POGIL approach to present students with a problem or questions requiring exploration and analysis. The pupils then collaborate to obtain knowledge, debate ideas, and develop their understanding. Students can use this method to improve their critical thinking skills, gain insight into the material, and collaborate as a team. Hence, the POGIL approach encourages students to use their creativity and problem-solving abilities, making learning more manageable by removing the need for teachers to overburden learners with knowledge.

Guided-Inquiry

A series of exercises that assist students in exploring an idea or procedure serves as the POGIL approach's guiding principles. The instructor introduces the concept at the outset, and several exercises that encourage investigation, debate, and analysis follow (Daubenmire et al., 2015). These exercises aim to aid pupils in creating a mental model of the idea. After the students finish the activities, the instructors ask them to review and connect the idea to other concepts. Besides, the POGIL method allows students to collaborate, hone their analytical and problem-solving abilities, and create conceptual frameworks for the subject matter. The POGIL approach aids students in developing into self-reliant learners who can own their education. The instructors guide the pupils to challenge presumptions, pose questions, and present answers throughout the process. Therefore, the guiding principles of the POGIL approach are several exercises that aid students in exploring a concept or procedure.

Active Learning

The POGIL method has its basis in the notion that learning should involve students participating actively instead of simply absorbing information. Walker and Warfa (2017) supposed that the POGIL approach emphasizes the learning process rather than the subject matter. Instructors accomplish this by having learners work in small groups to finish tasks that require critical thought, data analysis, and asking questions. Instead of just learning facts, this compels students to interact with the subject and create their understanding of the ideas. Equally, the POGIL approach's exercises encourage active learning. These exercises test the learners while letting them meaningfully investigate the subject matter. Students can build their knowledge and better comprehend ideas through these activities. Thus, the POGIL approach reinforces the idea that learning should involve learners actively participating rather than passively absorbing knowledge.

Authentic Assessment

POGIL exercises offer an accurate method to evaluate how well pupils are learning. Teachers can use the outcomes of POGIL activities to assess student comprehension and highlight areas that need more instruction (Idul and Caro, 2022). They have many chances to evaluate their students' learning due to the POGIL approach. Instructors can observe and assess student comprehension, problem-solving abilities, and knowledge application using structured activities. Through open-ended questions and exercises that compel them to analyze the content critically, students can show that they understand it. Likewise, instructors can also evaluate their students' learning by having them produce concrete items like models, written explanations, and diagrams. Teachers can assess student learning more meaningfully and realistically to comprehend their students' learning better with POGIL. Hence, POGIL activities provide a reliable way to determine how well students are learning.

Process-Oriented

The POGIL approach is process-oriented in that it emphasizes the learning processes and motivates learners to solve problems actively. This strategy strongly stresses that students should be free to independently investigate, debate, and learn the subject matter (Vincent-Ruz et al., 2020). Students perform a variety of tasks in small groups in a POGIL classroom. POGIL's process-oriented approach challenges learners to think creatively and critically about the subject. Students are encouraged to think analytically and creatively by allowing them to brainstorm and investigate various solutions to issues. Besides, POGIL's process-oriented methodology enables students to hone their teamwork and communication skills. POGIL exercises aim to place more emphasis on the process of learning than the result. They expect students to enhance their skills as they finish the tasks. Therefore, the POGIL method is process-oriented, emphasizing the learning processes and encouraging students to participate in solving issues actively.

Components of POGIL

Cooperative Learning

POGIL includes cooperative learning because it fosters collaboration, promotes the development of critical-thinking abilities, and assists students in making connections between various ideas. Cooperative learning creates discussion-based exercises that enhance collaboration, communication, and problem-solving (Hein, 2012). Through cooperative learning, students can collaborate to solve issues, build understanding, and gain a deeper grasp of the subject matter. Students who engage in this kind of learning develop their independence and autonomy as learners. Besides, the POGIL approach promotes cooperative learning by fostering a collaborative and interactive learning setting. POGIL expects students to collaborate to develop and implement appropriate strategies, come to conclusions, and make decisions. Learners must also actively participate in their education, be able to communicate their thoughts and ideas, and pose questions. Thus, cooperative learning is part of POGIL because it encourages cooperation and the growth of critical thinking abilities.

Learning environments can be competitive, individualized, or cooperative. According to Chacón-Díaz (2020), students learn, comprehend, and retain more information when collaborating. Students have positive feelings about the subject matter, the school, the instructors, and themselves and their classmates. Those who work in teams are more likely to develop critical and analytical thinking, problem-solving, collaboration, and communication skills. However, as a learning team engages in a lesson, disagreements will undoubtedly arise due to the disparities in the team members' knowledge, perceptions, thought processes, theories, opinions, and conclusions. Such conflict encourages questioning, an active search for more information, and ultimately a knowledge restructuring when handled productively using the right interpersonal, social, and collaborative skills. Therefore, POGIL includes cooperative learning since it offers numerous benefits to learners.

Guided-Inquiry

POGIL allows instructors to divide students into small groups while giving them a problem to solve. Irwanto et al. (2018) supposed that the teacher then leads the class through solving the problem by asking probing questions and assigning tasks encouraging students to research extensively into the subject matter. The instructor acts as a facilitator as the class collaborates to find a solution, encouraging the students to think analytically and generate their ideas. POGIL encourages students to engage in deeper learning because the teacher presents them with an issue to solve instead of receiving an answer. Although the instructor is there to help the pupils, it is ultimately the student's responsibility to learn. With this strategy, learners can broaden their knowledge of the subject, develop as independent thinkers, and improve their problem-solving abilities. Hence, guided inquiry is a significant component of POGIL since it enables teachers to assist learners in learning.

Guided inquiry comprises three stages: exploration, concept creation, and application. Students build their conceptual understanding during the learning cycle's exploratory phase by answering questions that guide them as they examine a model or perform a task (Miatun & Muntazhimah, 2018). Students attempt to explain or understand the presented material by putting forth, disputing, and testing theories during this exploration period. Concept formation is a part of the second stage. In this stage, instructors effectively direct and encourage students to investigate before coming to their conclusions and formulating predictions. Learners apply their new skills in exercises, problems, and even during research during the application part. POGIL activities provide students with the chance to gain confidence in normal circumstances. Hence, the three phases of guided inquiry are exploration, idea development, and application.

Metacognition

The POGIL instruction and learning methodology heavily emphasizes metacognition. Students can use metacognition, which illustrates the awareness of one's thought processes and learning strategies, as a valuable tool as they complete POGIL tasks. They can effectively track their development and modify their approaches if they know their thought processes (Udu et al., 2020). The POGIL method of instruction places a significant emphasis on metacognition. This method encourages students to think critically and independently as they complete tasks. Students can identify when they do not understand a concept through metacognition, and they can then modify their strategy as necessary. If students struggle with a POGIL exercise, they can pause and think about how their approach might hinder their development, prompting them to change their strategy. Therefore, the POGIL teaching and learning approach strongly emphasizes metacognition.

Metacognition fosters a climate of ongoing development. Students may need to assess both their own and one another's efforts. Instructors observe the teams and, as necessary, offer input to individuals, groups, and the class to help learners improve their skills and recognize areas that need improvement (Mamombe et al., 20220. It is also possible to establish a setting where such evaluations are safe, welcomed, and valued by differentiating between evaluation and assessment. Assessments are impartial and created to assist in development. However, evaluations aim to record the degree of achievement attained and are judgmental. Instructors can utilize assessments to provide feedback during daily learning experiences and embrace course examinations to evaluate learning. Thus, metacognition aids students in creating the substantial mental structures that connect conceptual and procedural knowledge necessary for problem-solving success.

Previous Research on POGIL in Science Education

Overview of the Existing Research on POGIL in Science Education

The majority of previous research on POGIL in science education has been positive. POGIL can enhance student-learning outcomes in science classes compared to conventional instruction (Mata, 2022; Muhammad & Purwanto, 2020; Murray, 2014). According to previous research, POGIL can be particularly helpful for students with difficulty in science because it offers a more structured learning environment. POGIL can boost students' self-efficacy in science and attitudes toward the topic. Besides, according to previous research, POGIL can help teach inquiry-based science because it motivates students to participate effectively in their education. Murray (2022) found that POGIL is beneficial in terms of student engagement and attitude. Compared to students taking a traditional science course, those taking a POGIL-based science study reported being more engaged (Soltis et al., 2015). Thus, earlier studies on POGIL in science teaching have been positive.

Most previous research on POGIL in science education has presented essential findings. Studies conducted by Roller and Zori (2017), Purkayastha et al. (2019), Pradiyanasari et al. (2020), and Prince et al. (2018) found that POGIL is effective in improving student learning outcomes. Students participating in POGIL activities have shown enhanced problem-solving, critical thinking abilities, and significant knowledge and comprehension of science material. The collaborative nature of POGIL activities has also increased student involvement and motivation in the classroom. Besides, POGIL successfully fosters social skills in students and can aid in developing abilities like critical thinking, collaboration, and communication (Datu-Dacula & Anda, 2021; Murray, 2019). POGIL exercises enhance these relationship skills, which are crucial for success in science. Thus, POGIL is a valuable resource for science teachers, necessitating them to utilize them in science classrooms all over the globe.

There have been several studies on POGIL's efficacy in science education, but researchers must consider its strengths and limitations. Vincent-Ruz et al. (2020) and Özkanbaş and Taştan Kırık (2020) conducted their studies with a variety of students from elementary school to college. This diversity gives the research on POGIL's efficacy in science education credibility. It enables a greater comprehension of how instructors can adjust POGIL techniques to different student levels, ensuring that all students can profit from the activities. POGIL activities have consistently enhanced pupil engagement, motivation, and understanding of scientific concepts. Despite its advantages, studying POGIL in science instruction has some limitations. One drawback is that the scientists' research was mainly in specific educational institutions, so the findings might not be generalizable to other nations or cultures. Hence, previous research on POGIL's efficacy in science education presents numerous strengths and limitations.

Although teachers widely use POGIL, there is a gap in the literature regarding earlier studies on the subject. The absence of empirical studies is the most significant gap in the literature regarding the earlier studies on POGIL in science education. While many theoretical works, such as Walker and Warfa (2017), hypothesize about the possible advantages of POGIL, few empirical studies have evaluated the program's efficacy in the classroom. Other researchers and instructors cannot precisely predict POGIL's impact on students' learning. This limitation restricts the current study's applicability to other educational settings. Scientists must conduct numerous empirical research and examine the effects POGIL has had on different student groups to fill in the gaps left by previous studies on POGIL in science education. Hence, additional research on POGIL in science education will help teachers learn more about implementing POGIL in the classroom.

Summary of Key Findings

The primary objective of POGIL in science education is to assist students in developing a better understanding of and abilities in problem-solving, critical thinking, and communication. POGIL activities such as service learning emphasize student-driven scientific idea exploration, collaboration, and discussion. According to Armstrong et al. (2021), students who participate in service learning courses benefit from improved leadership and communication abilities, an understanding of the relevance of the course material, and hands-on learning opportunities to learn about the real-world applications of their curriculum. These problem-solving, critical-thinking, and collaborative exercises aid in students' comprehension of the subject matter. Through POGIL, students can collaborate to come to decisions and find solutions while honing the abilities necessary to think independently. Thus, POGIL's primary goal in science education is to help students improve their knowledge of and skills in communication and critical thinking.

POGIL exercises aim to allow students to investigate scientific ideas in a practical, inquiry-based way. They enable learners to develop a deeper understanding of their subject matter. According to findings by Dole et al. (2017), teaching strategies should center on giving students a strengths-based, more individualized education by encouraging their learning to adapt to the demands of a world that is changing quickly. Students can actively participate in their learning process by participating in inquiry-based learning. They can pose questions, discuss, and think critically about the subject. Students can make connections between the subject matter and their own experiences and real-world situations due to POGIL exercises. This ability inspires students to consider science ideas more carefully and makes learning more fulfilling. Therefore, POGIL activities allow students to explore scientific concepts in a practical, inquiry-based manner.

POGIL activities allow students to practice problem-solving strategies and build crucial skills like critical thinking by requiring students to tackle problems in small groups. They demand active learning and collaboration among the students as they identify the essential ideas, examine the data, and apply them to the issue. The suppositions by Edwards (2015) reveal that when students participate in active learning, they become more involved in the learning process and are less dependent on the teacher. POGIL exercises allow students to practice problem-solving challenges and hone data analysis, decision-making, and deductive reasoning skills. Giving students an active learning experience emphasizing problem-solving techniques and critical thinking will help them develop and hone their skills to thrive in the real world. Hence, POGIL activities allow learners to practice problem-solving techniques and develop essential skills.

POGIL is effective in science education since it promotes active learning. The findings by Freeman et al. (2014) concur with these assertions since active learning stimulates students' critical thinking, curiosity, and use of their information in practical settings. Students are better able to assimilate and retain knowledge when they are actively participating in the learning process. Equally, POGIL exercises aid students understand scientific concepts on a deeper level by breaking down complex ideas into more manageable chunks. Students can also make inquiries as they progress through the content at their own pace. This freedom fosters deeper engagement with the subject and active learning. The exercises allow students to collaborate, exchange concepts, and discuss solutions. They enhance the underlying ideas while developing critical thinking and problem-solving abilities. Therefore, POGIL encourages active learning, which is why it is successful in science education.

POGIL is effective in science education since it allows instructors to tailor activities to the need of their students. As per Lee and Blanchard (2018), many factors can affect teachers' readiness to manage change. Teachers can alter activities to include real-world applications, increase resources, change the difficulty level, or provide more assistance to students who need it. This adaptability enables instructors to design activities suitable for every student, guaranteeing that every student will gain something from the training. Teachers can also utilize group work and group talks to ensure students learn from one another and make the activity more exciting and interactive. Therefore, instructors can ensure that their students receive the best education possible by creating activities tailored to each student's interests and abilities and adjusting the difficulty level to fit their needs.

POGIL promotes active student involvement in learning by giving students a structured method for tackling problems. Instructors utilizing the POGIL approach expect students to engage actively with the material by working in small groups, exploring and discussing the subject matter, and drawing connections between ideas. According to findings by Park et al. (2021), group activities, regular conceptual learning evaluation, and active learning that improve student engagement characterize teaching. POGIL exercises motivate students to take charge of their education and develop a self-directed learning style. They frequently give students a chance to hone their analytical and problem-solving skills. These exercises give students more confidence to take charge of their education and use what they learn in practical settings. Thus, POGIL encourages active student involvement in learning by providing learners with a systematic approach to solving issues.

POGIL is effective in science education since it offers learners a hands-on approach that will assist them in connecting various concepts. Boda and Weiser (2018) asserted that POGIL activities involve students in active problem-solving and critical thinking, which aids in developing a more thorough grasp of the material. Students who use this method can better visualize, comprehend, and implement ideas in various situations. These exercises also assist students in developing their communication and teamwork skills, identifying connections between ideas, and creating a deeper comprehension of the subject matter. POGIL activities offer students an enjoyable and engaging method to learn. Students can interact with the content by participating in these activities. They can learn more efficiently by maintaining motivation and interest in the subject matter. The collaborative character of these exercises aids in enhancing students' communication and problem-solving abilities. Hence, POGIL is successful in science education because it gives students a hands-on method to help them connect various ideas.

POGIL activities are student-led, inquiry-based lessons that encourage students to become active learners and problem-solvers while deepening their grasp of scientific ideas. The study by Idul and Caro (2022) found that students investigate a scientific concept or problem in small groups as part of POGIL activities, encouraging active learning. These findings seemingly concur with the suppositions of Daubenmire et al. (2015), who found that POGIL activities encourage pupils to think critically and creatively and to explore the problem from multiple perspectives. Students understand science is a continuous process of researching and finding through POGIL activities. Besides, POGIL activities also encourage an enthusiastic and involved mindset. Students become more engaged when they work together to solve an issue. This collaboration inspires learners to take charge of their education and to be passionate about it. Therefore, POGIL activities motivate students to become active learners and problem solvers while strengthening their understanding of scientific concepts.

Numerous studies have shown how POGIL is a popular approach to science education. However, despite POGIL's popularity, POGIL is not an effective strategy for teaching science. The findings by Mamombe et al. (2020) suggest that POGIL provides pupils with instructions and questions to answer. The primary problem with POGIL is that it does not sufficiently involve students in the scientific method. POGIL merely gives students a collection of questions and directions to follow instead of instructing them to interpret data and draw meaningful conclusions. Since POGIL does not encourage the critical thinking abilities necessary for success in science, this can make learning seem dull and uninspired. Students may not feel the need to think creatively because POGIL activities emphasize memorizing facts and ideas. Therefore, despite its widespread use in classrooms, POGIL is a poor method for teaching science.

POGIL activities do not allow for the individualization of science teaching. According to Irwanto et al. (2018), POGIL exercises give each group the exact instructions and questions, so students might not get the individualized support required to comprehend an idea fully. Making meaningful academic success can be challenging for students without individualized feedback. Due to the requirement that students work in groups, which enables them to access the group's collective knowledge and experience, POGIL does not offer individualized instruction. It emphasizes the growth of higher-order thinking abilities, necessitating collaboration among students to investigate and discuss the subject matter. It also strongly emphasizes group work, but it offers no tips on how to work together productively. Students might not take the learning process as carefully as they should, which can result in a lack of accountability. Thus, POGIL exercises prevent the individualization of scientific instruction.

Strengths and Limitations of the Research

Strengths

The focus on improving the educational experience is the strength of POGIL research. The studies by Boda and Weiser (2018), Datu-Dacula and Anda (2021), and Daubenmire et al. (2015) aim to teach the students content while imparting a wide range of other skills insightfully. They provide an objective and critical analysis of POGIL research. The articles present a range of theoretical and empirical perspectives to analyze their subjects objectively and critically. These articles' writers examine their topics using scientific methods and frequently offer several interpretations of their conclusions. They also discuss the ramifications of their findings, which aids readers in analyzing their conclusions. Readers can better comprehend and form opinions about the subject through this analysis. Therefore, the articles on POGIL research are reliable and credible since they focus on enhancing the educational experience of students undertaking POGIL activities.

The research articles' strengths are that they offer fresh perspectives on POGIL research. Studies conducted by Hein (2012), Idul and Caro (2022), Irwanto et al. (2018), Mamombe et al. (2022), and Mata (2022) found that comparing the POGIL technique to the conventional classroom, POGIL does perform better. They give new perspectives on POGIL use in science education by examining the POGIL method's effectiveness in various contexts, such as science, technology, engineering, and math (STEM) education, educational reform, professional development, and assessment. They also explore the various POGIL adaptations and implementations professionals can make across numerous fields and in diverse educational contexts. Research papers on POGIL that examine these subjects provide fresh perspectives on the effectiveness of this teaching and learning methodology. Thus, the articles' most significant features are their unique perspectives on POGIL research.

The research articles on POGIL research provide a basis for further research and discussion. Studies by Walker and Warfa (2017), Udu et al. (2020), and Soltis et al. (2015) provide evidence to support their arguments or interpretations. Through their comprehensive analysis of the effects of the method on student learning, the study articles on POGIL research serve as a foundation for additional investigation and discussion. The journals examine the findings of various studies and highlight areas that require more analysis. They address how instructors might use the results in teaching and learning, offering a foundation for further debate. They also provide a detailed overview of POGIL research today, which prospective researchers can use as a starting point for future studies by those seeking to contribute to existing knowledge. Hence, the research papers on POGIL research serve as a foundation for additional investigation and debate.

A significant strength of the research articles on POGIL research in science education is that they present new findings. The studies by Muhammad and Purwanto (2020) and Pradiyanasari et al. (2020) present new theories and findings regarding POGIL research that other articles have not explored or discussed previously. They have mainly concentrated on the efficacy of POGIL-based instruction compared to traditional education and found that POGIL-based instruction is more effective for teaching complex scientific concepts and fostering higher-order thinking skills. They have examined how POGIL-based instruction might improve student engagement and facilitate an interactive learning atmosphere. They have also analyzed how POGIL-based education affects students' drive and self-confidence. Therefore, the fact that the research articles on POGIL research in science education offer new findings is a significant strength.

The strength of the research articles on POGIL research is that they provide various sources. The studies conducted by Roller and Zori (2017) and Purkayastha et al. (2019) incorporate a variety of sources, including data from original research, polls, interviews, and published literature. This addition enables a more thorough examination of the subject. The study articles offer a variety of sources for instruction by providing teachers with strategies and resources supported by research. They explore the use of POGIL in various settings, discuss the advantages and difficulties of POGIL, and provide examples of successful POGIL instruction. They also offer a forum for exchanging fresh perspectives and methods for using POGIL in the classroom, and they can inspire teachers looking for new, creative ways to engage their students.

Thus, the research papers on POLIG research offer a variety of sources, allowing for a more in-depth investigation of the topic.

Limitations

There are numerous limitations to the POGIL research on science education. The articles highlight significant variations in their research areas that might have unintentionally influenced the outcomes. Muhammad and Purwanto (2020) investigated the impact of the POGIL model on learners' capacity for solving challenging mathematical problems in Indonesia. Mamombe et al. (2022) focused on how exposure to POGIL enhances the ability of 11th-grade physical sciences students to solve stoichiometry issues in South Africa. Other articles, such as studies conducted by Mata (2022) and Soltis et al. (2015), concentrated on the effectiveness of POGIL in America. Due to the researchers' primary focus on a group of nations when determining POGIL's efficacy, the study's final findings are primarily collective. The results do not accurately reflect the situation in any particular country. Hence, it would be incorrect for readers to presume that the articles' results apply to all nations.

The lack of diversity and experience in the research teams causes limitations that can influence the findings. The study conducted by Daubenmire et al. (2015) introduces many uncontrollable factors. In some studies, such as that undertaken by Irwanto et al. (2018), two instructors teach the same material. However, one uses the POGIL method, while the other utilizes the conventional lecture-based approach. The teacher's ability to communicate the course material to the students is the one factor the study cannot control. The studies' findings will differ if one teacher performs that task considerably better than the other does. The fact that many of the research teams undertaking the POGIL investigation comprise people with similar backgrounds and experiences also restricts the scope of results. Thus, the study teams' limitations, which may affect the results, result from the lack of diversity and expertise in those teams.

Numerous studies investigating the effectiveness of POGIL in science lacked control groups, making this a limitation. Mamombe et al. (2022) did not include a control group in their research, limiting the ability to make causal inferences from the data. Without a control group, the researchers cannot compare the outcomes of the experimental group with those of a group not subject to the same experimental conditions, which could result in inaccurate or incomplete findings. The researchers might be unable to recognize the actual effects of the experimental conditions without this comparison and might come to the wrong conclusions. Without a control group, the researchers might also not be able to control for the effects of unrelated variables, which could lead to biased or flawed findings. Hence, the limitation arises from the fact that many studies examining the efficacy of POGIL in science lacked control groups.

The research articles have limited sample sizes making it challenging to draw generalizable conclusions from the data. Studies conducted by Udu et al. (2020) and Pradiyanasari et al. (2020) had limited sample sizes affecting the article's reliability and credibility. The researchers found it challenging to make reliable conclusions since they had data from a smaller sample size. This situation occurred since, with a smaller sample number, there is less information to work with, which increases the possibility of making erroneous assumptions. Besides, small sample sizes can lead to inconsistent results, making it more challenging to identify meaningful trends in the data. A smaller sample size also makes sampling errors more likely, resulting in incorrect or lacking findings. Therefore, because of the study articles' small sample sizes, it is challenging to draw conclusions that instructors can apply in teaching.

Some research articles adopted the qualitative research design method to collect their data. Datu-Dacula and Anda (2021) embraced the qualitative research design in its structure, making it have unreliable conclusions. A qualitative research strategy has limitations because it depends heavily on irrational data. It can be challenging to draw generalizations that apply to a larger population because qualitative research depends on the researcher's interpretations of a circumstance and the meaning people attribute to it. Equally, qualitative research frequently needs more time and funding than quantitative research, and it can be challenging to control outside factors that could affect the findings. Fully grasping the research subject in the study by Datu-Dacula and Anda (2021) was challenging because some participants were maybe reluctant to disclose their personal experiences or opinions. Therefore, according to qualitative research, the researchers make conclusions from personal experiences rather than objective facts, making this a limitation.

Since measurement tools might not precisely measure the desired construct, they are frequently a limitation in research papers. Studies conducted by Irwanto et al. (2018) and Idul et al. (2022) utilized different measurement tools that affected their conclusions. Measurement tools limit research by supplying a predetermined list of inquiries or assignments to gauge a particular variable. This limitation may reduce the variety of responses the researchers can gather and the data they can collect. The researcher's proficiency may also limit the tools in correctly interpreting the data, as well as the precision and dependability of the instrument. Using measurement instruments that do not reliably measure the same construct across studies may make it more difficult to compare results. Hence, measurement tools are frequently a limitation in research papers because they might not accurately measure the intended construct.

Gaps in Research

There is still a gap in POGIL research, although instructors utilize POGIL frequently in their teaching exercises. Current research articles, such as those conducted by Muhammad and Purwanto (2020), lack a focus on a long-term understanding of the content teachers offer during POGIL activities. Future research should concentrate on the long-term comprehension of the material teachers present during POGIL activities to comprehend how students learn and how teachers can assist them. Understanding how students interact with one another during problem-solving activities, the questions they ask, and how instructors respond to those questions can help create effective instructional strategies for delivering the subject matter. It can offer a better grasp of how students internalize the material, which can help guide decisions about curricula and instruction. Understanding the content covered during POGIL activities can help identify and correct misconceptions students may have about it. Therefore, the long-term comprehension of the material teachers present during POGIL activities should be the focus of future research.

The limited study on POGIL in science education has mainly concentrated on how well the strategy increases student motivation and engagement. Although studies conducted by Pradiyanasari et al. (2020) and Purkayastha et al. (2019) have found POGIL successful in these areas, there is still a lack of empirical data demonstrating its effects on student achievement. Empirical evidence of POGIL's impacts on student achievement is necessary because it offers proof that researchers and instructors can adopt to evaluate POGIL's effectiveness in raising student achievement in science education. Judging POGIL's success in enhancing student performance would be challenging without empirical evidence. Researchers can better comprehend how POGIL affects student achievement by gathering and examining empirical data. The data can also assist researchers in understanding how instructors can utilize POGIL activities in science education. Thus, empirical evidence demonstrating POGIL's impacts on student achievement is still lacking.

There is a lack of research on the long-term impacts of POGIL on student learning, such as how students apply the information and abilities they gain in the POGIL classroom to other settings. However, the study conducted by Vincent-Ruz et al. (2020) attempted to highlight that the short-term effects of POGIL on student learning are more significant than its long-term effects despite not explaining it comprehensively. The inability to collect long-term data is the primary cause of the lack of research on POGIL's long-term effects on student learning. Due to the time required before it is possible to assess the impacts of POGIL on student learning appropriately, it is challenging to track and measure long-term student learning outcomes. The logistics and financial aspects of conducting such a study are also problematic. Hence, research on the long-term impacts of POGIL on student learning is lacking.

There is a lack of research into the effects of POGIL on student attitudes and perceptions about science. Udu et al. (2020) studied how instructors can utilize POGIL to enhance their students' achievement in science education but did not investigate how it affects student attitudes and perceptions about science. There may be several reasons why there has not been enough study done on POGIL's impact on students' attitudes and perceptions of science. POGIL is a teaching approach strongly emphasizing student-centered learning and exploration, making it challenging to assess its influence on students' attitudes and perceptions quantitatively and systematically. Besides, POGIL is a relatively new teaching method that has not received much in-depth study. It is challenging to rigorously control and quantify the effect of POGIL on student attitudes and perceptions because of the nature of student-centered learning. Thus, research into how POGIL affects students' views and perceptions of science is lacking.

Research into POGIL's ability to advance critical scientific thinking and problem-solving abilities is lacking. Soltis et al. (2015) investigated how POGIL enhances higher-level thinking skills but did not examine how it promotes students' critical scientific thinking and problem-solving abilities. There may be several reasons for the lack of studies on how POGIL enhances critical science reasoning and problem-solving skills. Researchers might need some time to become familiar with POGIL and its possible advantages because it is a comparatively new teaching methodology. Since POGIL necessitates more time and resources than traditional teaching techniques, it makes it difficult for researchers to conduct experiments. Generalizing findings from one study to another is challenging because POGIL's effectiveness relies on the instructor's expertise and instructional techniques. Therefore, there is a lack of research on POGIL's potential to improve critical science reasoning and problem-solving skills.

Further research is necessary into the use of POGIL in various learning settings. Although Murray (2014) and most other studies on the POGIL approach focus on higher education settings, more research is still needed to determine how teachers can implement POGIL in secondary and primary school contexts. The need for research into how instructors can utilize POGIL in secondary and primary school classrooms is crucial because it aids teachers in understanding the most effective ways to instruct students of various ages. Research can offer evidence-based approaches that cater to the particular requirements of each age group, ensuring that students get the best education possible. Educators can identify potential difficulties and challenges in the classroom and develop solutions by researching the approach's implementation. Therefore, the application of POGIL in different learning contexts needs additional research.

Research is required to determine the best ways to use POGIL to engage pupils from various backgrounds and learning preferences. Studies conducted by Özkanbaş and Taştan Kırık (2020) and Prince et al. (2018) focus on specific students without particular needs or preferences. POGIL is a relatively new approach to teaching and learning, and there is still much to learn about its efficacy in various contexts. Research is necessary to determine the best ways to use POGIL to engage students from different backgrounds and learning preferences. Although POGIL can potentially engage students from all backgrounds and learning preferences, it is crucial to know how to use it effectively to guarantee that all students receive assistance and can profit from the strategy. Research can provide evidence about the efficacy of POGIL for students from various backgrounds and learning preferences and offer effective instructional strategies for teachers. Hence, the most effective POGIL instructional strategies for involving students with different origins and learning styles require research.

More research is required to compare POGIL to other active learning strategies, like flipped educational environments, project-based learning, and inquiry-based learning, even though studies have compared POGIL to conventional lecture-based teaching. Studies such as that conducted by Idul and Caro (2022) focused primarily on comparing traditional instruction and POGIL activities. POGIL is a successful teaching approach promoting collaborative learning, critical thinking, and collaboration. Teachers can apply the POGIL technique to other active learning techniques, including flipped classes, project-based learning, and inquiry-based learning. However, there is a lack of study on how well these strategies perform when using POGIL. The advantages and disadvantages of using POGIL in these situations require further research so teachers can understand them. Hence, more research is necessary to compare POGIL to other active learning methods.

There needs to be additional research to identify which strategies of POGIL are most effective in different science disciplines. The study by Mata (2022) focuses on POGIL's effectiveness with secondary school students studying a science subject but does not address which strategies are most effective. Research into the efficacy of POGIL in various science subjects is necessary to assist teachers and curriculum developers in choosing which strategies to employ and how to do so most effectively. The learning goals for multiple fields can vary, as can the methods used to achieve those goals. The student populations in various classrooms may differ, as well as their levels of prior knowledge and learning preferences. Thus, teachers can benefit from research on POGIL's efficacy in different scientific disciplines to meet the individual requirements of their students.

Conclusion

Despite inconsistent findings from previous research, POGIL activities help foster a learning environment that enhances student engagement and comprehension. In a typical POGIL classroom, learners cooperate in pairs, with the instructor as a facilitator since POGIL is a student-centered instructional method. Students use specifically designed activities in a POGIL approach, which typically adheres to a learning cycle paradigm. POGIL's components include being guided-inquiry, metacognition, and cooperative learning. Besides, a summary of key findings about research conducted regarding POGIL in science education reveals that POGIL enhances problem-solving, critical thinking, and communication skills. The existing research on

POGIL in science education presents numerous strengths and limitations. There is also a gap in research despite instructors adopting POGIL activities into their teaching activities. Prospective researchers should conduct research on POGIL in science education to assist instructors in incorporating them into their teaching exercises to enhance student achievement.

Chapter III – POGIL Implementation and Research

Abstract

This capstone project explores the implementation of Process Oriented Guided Inquiry Learning (POGIL) in middle school chemistry, specifically focusing on the NGSS (Next Generation Science Standards) framework for MS-PS1 Matter and its Interactions. The study aimed to investigate the impact of POGIL methodology on students' understanding, engagement, and overall enjoyment of science. A diverse range of POGIL activities, aligned with NGSS standards, were integrated into the middle school chemistry curriculum. The research employed a mixed-methods approach, combining quantitative analysis of pre- and post-assessment scores with qualitative insights gathered through student surveys and classroom observations. The findings revealed a significant increase in students' understanding of key chemistry concepts, as evidenced by higher post-assessment scores. Additionally, the implementation of POGIL led to heightened levels of student engagement during classroom activities, with students actively participating in collaborative inquiry. The study also uncovered a notable rise in students' overall enjoyment of science, indicating that the POGIL approach positively impacted their attitudes toward learning and exploration. These results contribute valuable insights into the efficacy of POGIL in middle school chemistry education, emphasizing its potential to enhance both learning outcomes and students' general experiences in science classrooms. The success of this implementation underscores the importance of interactive and collaborative approaches in fostering a positive and enriching learning environment for middle school students.

Methodology

The incorporation of Process-Oriented Guided Inquiry Learning (POGIL) into the research forms a pivotal aspect of the study aimed at enhancing student engagement and learning outcomes within a middle school level chemistry course. The methodology was anchored in a structured process, commencing with a preliminary assessment, followed by the administration of a survey, and ultimately the integration of POGIL activities as a substitution for conventional note-taking practices.

To establish a foundation for the research, a process was initiated with a pre-assessment designed to gauge the students' foundational knowledge and competencies within the subject matter. This assessment played a crucial role in identifying areas of deficiency, thereby allowing there to be tailoring to the POGIL activities to address these specific needs. Additionally, the pre-assessment served as a baseline for gauging subsequent learning gains during the course of the study.

Subsequently, prior to the introduction of POGIL activities, a survey was administered that encompassed seven insightful questions. The first question asked students to rate their enjoyment of the science class on a scale from 1 to 10, with 1 representing "not at all" and 10 representing "very much." This question was complemented by a brief explanation soliciting their reasons for the chosen rating. Additionally, the survey probed students about their interests and challenges in science class, the primary goals they believed should be emphasized in science education, their note-taking preferences, preferred learning strategies, suggestions for more engaging science class activities, and the skills and knowledge they considered most essential for their future endeavors.

The survey results yielded a wealth of information that elucidated students' perspectives, expectations, and apprehensions concerning the forthcoming integration of POGIL activities. The POGIL's that are being given are in line with the Middle School Next Generation Science Standards, specifically, *MS-PS1 - Matter and Its Interactions*. This data was pivotal in tailoring the POGIL curriculum to align with students' preferences and learning needs, ultimately enriching their educational experience. The subsequent phase of our research involved the active participation of students in POGIL activities, wherein they were encouraged to collaborate and engage in inquiry-based learning, encouraging critical thinking and problem-solving abilities. Throughout this process, the implementation of POGIL was closely monitored and evaluated to assess its impact on student performance, conceptual comprehension, and overall satisfaction. Notes were given to students in certain cases to supplement or review the learning the students did in the POGIL activities. The students also were given multiple supplemental lab experiments to complete to enhance their understanding of the content being given.

The implementation of Process Oriented Guided Inquiry Learning (POGIL) in the research involved student groups of four, each with designated roles such as a manager, quality control, and two helpers, is a strategic approach to foster collaborative learning and enhance individual skills. In this dynamic setting, the manager takes on a leadership role, overseeing the overall direction of the group's work and ensuring that everyone is contributing effectively. This not only develops leadership skills but also encourages active participation and engagement among group members. The quality control role in the POGIL implementation serves as a mechanism to enhance the critical thinking and problem-solving abilities of the students. The quality control individual is responsible for assessing the accuracy and reliability of the group's work, promoting a culture of accountability and attention to detail. Through this process, students gain insights into the importance of thorough research and the significance of rigorous quality control in scientific inquiry. The presence of two helper roles within the POGIL framework promotes teamwork and cooperation among students. These helpers contribute to the group's collective efforts, facilitating the exchange of ideas and collaborative problem-solving. This collaborative learning approach not only mirrors real-world research environments but also provides students with a holistic understanding of the research process, emphasizing the importance of effective communication, division of labor, and mutual support in achieving shared goals. Overall, the POGIL strategy with designated roles fosters a rich learning experience, combining theoretical knowledge with practical skills in a collaborative and interactive setting.

The integration of POGIL within the instructional framework was complemented by a thoughtful balance of direct instruction. The students underwent a structured curriculum that included six POGIL lessons, providing them with the opportunity to actively engage in the inquiry process and develop problem-solving skills collaboratively. The incorporation of POGIL in tandem with three traditional lecture sessions ensured a well-rounded approach to learning, combining the benefits of both student-driven exploration and instructor-guided content delivery. To further enhance the practical application of theoretical concepts, the remaining lessons were enriched with hands-on activities and laboratory exercises. These components not only reinforced the knowledge acquired through POGIL and lectures but also provided students with a tangible understanding of how research methodologies translate into laboratory practices. This multifaceted approach aimed to cater to diverse learning styles, promoting a deeper understanding of the subject matter while nurturing a sense of curiosity and experimentation among the students. Moreover, the POGIL methodology, coupled with supplementary activities and labs, contributed to the development of crucial scientific skills. The students not only learned to work collaboratively but also honed their abilities to formulate hypotheses, design experiments, and critically analyze results. The integration of various instructional strategies within the research project sought to create a comprehensive and immersive learning experience, preparing students for the complexities of real-world research scenarios where a combination of teamwork, theoretical knowledge, and practical skills is essential for success.

Following the series of POGIL lessons, traditional lectures, and supplementary activities, students underwent an assessment phase to gauge their understanding of the key concepts covered in the research project. A quiz was administered to evaluate their grasp on fundamental topics such as phases and phase changes. This quiz served as a formative assessment, providing immediate feedback to both students and instructors, allowing for timely adjustments in teaching strategies to address any identified gaps in comprehension. Subsequently, a comprehensive unit assessment was conducted to measure the overall mastery of the material. This assessment covered a broader spectrum of the curriculum, such as phases, phase changes, the atom, the periodic table, elements, and Bohr models, challenging students to synthesize information, apply their knowledge to problem-solving scenarios, and demonstrate a deep understanding of the interconnected concepts. By encompassing various elements of the research project, the unit assessment aimed to assess not only factual recall but also higher order thinking skills, aligning with the multifaceted objectives of the instructional approach. In addition to the assessments, a survey was conducted to gather valuable insights into student perceptions of the POGIL approach compared to traditional lectures. This feedback mechanism aimed to capture the effectiveness of the pedagogical methods employed, shedding light on students' preferences, learning experiences, and perceived levels of engagement. Analyzing student responses to the survey provides educators with valuable information for refining and optimizing future implementations of POGIL within the context of research projects, allowing for continuous improvement and adaptation to student needs and preferences.

Data and Observations

Pre-Assessment Data

The pre-assessment results unveiled a diverse spectrum of student performance within the group. Contrary to an average performance level, the mean score of 45 percent indicated that many students were performing below expectations. The mode of 41 percent suggested a significant number of students clustered around this suboptimal score. The median score of 44 percent reinforced the notion of below-par performance as a central tendency in the distribution of scores. However, what remained particularly remarkable was the substantial variation in individual performances, as indicated by the minimum score of 19 percent and the maximum score of 78 percent. This significant spread underscored the disparities in student readiness, making it clear that a considerable portion of the class fell below the expected level of preparedness.

These pre-assessment statistics offer valuable insights into the diverse levels of readiness among students prior to the implementation of instructional interventions. The presence of a substantial number of students scoring below 50 percent highlighted that these individuals were not meeting the expected performance standards. Recognizing this initial landscape was pivotal in customizing our instructional approach to cater to the varying needs of students. It was essential to ensure that subsequent educational strategies, such as Process-Oriented Guided Inquiry Learning (POGIL), would effectively address this range of readiness, ultimately leading to improved learning outcomes and helping students meet the expected standards of achievement.

Pre POGIL Survey Data

The students were given seven questions for a survey to take prior to being exposed to the POGIL method. The questions were as follows:

1. On a scale of 1 to 10 (1 being not at all, 10 being very much), how much do you enjoy your science class? Please briefly explain why.
2. What do you find most interesting about science class, and why?
3. What do you find most challenging about science class, and why?
4. What do you think should be the primary goal of a science class? (e.g., learning facts, conducting experiments, critical thinking, etc.)
5. How do you typically take notes in science class, if at all? (For example, written notes, digital notes, no notes, etc.) Would you prefer a different strategy (other than notes) to learn or gather new information?
6. In your opinion, what types of activities or projects would make science class more engaging and enjoyable for you?
7. What skills or knowledge do you believe are most important to gain from science class to help you in the future?

The survey question posed to students, "On a scale of 1 to 10 (1 being not at all, 10 being very much), how much do you enjoy your science class?" yielded a wide array of responses that provided valuable insights into student perceptions of their science classroom experience. The data revealed an overall positive sentiment, with a mean enjoyment score of 7.09. The mode and median scores both rested at 7, indicating that a significant proportion of students consistently expressed a high level of enjoyment. The range of responses, spanning from a minimum score of 1 to a maximum score of 10, showcased the full spectrum of student sentiments, with some individuals reporting relatively lower enjoyment levels and others experiencing a profound sense of satisfaction. This general view of student enjoyment serves as an important foundation for understanding their engagement and motivation within the science classroom, ultimately guiding efforts to enhance the overall learning experience.

The student responses highlight several key themes that provide insights into their experiences in science class.

*Engagement through Hands-on Activities (51 mentions***):**

Many students expressed their enthusiasm for the hands-on aspect of science class, particularly through experiments and labs. They found these activities enjoyable, engaging, and exciting. This theme underscores the significance of interactive learning experiences in making science class appealing to students. The opportunity to witness chemical reactions, measure substances, or explore scientific concepts through practical experiments was a recurring source of excitement.

Challenges and Learning Difficulties (24 Mentions):

On the flip side, some students discussed the challenges they faced in science class. These challenges ranged from struggling with math-related calculations to finding specific topics or tests daunting. It is essential to acknowledge that while hands-on activities are engaging, students may encounter obstacles in certain aspects of science, highlighting the need for tailored support and guidance.

Emphasis on Learning (22 mentions):

Several students emphasized the primary goal of science class as learning. They believed that understanding scientific concepts, fostering critical thinking, and gaining knowledge were fundamental objectives. This emphasis on the educational aspect reflects the purpose of science education in cultivating students' understanding of the world around them.

Note-Taking Preferences:

Student preferences for note-taking methods varied, with some opting for traditional handwritten notes and others favoring digital notetaking. This variance highlights the importance of accommodating diverse learning styles and providing students with options to capture and retain information effectively.

Interest in Specific Topics:

A subset of students revealed their fascination with specific scientific topics or experiments. These topics ranged from chemical reactions to measurements and microscopes. Their curiosity and enthusiasm for these subjects display the potential for science class to ignite a passion for particular scientific fields.

Teacher's Impact (7 mentions):

In a few instances, students mentioned the positive influence of their teacher, Mr. Flint, in making the class interesting and enjoyable. The teacher's role in creating an engaging learning environment was evident in these responses, reinforcing the significance of effective teaching methods and relationships in science education.

In summary, the themes extracted from student responses underscore the importance of hands-on learning experiences, the need to address challenges and difficulties, and the overarching goal of learning in science class. Additionally, students' note-taking preferences, specific areas of interest, and the impact of teachers all contribute to the complex tapestry of their experiences in the science classroom. Understanding these themes can guide educators in designing more engaging and effective science curricula that cater to students' diverse needs and interests.

Observations

Observing the POGIL (Process Oriented Guided Inquiry Learning), setting in the classroom provided valuable insights into the dynamics of student engagement, understanding, and challenges within this innovative instructional approach. As compared to traditional lecture settings, it was evident that students exhibited heightened engagement during POGIL activities. The classroom ambiance buzzed with increased energy as students actively participated in discussions related to the material, particularly focusing on phases and atoms.

One notable aspect of the POGIL setting was the extended duration and depth of student discussions. The interactive nature of the activities encouraged students to delve into the material at a more profound level. Conversations among students were not only frequent but also more intricate, reflecting a genuine interest in comprehending the subject matter. The heightened engagement observed during POGIL activities suggested that the student-led and student-based structure fostered a collaborative learning environment, encouraging students to actively participate in the exploration of complex concepts.

The teacher's role in the POGIL setting also underwent a transformation, allowing for a more nuanced understanding of individual student comprehension levels. The shift towards a student-led approach provided the teacher with quicker insights into which students grasped the material effortlessly and which ones encountered challenges. The real-time feedback loop facilitated by POGIL allowed for timely intervention and support for students who needed additional assistance, contributing to a more personalized and effective teaching approach.

Despite the evident advantages of the POGIL model, certain challenges surfaced during the classroom observations. A notable concern was the occasional sense of overwhelm experienced by students, even with the presence of stop signs in the POGIL packets. The sheer volume of material in the packets appeared to be a potential source of stress for some students. This observation suggests a need for careful consideration of the balance between comprehensive content coverage and avoiding overwhelming students. Future implementations could benefit from revisiting the structure of POGIL packets, possibly breaking down content into more manageable sections or incorporating additional support mechanisms to mitigate feelings of overload.

The classroom observations of the POGIL setting highlighted its positive impact on student engagement, understanding, and the teacher's ability to assess individual student progress. The interactive nature of POGIL activities created a vibrant learning environment, fostering rich discussions among students. However, the challenge of student overwhelm signaled an opportunity for refinement in future implementations. The continuous evaluation and adaptation of POGIL strategies based on classroom observations are crucial for optimizing its effectiveness and ensuring a positive and constructive learning experience for all students.

Assessment Data

The research paper delved into an in-depth analysis of the implementation of Process Oriented Guided Inquiry Learning (POGIL) in a chemistry curriculum, specifically focusing on students' comprehension of critical topics such as phases, phase changes, atoms, the periodic table, elements, and Bohr models. The study aimed to assess the nuanced impact of the POGIL approach on students' understanding across a broad spectrum of chemical concepts.

An integral component of this assessment was a meticulous examination of students' performance on quizzes, beginning with a dedicated quiz centered on phases and phase changes. The results of this quiz unveiled a mean score of 75.9%, providing a statistical snapshot of the collective performance. Further scrutiny of the data revealed a median score of 79.2%, indicating the midpoint of the distribution. The variability in individual scores was notable, ranging from a minimum score of 25% to a maximum of 100%. This detailed breakdown aimed to capture the diverse learning trajectories among students when exposed to the POGIL methodology for specific topics.

Expanding the evaluation, the research paper extended its purview to encompass a comprehensive test, strategically designed to encapsulate a broader array of chemistry concepts. Beyond phases and phase changes, this test included elements such as atoms, the periodic table, and Bohr models. The mean score for this comprehensive test was recorded at 72.3%, reflecting an aggregate performance measure. Delving deeper into the data, the median score emerged at 78.1%, underlining the middle point of the distribution. Variability in individual performance was once again evident, with a minimum score of 40.9% and a maximum of 91.7%. This comprehensive test sought to provide a holistic understanding of students' grasp of chemistry concepts, offering a comprehensive view of the impact of POGIL on a diverse curriculum.

The detailed analysis of the data not only demonstrated the efficacy of POGIL in facilitating a solid understanding of chemistry topics but also revealed intricate patterns in students' performance across different facets of the curriculum. The results illuminated areas of strength and potential challenges, displaying the need for tailored instructional strategies to ensure a well-rounded comprehension of diverse chemistry concepts. As the study moved forward, it underscored the importance of continuous refinement and adaptation of pedagogical methods to optimize the benefits of POGIL in chemistry education.

Post Survey

The students were given seven questions for a survey to take after to being exposed to the POGIL method. The questions were as follows:

1. On a scale of 1 to 10 (1 being not at all, 10 being very much), how much do you enjoy your science class? Please briefly explain why.
2. On a scale of 1 to 5 (1 being the lowest and 5 being the highest), how would you rate your overall experience with POGIL? (Activities where you work with your group and have the STOP signs)
3. What did you like most about the POGIL activities?
4. Were there any aspects of POGIL that you found challenging or difficult? If so, please explain.
5. Do you prefer the POGIL activities (STOP sign/group) or Note-Taking/Lecture (Mr. Flint giving notes at the front of the room)
6. Explain why you chose POGIL or Lecture (does one keep you more engaged, does one help you understand the material better, does one help you remember the information more, or does one help your problem-solving ability)

The answers to the survey were then broken down into seven themes, which are found below.

1. Engagement and Enjoyment (32 Mentions):
A predominant theme across the student responses is the increased engagement and enjoyment associated with POGIL activities compared to traditional lectures. Many students highlighted the dynamic nature of POGIL, expressing that working in groups and having regular interactive elements, such as stop signs, made the learning experience more enjoyable. The mean enjoyment score for science in general was noted to be 7.25 out of 10, reflecting a generally positive sentiment among students. This score also represents a slight increase from their initial score of 7.09, suggesting a growing fondness for science. “I put 10 becuase we can work with partners and in others calss we rarley do that and we do labs and that fun because we get to use chemicals and we have more freedom.”

2. Group Dynamics and Collaboration (28 mentions):
Students consistently mentioned the positive aspects of working in groups during POGIL activities. They appreciated the opportunity to collaborate with peers, discuss ideas, and learn from one another. The group setting was seen as conducive to a more interactive and engaging learning environment. The preference for group work was evident in their comments, emphasizing the importance of teamwork in enhancing their understanding of scientific concepts. “I Like how we work in groups and get to check at every stop sign instead of when we finish.” “You get to work with others, which I like because if you get something wrong one of your group members can point it out and help with some hard questions.”

3. Challenges and Overwhelm (19 mentions):

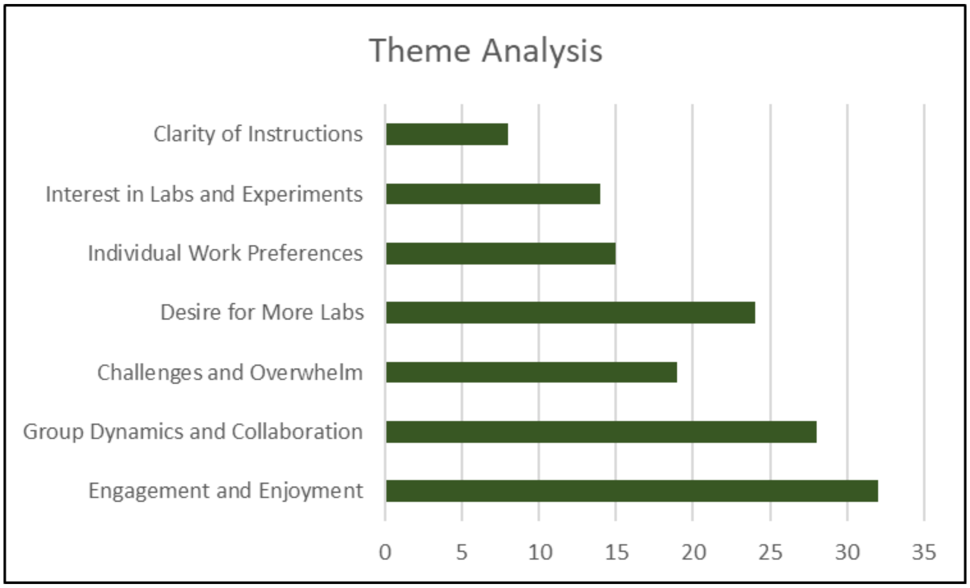
While students generally favored POGIL, some acknowledged challenges associated with the approach. A recurring concern was the potential for feeling overwhelmed, particularly due to the volume of material presented in packets. Despite the presence of stop signs, which serve as checkpoints, a number of students expressed that the sheer size of the packets could be daunting. This feedback suggests a need for potential adjustments in the format or structure of POGIL activities to better cater to student comfort levels. “The way it is worded on some questions is hard to understand and makes it difficult.”

4. Desire for More Labs (24 Mentions):
Several students expressed a desire for more hands-on experiences, particularly labs, in their science class. While they generally enjoyed the labs, they felt that these practical activities were not as frequent as they would prefer. This theme highlights a student preference for a balance between theoretical concepts, like those covered in POGIL, and practical, hands-on experiments.

5. Individual Work Preferences (15 mentions):
A subset of students conveyed a preference for individual work over group activities, citing reasons such as distractions or differing work paces within their groups. While they acknowledged the benefits of collaboration, these students found more comfort and efficiency in working on their own. This preference suggests that future implementations of POGIL might benefit from considering a balance between group and individual tasks.

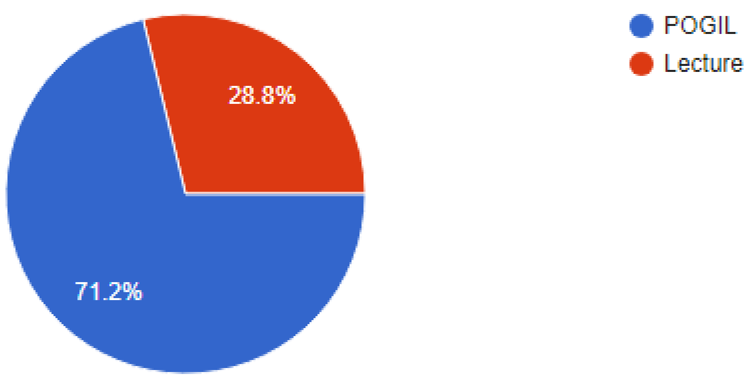
6. Interest in Labs and Experiments (14 mentions):
Many students expressed enthusiasm for labs and experiments, emphasizing their enjoyment of the practical, interactive aspects of science education. The hands-on nature of labs was seen as a positive factor contributing to their overall liking of science class. This aligns with the broader preference for interactive and engaging activities in science education.

7. Clarity of Instructions (8 mentions):
Some students mentioned challenges related to the clarity of instructions, particularly within POGIL activities. They noted instances where questions were worded in ways that were difficult to understand. This feedback highlights the importance of clear and concise communication in instructional materials, ensuring that students can easily comprehend and navigate the tasks assigned.



Graph 1 – Breaks down the different themes found in the Post survey and how many times they were mentioned

8. Preference for POGIL over Lecture:
A substantial number of students explicitly stated a preference for POGIL over traditional lectures. This was indicated in the post survey as 71.2% of students stated they prefer the POGIL style of class over the lecture based classes. They appreciated the variety and interactive nature of POGIL activities, which, in their view, enhanced understanding and engagement. The mean enjoyment score for POGIL was reported as 3.89 out of 5, indicating a generally positive sentiment toward this instructional approach. The qualitative feedback supports this, as students frequently cited aspects of POGIL that they found more enjoyable and beneficial compared to lecture-based formats.



Graph 2 – Student Preferential style of lesson

Analysis

The research conducted provides a detailed examination of the implementation of Process Oriented Guided Inquiry Learning (POGIL) in a chemistry curriculum, with a specific focus on critical topics like phases, phase changes, atoms, the periodic table, elements, and Bohr models. The aim was to assess the nuanced impact of POGIL on students' understanding across a broad spectrum of chemical concepts. The assessment involved a meticulous examination of students' performance on quizzes, beginning with a dedicated quiz on phases and phase changes. Results showed a mean score of 75.9%, with a median score of 79.2%. The data exhibited notable variability in individual scores, ranging from a minimum of 25% to a maximum of 100%. This breakdown aimed to capture diverse learning trajectories among students when exposed to the POGIL methodology for specific topics. Expanding the evaluation, the study included a comprehensive test covering a broader array of chemistry concepts beyond phases and phase changes, incorporating atoms, the periodic table, and Bohr models. The mean score for this test was 72.3%, with a median score of 78.1%. Once again, variability in individual scores was evident, ranging from 40.9% to 91.7%. This comprehensive test aimed to provide a holistic understanding of students' grasp of chemistry concepts, offering a comprehensive view of the impact of POGIL on a diverse curriculum. The detailed analysis of the data not only demonstrated the efficacy of POGIL in facilitating a solid understanding of chemistry topics but also revealed intricate patterns in students' performance across different facets of the curriculum. The results illuminated areas of strength and potential challenges, displaying the need for tailored instructional strategies to ensure a well-rounded comprehension of diverse chemistry concepts. As the study moved forward, it underscored the importance of continuous refinement and adaptation of pedagogical methods to optimize the benefits of POGIL in chemistry education.

Table 1 – Phases and Phase Change Quiz Results

Mean Score	**Median Score**	**Minimum Score**	**Maximum Score**
75.9%	79.2%	25.0%	100.0%

Table 2 - Unit Assessment Results

Mean Score	**Median Score**	**Minimum Score**	**Maximum Score**
72.3%	78.1%	40.9%	91.7%

Moving beyond academic performance, the study delved into students' perspectives on engagement, enjoyment, and the overall learning experience with POGIL. A predominant theme across student responses was the increased engagement and enjoyment associated with POGIL activities compared to traditional lectures. Many students highlighted the dynamic nature of POGIL, expressing that working in groups and having regular interactive elements, such as stop signs, made the learning experience more enjoyable. Students consistently mentioned the positive aspects of working in groups during POGIL activities. They appreciated the opportunity to collaborate with peers, discuss ideas, and learn from one another. The group setting was seen as conducive to a more interactive and engaging learning environment. While students generally favored POGIL, some acknowledged challenges associated with the approach. A recurring concern was the potential for feeling overwhelmed, particularly due to the volume of material presented in packets. Despite the presence of stop signs, which serve as checkpoints, a number of students expressed that the sheer size of the packets could be daunting. Several students expressed a desire for more hands-on experiences, particularly labs, in their science class. While they generally enjoyed the labs, they felt that these practical activities were not as frequent as they would prefer. This theme highlights a student preference for a balance between theoretical concepts, like those covered in POGIL, and practical, hands-on experiments. A subset of students conveyed a preference for individual work over group activities, citing reasons such as distractions or differing work paces within their groups. While they acknowledged the benefits of collaboration, these students found more comfort and efficiency in working on their own. Many students expressed enthusiasm for labs and experiments, emphasizing their enjoyment of the practical, interactive aspects of science education. The hands-on nature of labs was seen as a positive factor contributing to their overall liking of science class. This aligns with the broader preference for interactive and engaging activities in science education. Some students mentioned challenges related to the clarity of instructions, particularly within POGIL activities. They noted instances where questions were worded in ways that were difficult to understand. This feedback highlights the importance of clear and concise communication in instructional materials, ensuring that students can easily comprehend and navigate the tasks assigned.

A substantial number of students explicitly stated a preference for POGIL over traditional lectures, as indicated in the post survey where 71.2% of students expressed a preference for the POGIL style of class over lecture-based classes. They appreciated the variety and interactive nature of POGIL activities, which, in their view, enhanced understanding and engagement. The mean enjoyment score for POGIL was reported as 3.89 out of 5, indicating a generally positive sentiment toward this instructional approach. The qualitative feedback supports this, as students frequently cited aspects of POGIL that they found more enjoyable and beneficial compared to lecture-based formats. The comprehensive analysis of academic performance and student feedback indicates that POGIL is a promising approach for enhancing comprehension and engagement in chemistry education. The study emphasizes the need for ongoing refinement, addressing specific challenges, and adapting instructional methods to cater to diverse learning needs. The positive shift in students' enjoyment scores and explicit preference for POGIL over traditional lectures signal the potential of POGIL to contribute positively to the evolving landscape of science education.

Chapter IV - Conclusion

Reflections and Future Recommendations

The integration of Process Oriented Guided Inquiry Learning in our science classrooms has proven transformative, sparking increased student interest and elevating the overall enjoyment of science. This reflective analysis delves into the observed academic performance; challenges faced, and outlines future implications for refining the POGIL approach. A standout observation during POGIL sessions was the palpable excitement among students to engage with scientific content. The interactive and collaborative nature of POGIL activities successfully tapped into students' curiosity, fostering an environment where enthusiasm for science flourished. This heightened engagement directly contributed to an increased overall enjoyment of the subject. More gratifying was the remarkable performance exhibited by students in assessments. Even among seventh-grade students facing their inaugural science test, POGIL demonstrated its effectiveness not only in transmitting information but also in ensuring comprehension and practical application. Despite the overall success, it is crucial to address challenges faced by special education students. The abstract nature of atomic concepts posed difficulties for some, emphasizing the need for tailored strategies to accommodate diverse learning styles. Recognizing and addressing these challenges is key to creating a more inclusive and supportive learning environment.

Looking ahead, a more targeted approach is essential to support students with diverse needs. One promising strategy involves fostering a collaborative ethos within the classroom. Instead of relying solely on the instructor for assistance, implementing peer-to-peer support could prove beneficial. Assigning proficient groups to assist struggling ones can not only share the responsibility of comprehension but also cultivate a sense of community and mutual support among students.

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