

Assessing the Effects of POGIL-Based Instruction versus Lecture-Based Instruction on Grade 12 Self-Efficacy and Performance in Circular Motion Unit

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Abstract

This study investigates the impact of lecture-based instruction and process-oriented guided inquiry learning (POGIL)-based instruction on the self-efficacy and performance of Grade 12 students. The researchers used a quasi-experimental, pretest-posttest design to compare the effects of POGIL-based instruction to lecture-based instruction, as measured by three cognitive outcomes: knowing, applying, and reasoning (KAR). self-efficacy as measured by physics learning variables", "understanding of physics", and "willingness to learn". The study included 110 participants (54 in the treatment group and 56 in the control group) and was conducted in two government high schools in Alain, one for boys and one for girls. POGIL-based instruction was used to teach a circular motion unit in physics to the treatment group, while lecture-based instruction was used for the control group. The findings show that POGIL-based instruction had a statistically significant positive impact on science performance and self-efficacy when compared to lecture-based instruction. Furthermore, after the intervention, there was a positive correlation between participants' KAR test performance and their self-efficacy toward scientific inquiry. The study recommends a shift toward POGIL-based instruction to improve students' performance and self-efficacy and suggests that future research should include a broader range of schools, teachers, and advisors.

Keywords: POGIL-based instruction, lecture-based instruction, the unit of circular motion, science performance, self-efficacy.

Introduction

Many studies in science, technology, engineering, and mathematics (STEM) education have examined how first-year college students suffer in their initial courses. Due to various cognitive, intellectual, and social-psychological issues, students may suffer for various reasons (Frey *et al.*, 2020). Students have long-standing problems applying chemical knowledge to microscopic, macroscopic, and symbolic forms; numerous studies have noted these problems and sought to offer alternatives (Talanquer, 2022). Perhaps every academic program or discipline shares the same educational goal of helping pupils develop their critical thinking and problem-solving abilities (Wardat *et al.*, 2022 ; Jarrah *et al.*, 2020; Gningue *et al.*, 2022 ; Tashtoush *et al.*, 2022). Employing teaching and learning methodologies that engage students and support the development of application, analysis, and evaluation process skills is essential to reaching this goal (Idul and Caro, 2022). Most instructional tactics used in Science and math are passive, which disengages students and contributes to Science's "leaky pipeline" (De Loof *et al.*, 2022). The significant time required to prepare materials, the reluctance to cut back on the amount of material covered, and the belief that students are unwilling to participate in or prepare for these types of classroom activities are among the reasons science faculty members give for their resistance to adopt active-learning strategies. In response, the field of STEM education research has investigated numerous strategies supported by the data (Frey *et al.*, 2020). Studies have evaluated interventions and looked at how they affected a class's overall performance, and more recently, the focus has expanded to include student subgroups inside a class (Young *et al.*, 2022). Several researchers have examined how affective traits and social identity affect exam performance and class retention (Easterbrook and Hadden, 2021). Even other studies have looked at how students approach problems and whether they comprehend the ideas behind them or only use algorithms to solve them (Knight *et al.*, 2015).

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Research Problem

Science education, in general, and physics, in particular, have tremendous contributions to the technological and digital advancement that serves humanity (Haleem *et al.*, 2022). Yet, in many countries, judging from the results of international exams like the Program for International Student Assessment (PISA), learners performed low in science, including physics. For this research, in the UAE, for example, the results in physics are not where they should be (Hassan Al Marzouqi *et al.*, 2019). Other researchers suggest that, for students, physics is considered the most challenging area of learning within the field of Science, and it usually magnetizes fewer students compared to other science-related subjects from secondary school to university (Kaleva *et al.*, 2019). Generally, according to these authors, students tend to have a negative self-efficacy towards physics, presumably because they lack interest in the subject and the syllabus itself. To make up for these negative attitudes, colleagues, in their review, argued that “These motivate educators to use a variety of strategies to put student’s performance in physics on a pedestal (Assem *et al.*, 2023). Also, to address the demand to produce learners who knew not only how to write, read and do arithmetic but learners who can perform process skills”,

In this paper, we examined students’ differences in concept building as potentially one key factor in explaining student struggles and differing outcomes of otherwise similar students. We did so with two approaches. First, we investigated the impact of POGIL-based instruction on student performance as measured by three types of cognitive outcomes, namely: knowing, applying and reasoning (KAR). We then extended our understanding of this concept- determine the impacts of POGIL-based instruction on students' self-efficacy as measured by the variable of physics learning, understanding of physics, and the willingness to learn it in their future careers (Hidayat & Wardat, 2023; Tashtoush *et al.*, 2023a; Alneyadi *et al.*, 2022a; Jarrah *et al.*, 2022a; Wardat *et al.*, 2021). Although the team experience of students has not received much attention in physics, previous research has looked at characteristics that affect student results in physics. Self-efficacy, which has repeatedly been demonstrated to be a critical construct that predicts student success in physics, particularly problem-solving, is one of the factors. Bandura first defined self-efficacy as the conviction that one can "successfully execute the behaviour required to produce the outcomes" (Bandura, 1977) Bandura also argued that one's self-efficacy beliefs influence how much effort one puts into a task and how long one perseveres in the face of setbacks.

According to research, self-efficacy is a significant predictor of student performance in STEM education, even when other factors (such as prior academic experience, success indicators, behavioural traits, self-esteem, learning styles, and learning strategies) are considered. While self-efficacy is the most significant predictor of performance, Lishinski and colleagues discovered that it also has a reciprocal effect, where self-efficacy influences performance, which then influences self-efficacy, which again influences performance (Sakellariou and Fang, 2021). We also intended to investigate how students' views of collaborative learning in teams and their actual learning were related to their sense of self-efficacy.

The Purpose of the Study

The purpose of this study was to compare the effects of lecture-based instruction and process-oriented guided inquiry learning (POGIL)-based instruction on the self-efficacy and performance of Grade 12 students in a physics unit on circular motion. The study aimed to compare the effectiveness of POGIL-based instruction and traditional lecture-based instruction in improving students' performance and self-efficacy in scientific inquiry. The study also sought to investigate the relationship between students' cognitive outcomes and their self-efficacy in scientific inquiry following the intervention. The study's findings can be used to improve teaching practices and students' performance and self-efficacy in science classes.

Research Question

The present study aims to find answers to the following main question:

Research Question 1: How does 12th grader perform with POGIL-based instruction compared to lecture-based instruction in the circular motion unit of the physics curriculum?

Research Question 2: How does POGIL-based instruction compare to lecture-based instruction influence student self-efficacy toward physics learning, understanding of physics, and the willingness to learn it in their future careers?

Research Question 3: Are there any correlation between grade-12 performance and self-efficacy when learning through POGIL-based instruction and lectures?

Contribution to the Literature

The present study fills a gap in the literature regarding the main learning difficulties and alternative conceptions of pre-service teachers concerning the digestive system.

First, of its kind in the UAE, present study is vital in understanding the benefits of inquiry-based approaches to learning.

This research study represents a deep investigation of the theoretical frameworks of the POGIL in teaching Science in particular. Such strategies are vital in ensuring learners exploit their abilities in areas like knowing, applying and reasoning in an implicit manner that guides their acquisition of the recommended skills and competencies.

As shown, such competencies are attained due to the determination of the impact of POGIL-based instruction on improving self-efficacy in physics. The data collected for this study is hoped to guide the field practices in science teaching and learning.

Methodology; Research Design

The study adopted a cause-effect, pretest-post-test design. This design is used to study the impact of POGIL-based instruction for physics subject students on their performance and self-efficacy. The concert was demonstrated by three outcomes, namely “Knowing”, “Applying”, and “Reasoning”. Self-efficacy is described by three outcomes, expressly” physics learning”, “understanding of physics”, and “the willingness. One of the attributes of the design adopted for the study is that it allowed this researcher to manipulate self-efficacy as an independent variable. This design is the best approach to evaluating the forms of causality that will be evident among the variables in the study. Such design, Creswell (2012) explains further, is the most beneficial method in education since little interference occurs. It is also appropriate to the nature of the study that compares pre- and post-intervention, including the study’s dependent variables.

Context

The study was carried out in two Emirati high schools, one for male students and one for female students. The participants were enrolled in the advanced stream, which included physics as one of the subjects, and they followed the curriculum of the UAE Ministry of Education (Ministry of Education, 2019). The students were in Grade 12 and ranged in age from 17 to 19 years.

Population, Participants and Sampling

The study included 3601 students from two governmental secondary schools in Al Ain, UAE, one for boys (1721 students) and one for girls (1880 students). Convenient sampling was used to randomly select two classes from each school, with one class designated as the experimental group and the other as the control group. Although convenient sampling has the potential for selection bias, the researcher chose the schools based on their size and gender representation. Additionally since he was teaching in one of them and could share his experience with the girls' schoolteacher.

Furthermore, according to the most recent ADEK inspection reports, these schools are the largest and highest-performing high schools in the city of Al Ain. There were 110 pupils in all, with 54 assigned to the experimental group (25 females and 29 boys) and 56 assigned to the control group (27 girls and 29 boys).

Instrument (Test of Circular Motion)

The circular motion concepts test was created to assess students' comprehension of the circular motion learning outcomes in their textbook. Questions on the test measured cognitive results in the domains of Knowing, Applying, and Reasoning. There were six questions in the Knowing domain, ten in the Applying domain, and fourteen in the Reasoning domain. The TIMSS standardized test creation approach was used to create the test, which has been generally recognized for its validity and reliability. This method is also commonly utilized in UAE schools. The test items were patterned around TIMSS and PISA cognitive ability tests.

Validity and Reliability of Test of Circular Motion

The Test revised by two university professors, two scientific supervisors, and two experienced science teachers assessed the test and proposed that the number of items be increased to provide a more thorough examination. They specifically suggested adding items to the "Applying" and "Reasoning" subdomains, despite the fact that the "Knowing" domain was already implicitly included in the other domains. Because the participants were in Grade 12, it was critical to evaluate their cognitive levels of Applying and Reasoning, both of which have several subdomains. The test's 30 items were developed to cover all three domains and subdomains, in accordance with the TIMSS and PISA standardized examinations, as well as the learning outcomes of the local curriculum. Furthermore, the internal consistency coefficient (Cronbach's Alpha) for the total scale was 0.83, with 0.87 and 0.85 for the "Applying" and "Reasoning" domains, respectively, showing strong reliability. (George & Mallery, 2016)

Instrument (Self Efficacy)

The conceptual term self-efficacy is used in this study to analyze the impact of the POGIL strategy on participants' self-efficacy. (Bandura 1977) first proposed self-efficacy as a component of social cognitive theory in the late 1970s. Enochs and Riggs created the Science Teaching Efficacy Belief Instrument (TOSRA) to demonstrate that teachers' efficacy varied depending on context and topic matter. To assess student self-efficacy, the researcher updated the Survey of Self-Efficacy. Students' self-efficacy affects their ability to use advanced cognitive skills, apply scientific knowledge and skills in everyday circumstances, and convey scientific concepts and ideas to others. The study defines self-efficacy as three constructs: physics learning, physics comprehension, and willingness to learn physics for future career.

The data from the self-efficacy test were obtained before and after the deployment of POGIL-based instruction. The primary goal of the survey was to determine each student's level of self-efficacy in learning physics and whether the students were interested in pursuing physics as a future career (Lin, Liang, Tsai, 2015; Enochs & Riggs, 1990).

Validity and Reliability of Self Efficacy

The survey's concept and content were validated and reviewed by a TA team of experts, which included two science education academics, two scientific education consultants from "Academic Quality Improvement," and two experienced physics teachers. They offered ideas and comments on the components being measured, as well as the survey's purpose and instructions. Two elements were added to the "Learning Physics" construct based on their feedback, and four things were added to the "Willingness to learn physics in future careers" construct. The final version was evaluated once more by the specialists, who made minor comments and suggestions.

To validate the reliability of the survey results, the Cronbach's Alpha coefficient was employed to assess the survey's internal consistency. The split-half dependability coefficient was determined as well. The reliability score for the "Learning Physics" construct was 0.96, while the reliability scores for the "Understanding Physics" and "Willingness to learn physics in future careers" constructs were 0.74 and 0.78, respectively. The overall internal consistency coefficient (Cronbach's Alpha) of the students' Self-Efficacy measure was 0.90.

Instructional Methodology & Procedures

The teachers collaborated to create the curriculum and used the same teaching tactics to ensure consistency in delivering the unit on Circular Motion to both male and female students, with the control group getting lectures and the treatment group taught utilizing POGIL-based instruction. The unit was taught in 16 periods, four physics periods a week for four weeks. Each period was 45 minutes. While teaching the circular motion unit, the researcher and another female physics teacher made a concentrated effort to use both methodologies (POGIL and traditional) and adhere to the standards connected with each method. Following the development of the research tools, consent forms were distributed to parents of children at both schools. Following approval, students were randomized to either the experimental or control group within their class.

(KAR) Pre-test and Post-test

The two researchers administered a pre-achievement test and informed the students of the date of the post-achievement test a week in advance. They personally supervised the test with the help of other teachers and provided test instructions, including the student's name, class, section, school name, and an example of how to answer the test questions. The test had 36 multiple-choice items, and one point was given to the correct answer and zero to the incorrect answer. Unanswered questions or those containing more than one answer were treated as incorrect. For POGIL lessons, the teacher provided a brief lecture of up to ten minutes on one of the topics, and then students worked in groups to discuss the topic. The teacher called students' attention to the whole class, and each group reported what they had learned or discovered. The lesson concluded with the teacher providing some background information and guided questions to steer the inquiry, and the students were responsible for their learning. The control group was taught using a lecture-based instructional method.

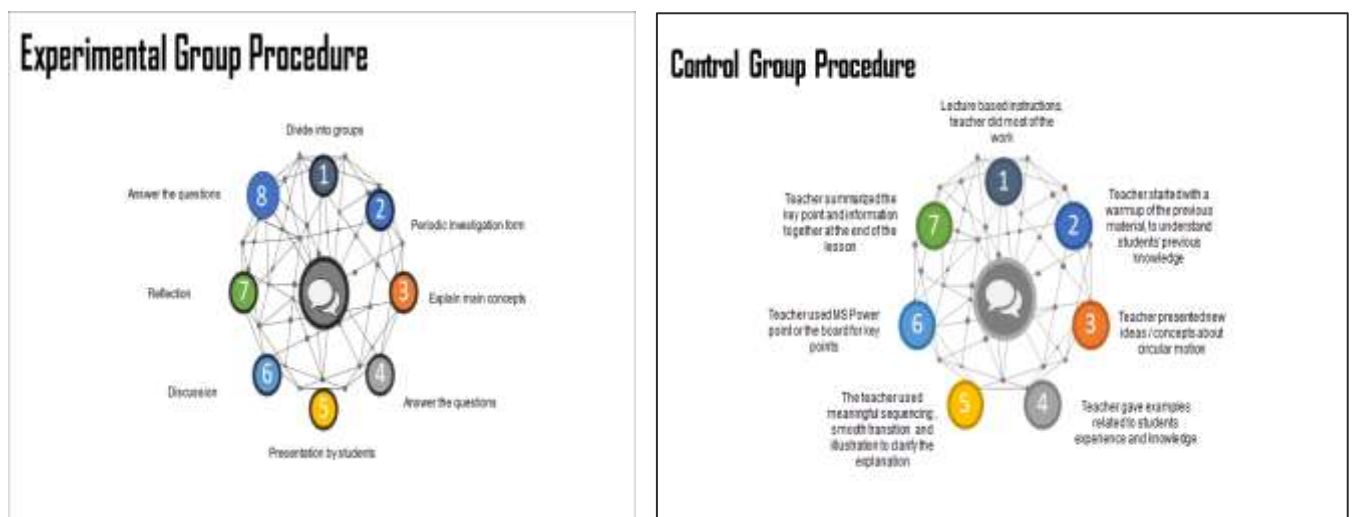


Figure 1. POGIL Procedure: Experimental and control groups

Data collection

The Circular Motion test data was collected in two stages: pre-intervention and post-intervention. The KAR instrument was administered to both the control and treatment groups prior to the intervention, and it was also administered after the intervention. The 45-minute pre-test was completed by grade 12 students from both schools. To ensure correctness, the researcher corrected the exam papers while another teacher monitored them.

Self-efficacy Students were invited to participate in the study and signed consent forms during the first week of the semester. Students completed the teamwork perceptions and self-efficacy survey towards the end of the semester. To ensure student confidentiality and the validity of the data, they were provided with an anonymous link to the survey and informed that the instructor would not have access to the data. To gauge students' self-efficacy in physics, we modified the self-efficacy sub-scale from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich *et al.*, 1993). Cronbach's alpha was used to evaluate the sub-scale reliability ($= 0.96$, indicating that the items' internal consistency was good).

Results of Research Question

Results of Research Question 1:

How does 12th graders perform with POGIL-based instruction compared to lecture-based instruction in the circular motion unit of the physics curriculum?

Table 1: Results of Paired Sample T-Test for the Cognitive Outcomes of the (KAR) Test in the Pretest and Post-Test for the Experimental Group

Scale	Test	Mean	Std. Dev.	Mean diff.	SD diff.	T	df	Sig.	d
Knowing	Pretest	4.02	1.21	1.15	1.54	5.50	53	0.000	0.75
	Post-test	5.17	0.88						
Applying	Pretest	5.98	1.84	1.72	3.41	3.72	53	0.000	0.50
	Post-test	7.70	2.13						
Reasoning	Pretest	3.89	1.18	4.94	1.66	21.8	53	0.000	2.98
	Post-test	8.83	1.41						
KAR	Pretest	13.89	2.28	7.82	4.08	14.1	53	0.000	1.92
	Post-test	21.70	2.96						

Mean Diff. = Mean Difference SD diff. = Pooled Standard Deviation d= Effect size

The results in **Table 1** display the Paired Sample T-test for related samples of the scores of three subscales of (the KAR) test in the pretest and post-test for the experimental group taught by POGIL-based instruction. The results indicated that there was a highly significant difference in means of the scores of knowing in favour of post-test ($t = 5.30, DF = 53, p - value (0.00) < 0.05$). The mean knowledge scores for students in the post-test were higher than that observed in the pretest. Students in the experimental group were more likely to have high performance in knowing after the intervention, compared with their scores in the pretest. In addition, there was a highly significant difference in means of the scores of applying in favour of post-test ($t = 3.72, DF = 53, p - value (0.00) < 0.05$). The mean scores of applying students in the post-test were higher than that observed in the pretest. Students in the experimental group were more likely to have high performance in applying after the intervention, compared with their scores in the pretest.

Moreover, there was a highly significant difference in means of the scores of reasoning in favour of the post-test ($t = 21.83, DF = 53, p - value (0.00) < 0.05$). The mean reasoning scores for students in

the post-test were higher than that observed in the pretest. Students in the experimental group were more likely to have high performance in reasoning after the intervention, compared with their scores in the pretest. Overall, there was a highly significant difference in means of the total scores of (KAR) in favour of the post-test ($t = 13.96, DF = 53, p - value (0.00) < 0.05$). The mean scores of KAR for students after the intervention were higher than that observed in the pretest. Students in the experimental group were more likely to have high performance in the KAR test after the intervention, compared with their scores in the pretest.

In addition, the researcher calculated the Effect Size of the POGIL-based instruction for the post-scores of the experimental group in each subscale of the KAR test.

The Effect size (d) through T-test for related samples given by

$$d = \frac{\text{Mean difference}}{\text{SDdiff}}$$

Where Mean difference= Difference between means of pre and post-tests.

SD.diff. = Pooled Standard Deviation

Using the data presented in **Table 1**, the effect size of the POGIL approach for knowing scores for the experimental group will be: $d = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{1.13}{1.57} \times 100 = 0.75 \times 100 = 75\%$

The effect size calculated above shows that the percentage of the POGIL approach for knowing scores for the experimental group is 75%. This percentage indicates that this tool is effective in elevating knowing ability among the students in the experimental group by approximately 0.75 level of standard deviation. Further, Cohen's effect size value ($d = 0.75$) suggested a high practical significance. Likewise, the effect size of the POGIL approach for applying scores for the experimental group will be:

$$d = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{1.72}{3.41} \times 100 = 0.50 \times 100 = 50\%$$

The effect size calculated above shows that the percentage of the POGIL approach for applying scores for the experimental group is 50%. This percentage indicates that this tool is effective in elevating applying ability among the students in the experimental group by approximately 0.50 level of standard deviation. Further, Cohen's effect size value ($d = 0.50$) suggested a medium practical significance.

In addition, the effect size of the POGIL approach for overall KAR scores for the experimental group will be:

$$D = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{7.82}{4.08} \times 100 = 1.92 \times 100 = 192\%$$

The effect size calculated above shows that the percentage of the POGIL approach for overall KAR scores for the experimental group is 190%. This percentage indicates that this tool is effective in elevating overall

KAR ability among the students in the experimental group by approximately 1.90 level of standard deviation. Further, Cohen's effect size value ($d = 1.90$) suggested a high practical significance (**Figure 2**).

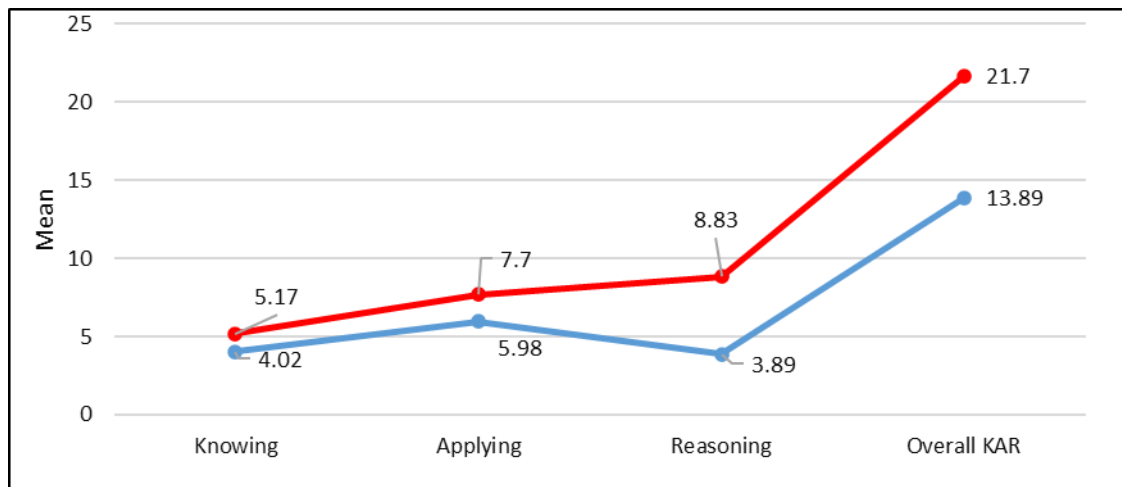


Figure 2: Profile of the cognitive outcomes Test of (KAR)-Pretest vs Post-test.

Results of Research Question 2:

The self-efficacy of grade 12 pupils is impacted by POGIL-based instruction instead of lecturing-based instruction.

The students' scores in the self-efficacy survey pretest were obtained. Then, descriptive statistics such as mean and standard deviation were used to compare the student's performance in the two groups (control and experimental) regarding physics learning, understanding of physics, Willingness to learn physics, and the total scores of Self-Efficacies. The data analysis employed a T-test for an independent sample to determine if there were statistically significant differences between the mean scores of the two groups. In contrast, T- a test for related samples, was used to determine if there were statistically significant differences between the mean scores of the pre-and post-measured in this study in each domain. The results in **Table 2** display the test scores of Self-efficacy subscales in the pretest in the control group taught by the lecturing-based instruction method and the experimental group taught by POGIL-based instruction.

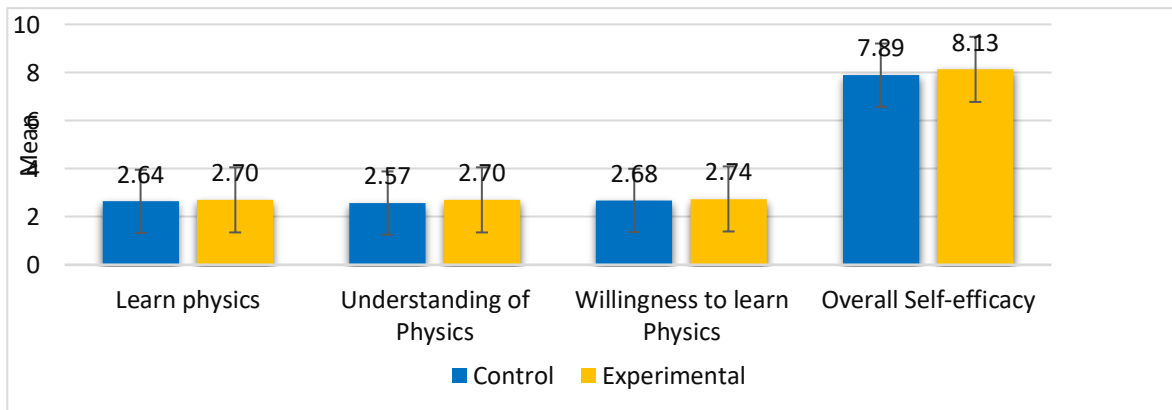
Table 2: Results of Independent Samples T- Test for Physics Learning, Understanding of Physics, Willingness to Learn Physics, and Overall Self-Efficacy: Pretest

Scale	Group	N	Mean	Std. Dev.	t	df	Sig.
Physics Learning	Control	56	2.64	0.62	0.38	108	0.703
	Experimental	54	2.70	0.54			
	Total	110	2.66	0.58			
Understanding of Physics	Control	56	2.57	0.68	1.08	108	0.285
	Experimental	54	2.70	0.60			
	Total	110	2.64	0.65			
Willingness to learn Physics	Control	56	2.68	0.61	0.55	108	0.587
	Experimental	54	2.74	0.59			
	Total	110	2.71	0.60			
Overall efficacy	Control	56	7.89	1.02	1.23	108	0.220
	Experimental	54	8.13	0.99			
	Total	110	8.01	1.01			

Std. Dev.=Standard Deviation

Table 2 and **Figure 3** showed that participants' performance in willingness to learn Physics was the highest in both groups (Control group: $M = 2.68$, $SD = 0.61$) and (Experimental group: $M = 2.74$, $SD = 0.59$) followed by their Learn physics abilities (Control group: $M = 2.64$, $SD = 0.62$) and (Experimental group: $M = 2.69$, $SD = 0.54$). However, participants' understanding of Physics abilities reported the lowest in both groups (Control group: $M = 2.57$, $SD = 0.68$) and (Experimental group: $M = 2.70$, $SD = 0.60$). In the total scores of the Self-efficacy test, participants scored higher in the experimental group ($M = 8.13$, $SD = 0.99$) than in the control group ($M = 7.89$, $SD = 1.02$).

In addition, T-test for independent samples was conducted to find if there were statistically significant differences between the mean scores of the pretest measured in this study for the subscales of the Self-Efficacy Survey for grade 12 students in both control and experimental groups before the intervention. The results showed that statistically, there were no significant differences between the control group ($M = 2.64$, $SD = 0.62$) and experimental group ($M = 2.70$, $SD = 0.54$) regarding students' performance in learning physics ($t = 0.38$, $DF = 108$, $p - value (0.703) > 0.05$), which indicated that students' performance in learning physics in the pretest was the same. Statistically, there is no significant difference found between the control group ($M = 2.57$, $SD = 0.68$) and experimental group ($M = 2.70$, $SD = 0.60$) regarding students' performance in understanding of Physics ($t = 1.08$, $DF = 108$, $p - value (0.285) > 0.05$), which indicated that students' performance in understanding of Physics before the intervention was the same.



Moreover, no statistically significant difference was shown between the control group ($M = 2.68$, $SD = 0.61$) and experimental group ($M = 2.74$, $SD = 0.59$) regarding students' performance in willingness to learn Physics ($t = 0.55$, $DF = 108$, $p - value (0.587) > 0.05$), which indicated that students' performance in willingness to learn Physics before the intervention was the same. Statistically, there is no significant difference found between the control group ($M = 7.89$, $SD = 1.02$) and experimental group ($M = 8.13$, $SD = 0.99$) regarding students' performance in the Self-efficacy test ($t = 1.23$, $DF = 108$, $p - value (0.220) > 0.05$), which indicated that the students' Self-efficacy before the intervention was the same. The same results were obtained after using the Bonferroni adjusted significance criterion of the p -value 0.05. The adjusted p -value was = 0.0125 ($.05/4$) since four tests were conducted.

Figure 3: Profile of the Students in the Pretest for the Subscales and Whole Test of Self-Efficacy

Table 3: Results of T-Test for Related Samples in the Pretest and Post-Test for the Control Group for the Subscales of Self-Efficacy Survey

Scale	Test	Mean	Std. Dev.	Mean Diff.	t	df	Sig.
Physics Learning	Pretest	2.64	0.62	0.20	1.56	55	0.12

		Post-test	2.45	0.63				
Understanding of Physics	of	Pretest	2.57	0.68	0.13	0.98	55	0.33
		Post-test	2.70	0.63				
Willingness to learn Physics	to	Pretest	2.68	0.61	0.02	0.16	55	0.87
		Post-test	2.66	0.61				
Overall Efficacy1	Self	Pretest	7.89	1.02	0.09	0.44	55	0.66
		Post-test	7.80	1.07				

Std. Dev.= Standard Deviation Mean Diff. = Mean Difference

As presented in **Table 3**, for the control group, the participants' understanding of Physics was the highest ($M = 2.70$, $SD = 0.63$), followed by a willingness to learn Physics ($M = 2.66$, $SD = 0.61$). In contrast, participants' Physics learning reported the lowest ($M = 2.45$, $SD = 0.63$). In the total scores of the Self-efficacy test, participants scored a mean of 7.80 ($SD = 1.07$). Results of the T-test for related samples indicated no significant differences in means of the student's performance in the control group in learning physics in the pretest and post-test ($t = 1.56$, $DF = 55$, $p - value (0.12) > 0.05$), which indicated that the performance of the students in the pretest and post-test of learning physics was the same. Concerning students' understanding of physics, there was no significant difference in means of in the control group in the pretest and post-test ($t = 0.98$, $DF = 55$, $p - value (0.33) > 0.05$), which indicated that the performance of the students in the pretest and post-test of understanding of physics was the same.

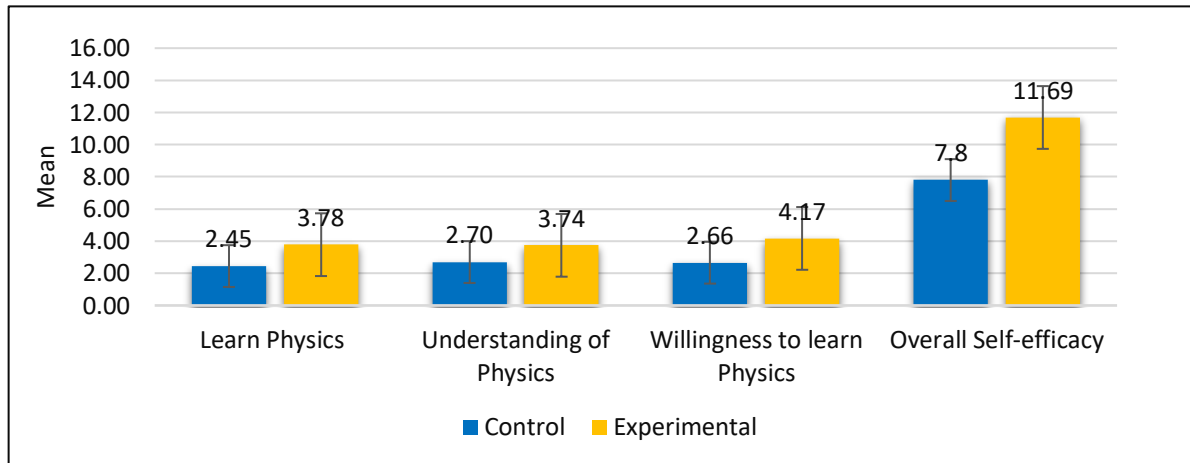
Likewise, statistically, no significant difference was shown in means of the student's willingness to learn physics in the control group in the pre and post-test ($t = 0.16$, $DF = 55$, $p - value (0.87) > 0.05$), which indicated that the performance of the students in the pretest and post-test of willingness to learn physics was the same. Overall, no significant difference in means of total scores of Self-efficacy in the pretest and post-test for the control group ($t = 0.44$, $DF = 55$, $p - value (0.66) > 0.05$). We can conclude that the student's performance in the Self-efficacy survey for the control group was the same before and after the intervention. The same results were obtained after using the Bonferroni adjusted significance criterion of the p -value 0.05. The adjusted p -value was = 0.0125 ($.05/4$) since four tests were conducted.

Table4: Results of Independent Samples T- Test of the Subscales of Self-Efficacy for the Students in the Two Groups: Post-Test

Scale	Group	N	Mean	Std. Dev.	t	df	Sig.
Physics Learning	Control	56	2.45	0.63	11.31	108	0.000
	Experimental	54	3.78	0.60			
	Total	110	3.10	0.91			
Understanding of Physics	Control	56	2.70	0.63	7.88	108	0.000
	Experimental	54	3.74	0.76			
	Total	110	3.21	0.87			
Willingness to learn Physics	Control	56	2.66	0.61	11.60	108	0.000
	Experimental	54	4.17	0.75			
	Total	110	3.40	1.02			
Overall efficacy	Control	56	7.80	1.07	17.60	108	0.000
	Experimental	54	11.69	1.24			
	Total	110	9.71	2.26			

Std. Dev.=Standard Deviation

Table 4 shows that participants' willingness to learn Physics was the highest in the experimental group ($M = 4.17$ and $SD = 0.75$), then Physics learning came with a mean of 3.78 ($SD = 0.60$). At the same time, participants' understanding of Physics came last with mean scores of 3.74 ($SD = 0.76$). Concerning the control group, participants' understanding of Physics was the highest ($M = 2.70$, $SD = 0.63$). Willingness



to learn Physics came with a mean of 2.66 ($SD = 0.61$), while participants' Physics learning came last with mean scores of 2.45 ($SD = 0.63$). In the total scores of the Self-efficacy test, participants scored higher in the experimental group ($M = 11.69$, $SD = 1.24$) than in the control group ($M = 7.80$, $SD = 1.07$).

A T-test for independent samples was conducted to find if there were statistically significant differences between the mean scores of the post-test measured in this study for students' Self-efficacy outcomes for students in grade 12 in both control and experimental groups after the intervention. Statistically, there was a highly significant difference between the control group and experimental group regarding students' Physics learning in favour of the experimental group ($t = 11.31$, $DF = 108$, $p - value (0.00) < 0.05$). Students in the experimental group were more likely to perform better in Physics learning in the post-test than in the control group. In addition, statistically, there was a highly significant difference found between the control group and experimental group regarding students' understanding of Physics in favour of the experimental group ($t = 7.88$, $DF = 108$, $p - value (0.00) < 0.05$). Students in the experimental group were more likely to perform better in understanding Physics in the post-test than in the control group. The results of the T-test for independent samples showed that statistically, there was a highly significant difference between the control group and experimental group regarding students' willingness to learn Physics in favour of the experimental group ($t = 11.60$, $DF = 108$, $p - value (0.00) < 0.05$). Students in the experimental group were more likely to have good performance in willingness to learn Physics in the post-test compared to the control group. Statistically, there was a highly significant difference found between the control group and experimental group regarding students' Self-efficacy as a whole in favour of the experimental group ($t = 17.60$, $DF = 108$, $p - value (0.00) < 0.05$). Students in the experimental group were more likely to have good Self-efficacy in the post-test compared to the control group. The same results were obtained after using the Bonferroni adjusted significance criterion of the p -value 0.05 . The adjusted p -value was $= 0.0125 (0.05/4)$ since four tests were conducted.

Figure 4: Profile of the Students in the Post-Test for the Subscales and Whole Test of Self-Efficacy

Table 5: Results of T-Test for Related Sample in the Pretest and Post-Test for the Experimental Group for the Subscales of Self-Efficacy Survey

Scale	Test	Mean	Std. Dev.	Mean diff.	SD diff.	T	df	Sig.	d
Physics Learning	Pre	2.69	0.54	1.09	0.78	10.25	53	0.000	1.40

	Post	3.78	0.60						
Applying Understanding of Physics	Pre	2.70	0.60	1.04	0.73	10.50	53	0.000	1.42
	Post	3.74	0.76						
Reasoning	Pre	2.74	0.59	1.43	0.98	10.66	53	0.000	1.46
	Post	4.17	0.75						
Willingness to learn Physics	Pre	8.13	0.99	3.56	1.40	18.71	53	0.000	2.54
	Post	11.7	1.24						

Mean Diff. = Mean Difference SD diff. = Pooled Standard Deviation d= Effect size

The results presented in **Table 5** and **Figure 4** display the T-test for related samples of the scores of the domains of Self- efficacy in the pretest and post-test for the experimental group taught by POGIL-based instruction. The results indicated that there was a highly significant difference in means of the scores of learning Physics in favour of post-test ($t = 10.25, DF = 53, p - value (0.00) < 0.05$). The mean scores of students' Physics learning were higher than that observed in the pretest. Students in the experimental group were likelier to perform well in Physics learning after the intervention. In addition, there was a highly significant difference in means of the scores of understandings of Physics in favour of post-test ($t = 10.50, DF = 53, p - value (0.00) < 0.05$). The mean scores of students' understanding of Physics were higher than that observed in the pretest. Students in the experimental group were more likely to have had good performance in understanding Physics after the intervention.

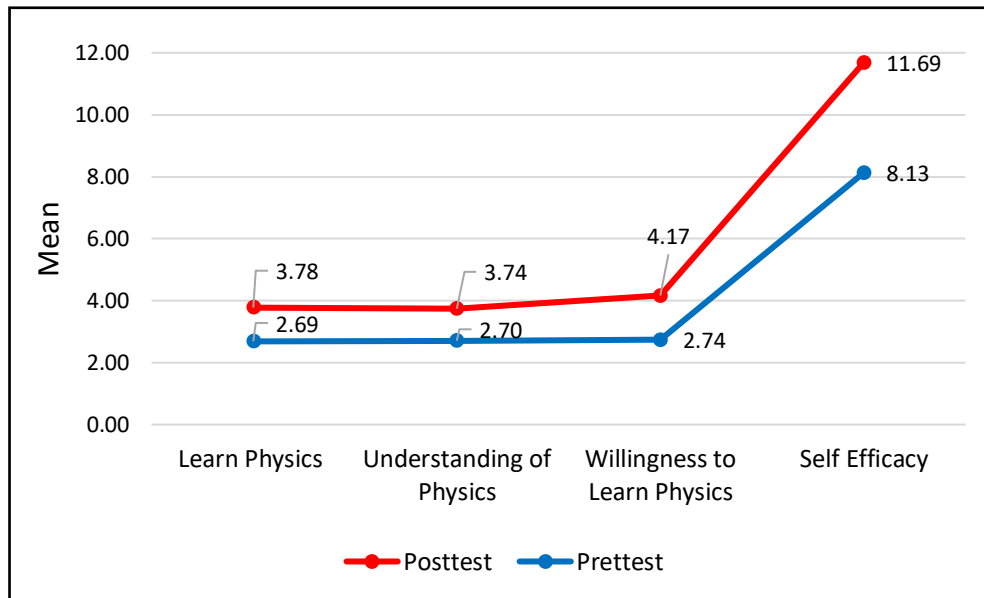
Moreover, there was a highly significant difference in means of the scores of willingness to learn Physics in favour of post-test ($t = 10.66, DF = 53, p - value (0.00) < 0.05$). The mean scores of students' willingness to learn Physics were higher than that observed in the pretest. Students in the experimental group were more likely to have had good performance in willingness to learn Physics after the intervention.

Overall, there was a highly significant difference in means of the scores of the total scores of Self-efficacy in favour of the post-test ($t = 18.71, DF = 53, p - value (0.00) < 0.05$). The mean scores of students' self-efficacy were higher than that observed in the pretest. The same results were obtained after using the Bonferroni adjusted significance criterion of the p -value 0.05. The adjusted p -value was = 0.0125 (.05/4) since four tests were conducted.

Thus, students in the experimental group were more likely to have good Self- efficacy after the intervention (**Figure 4** below). Using the data presented in **Table 5**, the effect size of the POGIL approach for Physics learning scores for the experimental group will be: $D = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{1.09}{0.78} \times 100 = 1.40 \times 100 = 140\%$

The effect size calculated above shows that the percentage of the POGIL approach for Physics learning scores for the experimental group is 140%. This percentage indicates that this tool is effective in elevating Physics learning ability among the students in the experimental group by approximately 1.40 level of standard deviation.

The effect size calculated above shows that the percentage of the POGIL approach for willingness to learn Physics scores for the experimental group is 146%. This percentage indicates that this tool effectively elevates willingness to learn Physics ability among the students in the experimental group by approximately 1.43 level of standard deviation. Further, Cohen’s effect size value ($d=1.43$) suggested a high practical significance. Concerning overall students’ self-efficacy, the effect size of the POGIL approach for Self-efficacy scores for the experimental group will be:



$$D = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{3.56}{1.40} \times 100 = 2.54 \times 100 = 254\%$$

The effect size calculated above shows that the percentage of the POGIL approach for Self- efficacy scores for the experimental group are 254%. This percentage indicates that this tool is effective in elevating Self-efficacy ability among the students in the experimental group by approximately 2.54 level of standard deviation. Further, Cohen’s effect size value ($d = 2.54$) suggested a very high practical significance (Figure 4).

Figure 4: Profile of the Experimental Group in the Subscales of Self-Efficacy Survey: Prettest vs Post-Test

Results of Research Question 3

Correlation between student performance and self-efficacy in grade 12 when learning through POGIL versus lecturing.

Correlation Analysis

A Pearson’s correlation coefficient was conducted to determine the correlation between students’ performance in KAR, Self-Efficacy, and views towards science inquiry amongst 56 participants in the control group. Statistically, there was no significant correlation between students’ performance in KAR and their Self-Efficacy ($r = 0.076, p - \text{value} (0.57) > 0.05$), no significant correlation between students’ performance in KAR and their views towards science inquiry ($r = 0.037, p - \text{value} (0.78) > 0.05$), and no significant correlation between students’ Self-Efficacy and their views towards science inquiry ($r = 0.194, p - \text{value} (0.15) > 0.05$).

Table 6: Correlation between Grade 12 Students’ Performance in KAR and Self-Efficacy in Control Group: Pearson’s Correlation Coefficient

Scales	KAR	Self-Efficacy
KAR	Correlation Coefficient	1.000

	P-value		
	n	56	
Self-Efficacy	Correlation Coefficient	0.076	1.000
	P-value	0.579	
	n	56	56

Table 7: Correlation between Grade 12 Students' Performance in KAR and Self-Efficacy in Experimental Group: Pearson's Correlation Coefficient

Scales		KAR	Self-Efficacy
KAR	Correlation Coefficient	1.000	
	P-value	.	
	N	54	
Self-Efficacy	Correlation Coefficient	0.704**	1.000
	P-value	0.000	.
	N	54	54

** Correlation is significant at the 0.05 level (2-tailed).

A Pearson's correlation coefficient was conducted to determine the correlation between students' performance in KAR, Self-Efficacy, and views towards science inquiry amongst 54 participants in the experimental group. Statistically, there was a robust, positive and significant correlation between students' performance in KAR and their Self-Efficacy ($r = 0.704, p - value (0.00) < 0.05$) which indicated that as students' performance in KAR increase, their Self-Efficacy increase.

In addition, there was a strong, positive and significant correlation between students' performance in KAR and their views towards science inquiry $r = 0.565, p - value (0.00) < 0.05$, which indicated that as students' performance in KAR increase, their views towards science inquiry more positive.

Moreover, there was a strong, positive and significant correlation between students' Self-Efficacy and attitudes towards science inquiry ($r = 0.569, p - value (0.00) < 0.05$), which indicated that as students' Self-Efficacy increase, their views towards science inquiry more positive.

Regression Analysis

Multiple Liner Regression was conducted to find the relationship between Grade 12 students' performance as the dependent variable and self-efficacy and scientific attitudes as independent variables when they learn by POGIL-based instruction and lecturing-based instruction. To this end, the research used SPSS to examine all the relations paths through the resultant path coefficients.

Table 8: Model Summary: Relationship between Students' Performance and Self-Efficacy when They Learn by POGIL-Based Instruction

R	R Square	Adjusted R Square	Std. An error in the Estimate
0.732	0.536	0.513	2.053

Table 9: ANOVA for the Relationship between Students' Performance and Self-Efficacy Learned by POGIL-Based Instruction

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Regression	248.290	2	124.145	29.45	0.000
Residual	214.970	51	4.215		

Total	463.259	53
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The prediction model contained two predictors: Self-Efficacy and students' attitudes towards science inquiry, used to predict Students' performance in KAR. As **Tables 8-9** showed, the multiple correlations R indicated a positive correlation between the independent and dependent variables ($r = 0.732$). The model was statistically significant, $F(2, 51) = 29.45$, $p\text{-value} < 0.05$, and accounted for approximately 51.3% of the variance of students' attitudes towards science inquiry ($R^2 = 0.53.6\%$, Adjusted $R^2 = 51.3\%$).

Table 10: Model Coefficients for the Relationship between Students' Performance and Self-Efficacy Learned by POGIL-Based Instruction

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	p-value
	B	Std. Error	Beta		
(Constant)	-1.96	3.30		-0.59	0.555
Self-Efficacy	1.35	0.28	0.57	4.88	0.000

Dependent Variable: Students' Performance

The raw and standardized regression coefficients of the predictors are shown in **Table 10**. The Coefficients table provides the necessary information to predict the dependent variable from the predictors and determine whether the predictors contribute statistically significantly to the model. Self-Efficacy received the most substantial weight in the model. Therefore, Self-Efficacy statistically has a positive effect on student performance since the results indicated that ($\beta = 0.57$, $t = 4.88$, $p\text{-value} (0.00) < 0.05$). Overall results of the fourth question showed no correlations between the variables: students' performance and Self-efficacy when learning by POGIL-based instruction and lecturing instruction before the intervention. On the other hand, there were strong and positive correlations between all variables of the participants' performance in the KAR Test, participants' Self-efficacy towards Scientific Inquiry after the intervention. In addition, the results showed that students' Self-Efficacy towards science inquiry positively affect students' performance.

Discussion

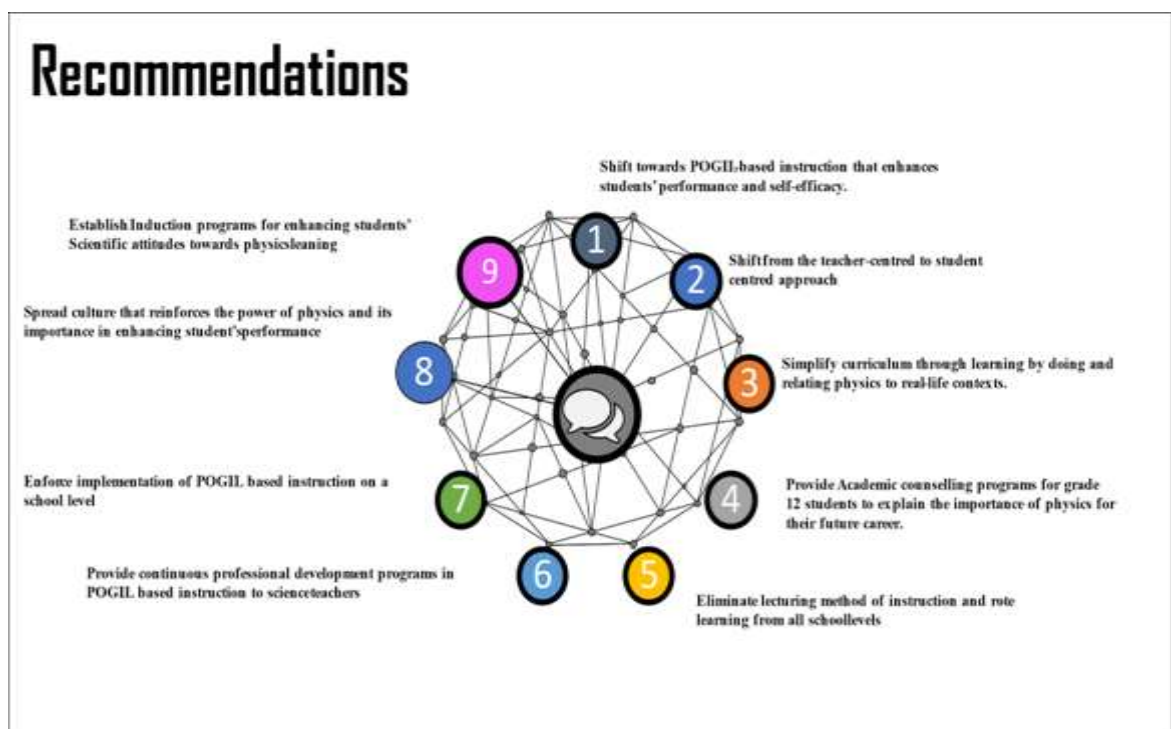
Our findings indicate that, on the whole, students felt that working in teams to learn was a worthwhile experience that helped them learn compared to lectures. Additionally, we discovered that collaboration helped students acquire process skills, including teamwork, respect for others' opinions, and problem-solving. The results show that students are aware of the advantages of POGIL, which explicitly emphasizes the development of process skills (KAR) as a crucial part of the student learning process. Students can identify, develop, and carry out a strategy that goes beyond regular action to find a solution to a problem or question when they connect with others and build on each other's strengths and talents (Zakariya & Wardat, 2023; Jarrah et al., 2022b).

As previously said, POGIL teams have defined roles that help with learning and developing process skills. These roles give the students the scaffolding they need to participate in the "interactive" form of learning as they learn to clarify, build, and defend their ideas to others while discovering a new subject for the first time (Zamista *et al.*, 2019). In particular, the scaffolding within the roles allows for enough turn-taking frequency to "enable more frequent revisions on smaller components of knowledge" and "make it easier for students to incorporate their partners' understanding of the domain and to make adjustments to their mental model" (Aiman *et al.*, 2020).

Our findings are positive that students understand the value of working in teams, given the focus of POGIL on improving process skills (KAR). According to the regression results, self-efficacy was also a significant

predictor of learning outcomes. This implies that although students felt the opportunity to work in a team was beneficial for their learning and the development of process skills, their actual learning was unaffected. These results align with an earlier study, which discovered that self-efficacy is among the most important indicators of students' learning in computer science (Bandura, 1977; Sakellariou and Fang, 2021; Vishnumolakala *et al.*, 2017). Prior research has suggested that rather than outperforming students who learn through traditional lecture-based approaches on traditional assessments, students who learn through inquiry-based approaches, like problem-based learning, significantly outperform students on assessments that measure clinical and application skills (Yadav *et al.*, 2011, 2014). Therefore, future research should concentrate on creating instruments that can assess students' procedural abilities and allow them to apply rather than merely regurgitate what they have learned (Stoica & Wardat, 2021; Alneyadi *et al.*, 2022b).

Future studies should look into POGIL's long-term effects and how collaborative learning in the classroom applies



to the workplace. Graduates of POGIL-based curricula could be used in a cross-sectional study to determine whether and how POGIL prepared them for professional employment. Future research could also examine how POGIL in foundational computer science courses affects students' transition to upper-level physics courses (Tashtoush *et al.*, 2023b; Wardat *et al.*, 2024)

Conclusion

In recent years, Physics classes have used Process Oriented Guided Inquiry Learning. This study adds findings concerning its effect on students' views and performance. Our findings are encouraging, especially in light of research showing that collaborative learning is superior to individualistic and competitive strategies. Future studies should, however, investigate POGIL's long-term effects and how students apply their collaborative learning outside of the classroom to real-world situations. Our results provide a first step in that approach because they demonstrate that students felt POGIL assisted them in improving their problem-solving and collaborative abilities.

Figure 5: Profile of the significant findings from the three research questions provide suggestions and recommendations for improving scientific research, instruction, and pedagogy.

Limitations and Future Research Opportunities

As the research investigated has provided insights into the impact of POGIL-based education on the performance and self-efficacy of Grade 12 students, some limitations must be acknowledged. The study only included 110 Grade 12 students from two high governmental schools in one emirate in the UAE, and it was only conducted for one academic year (2019-2020). As a result, future study studies involving various grades, schools, educators, and emirates, as well as other science topics, are required. Future research studies employing a mixed-method approach are also encouraged to ensure triangulation and the establishment of a causal association between the use of POGIL as an independent variable and the other dependent variables.

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