

Article

Not peer-reviewed version

Comparing the Effects of Lecture-Based Instruction with POGIL-Based Instruction on Self-Efficacy in Grade 12

[Saif Saeed Alneyadi](#) *

Posted Date: 29 April 2023

doi: 10.20944/preprints202304.1213.v1

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



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article

Comparing the Effects of Lecture-Based Instruction with POGIL-Based Instruction on Self-Efficacy in Grade 12

Saif Saeed Salem Al Neyadi ¹

¹ Postgraduate Professional Diploma in Teaching, College of Education, Al Ain University, Al Ain 15551, UAE; saif.alneyadi@aau.ac.ae

Abstract: This study compares the effects of lecture-based instruction and process-oriented guided inquiry learning (POGIL)-based instruction on the self-efficacy performance of Grade 12 students. A quasi-experimental, pretest-posttest design was adopted to investigate and assess the impact of POGIL-based instruction versus lecture-based instruction on students' performance as measured by three types of cognitive outcomes; Knowing, Applying and Reasoning (KAR). Two government high schools in Alain were selected as research sites, one for the boys and one for the girls. The total number of participants was approximately 110 students (N=110); 54 were assigned to treatment groups (25 girls and 29 boys), and 56 were assigned to control groups (27 girls and 29 boys). The treatment group was taught a circular motion unit in physics using POGIL-based instruction, while the control group was taught the unit using lecture-based instruction. The study's findings showed statistically significant differences between students of the control group and the treatment group in favour of the latter regarding their science performance, self-efficacy and science-related attitudes. Moreover, positive correlations were found between participants' performance at the KAR test, self-efficacy and scientific attitudes towards scientific inquiry after the intervention. In conclusion, it is recommended to shift teaching towards POGIL-based instruction due to its positive impact on students' performance and self-efficacy. It is also suggested to replicate the study to include government and private schools, elementary and high schools, teachers and advisors.

Keywords: POGIL-based instruction; lecture-based instruction; the unit of circular motion; science performance attitude; 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. 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)

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 attitude towards physics, presumably because they lack interest in the subject and the syllabus itself. To make up for these negative attitudes, Asem and 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. 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 made the case that one's self-efficacy beliefs influence how much effort one will put into a task and how long one will persevere 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, behavioral 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.

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, the 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.

Literature Review

POGIL is a strategy and a philosophy for learning and teaching. It is a strategy since it provides a specific methodology and procedural structure that are constant with the method students learn and that lead to the desired learning outcomes. It is also a philosophy as it involves specific ideas about the nature of the learning process and the expected learning outcomes (Brown, 2010). Based on social constructivist learning theory, POGIL is a student-centred teaching method science educators developed in the 1990s. Here, learners develop their conceptual understanding collaboratively and work in groups on carefully designed learning cycle activities (Le *et al.*, 2018).

Soltis and his group argue that it helps students construct their scientific understanding based on their prior knowledge, experiences, skills, attitudes, beliefs and self-efficacy (Soltis *et al.*, 2015). The students, Soltis and colleagues explain, also experience a learning cycle of exploration, concept formation, and application. Besides, students using the POGIL module connect and visualize concepts and multiple representations and discuss and interact with one another.

To shed some light on the roles of the POGIL group, the *manager* ensures that the members are doing their roles, achieving the tasks on time, and all members are participating in the activities and understanding the concepts. The *recorder* reports the discussions and essential aspects of the group's observations, insights and the significant concepts learnt. The "presenter" provides oral reports to the class. The "reflector" observes group dynamics, behaviour and performance and may report to the group (or the class) about how well the group operates (Hu and Shepherd, 2013). The POGIL activities emphasize core concepts and encourage a deep understanding of the course materials through an exploration to construct understanding while developing higher thinking skills. Here, Trevathan and Myers explain that learning is achieved through fun exercises that prove effective to students with the benefits of shared information and collaborative learning (Trevathan, Jarrod, and Myers, 2013).

A study by Walker and Warfa established that students that taught using a POGIL-based instructional strategy registered higher levels of achievement and developed positive attitudes towards using the approach (Walker and Warfa, 2017). On the other hand, Lin and Tsai established that using the POGIL-based instructional approach enhanced the ability of the students to perfect their learning capabilities compared to other approaches (Lin and Tsai, 2013). Further, Wozniak found that using POGIL was instrumental in identifying the different conceptions by students and facilitated their ability to change or alter such conceptions (Wozniak, 2012). However, a study by Barthlow contrasts these findings as the study found that the learners that taught using POGIL did not have any different or alternative conceptions compared to the learners that have been taught using the traditional forms of instruction. In sum, one has to keep an open mind when analyzing later in the research study and be cautious with the conclusions one reaches (Barthlow and Watson, 2014).

Deora and colleagues conducted research in the U.S. to examine the impact of the flipped classroom and POGIL methods on the chemistry of college students (Nipa Deora, Nathalie Rivera, Sheila Sarkar, Marcos Betancourt, 2020). The results revealed positive trends favouring POGIL students. Unlike Barthlow's study, however, no significant differences were found between students' overall grades learnt by POGIL and their counterpart students learnt by traditional instruction. However, there was an increase in passing grades (Barthlow and Watson, 2014).

Self-efficacy is the learners' belief in their ability to accomplish tasks in specific situations, that is, their competencies to organize and complete courses of action required to achieve selected types of performances (Artino Jr., 2012). Since self-efficacy is confidence in one's ability to perform, which will be reflected in students' actions. Students with high self-efficacy for performing a specific task will have high expectations towards performing it and are likely to succeed, for example, in Science

at school and choose majors that align with their self-belief about personal competencies and abilities (Kaleva *et al.*, 2019).

Situated within the social cognitive theory, self-efficacy indicates behaviour can be best understood in terms of a reciprocal system, including reasoning, behaviour and context. This reciprocal system, Lin explains, refers to the perceived ability to carry out the task, behaviour, performance, and environment setting (Lin, 2009). Within this reciprocal system, moreover, self-efficacy becomes a vital construct for learners to monitor their performance as it attracts their attention to beliefs about the effectiveness of their learning methods (Anam and Stracke, 2016).

Examining students' attitudes toward using POGIL in teaching physics is essential, and this can help us better understand the impact of POGIL on students' attitudes and science learning achievement. For this study and the subsequent discussion, by attitude towards Science, I am referring to "the feelings, beliefs, and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves." (Osborne *et al.*, 2003).

Though the previous studies have not tackled POGIL directly, they shed light on the relationships between students' attitudes and their science learning that might be done through POGIL or any other methods or models of inquiry. These conclusions are highly relevant and essential to this study. The same relevance can be seen in the studies discussed in the following paragraphs (Vishnumolakala *et al.*, 2017).

In the Philippines, a quantitative study was conducted by Guido to analyze and evaluate the relationship between engineering and technology students' attitudes and motivations towards learning physics. The study's results found no significant difference in the attitude and motivation of students towards learning physics. Furthermore, most students participating in the study felt good when they were successful in physics (Guido, 2013). The students thought that their success was due to the simple and practical method of teaching used by teachers, which enhanced their attitude towards physics learning. The participants also enjoyed studying physics since they could see its utility in everyday life.

Despite the prevalence of studies that are based on the efficacy of the use of constructivist methodologies in teaching students, a gap exists in the literature due to the lack of studies that involve high school students in the use of inquiry-based instruction, especially the use of approaches such as POGIL in the UAE context (Daubenmire *et al.*, 2015). An instrument-based survey conducted in the UAE by Tairab and Al-Naqbi that evaluated the effectiveness of constructivist pedagogical strategies established unanimity between students and teachers that most curriculum materials require inquiry-based instructional strategies to enhance effectiveness (Tairab and Al-Naqbi, 2017). A study by Al-Naqbi showed significant differences in high school students' perceptions of chemistry as a subject, chemistry research and jobs related to chemistry. In the self-efficacy scale, the main differences amongst the students were found in their performance, scores, and the percentiles of the secondary schools. However, regarding gender, nationality and matriculation, there were no significant or notable differences among the students on the self-efficacy scale (Al-Naqbi and Alshannag, 2018). Another quasi-experimental study was carried out by Qureshi and Vishnumolakala to explore Qatari Foundation first-year students' understanding of chemistry concepts in a POGIL context (Qureshi *et al.*, 2017). The study's results found positive effects of POGIL on students' understanding of chemistry concepts. The authors thus concluded that student-centred pedagogical practices like POGIL enhanced students' understanding of the field of Science.

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 concept 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". Scientific attitudes showed by three outcomes,

particularly “Scientific inquiry”, “Enjoyment”, and “Career interest”. 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.

Data collection

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.

Self-efficacy

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

The results presented in Table 1 display the test scores of (KAR) in the pretest in the control group taught by the lecturing-based instruction method and the experimental group taught by POGIL-based instruction.

Table 1. Results of Independent Samples T-test for Equality of Means of the Cognitive Outcomes of the variables of Knowing, Applying and Reasoning (KAR)- Pretest.

Scale	Group	N	Mean	Std. Dev.	t	df	Sig.
Knowing	Control	56	3.93	1.10	0.41	108	0.682
	Experimental	54	4.02	1.21			
	Total	110	3.99	1.18			
Applying	Control	56	5.63	1.46	1.129	108	0.261
	Experimental	54	5.98	1.84			
	Total	110	5.80	1.66			
Reasoning	Control	56	3.66	1.07	1.067	108	0.289
	Experimental	54	3.89	1.18			
	Total	110	3.77	1.12			
Overall KAR	Control	56	13.23	2.00	1.635	108	0.105
	Experimental	54	13.91	2.33			
	Total	110	13.56	2.18			

Std. Dev.=Standard Deviation.

Table 1 (above) and Figure 1 showed that participants’ Applying abilities were the highest in both groups (Control Group M = 5.63, SD = 1.46) and (Experimental Group M=5.98, SD =1.84), followed by their Knowing abilities (Control Group M = 3.93 and SD =1.10) and (Experimental Group M= 4.02, SD =1.21). However, participants’ Reasoning abilities were reported to be the lowest in both groups (Control Group M= 3.66, SD = 1.07) and (Experimental Group M= 3.89, SD =1.18). In the total score of the cognitive outcomes Test (KAR), participants scored higher in the experimental group (M= 13.91, SD =2.33) than in the control group (M= 13.23, SD = 2.00).

A T-test for Equality of Means for independent samples was conducted to find if there were statistically significant differences between the mean scores of the pretest measured in this study in

the circular motion unit in the physics curriculum of grade 12 in both control and experimental groups before the intervention. The results of the T-test showed that there were no statistically significant differences between the control group ($M = 3.93$, $SD = 1.10$) and experimental group ($M = 4.02$, $SD = 1.21$) about students' knowing abilities ($t = 0.41$, $DF = 108$, $p - value > 0.05$), which indicated that the performance of the students in the pretest of knowing was the same.

In addition, no statistically significant difference was found between the control group ($M = 5.63$, $SD = 1.46$) and experimental group ($M = 5.98$, $SD = 1.84$) about students' applying abilities ($t = 1.129$, $DF = 108$, $p - value > 0.05$), which indicated that the performance of the students in the pretest of applying abilities was the same. Moreover, no statistically significant difference was shown between the control group ($M = 3.66$, $SD = 1.07$) and experimental group ($M = 3.89$, $SD = 1.18$) regarding students' reasoning abilities ($t = 1.067$, $DF = 108$, $p - value > 0.05$), which indicated that the performance of the students in the pretest of reasoning abilities was the same.

Overall, no statistically significant difference was found between the control group ($M = 13.23$, $SD = 2.00$) and experimental group ($M = 13.91$, $SD = 2.33$) regarding student performance in the total score of the cognitive outcomes Test of (KAR) since ($t = 1.635$, $DF = 108$, $p - value(0.105) > 0.05$), which indicated that the performance of the students in the pretest of KAR 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. As Huck (2011) showed, Bonferroni adjusted the significance criterion of the p -value can be obtained by "dividing the desired Type I error risk for the full study by the number of times the hypothesis testing procedure will be used".

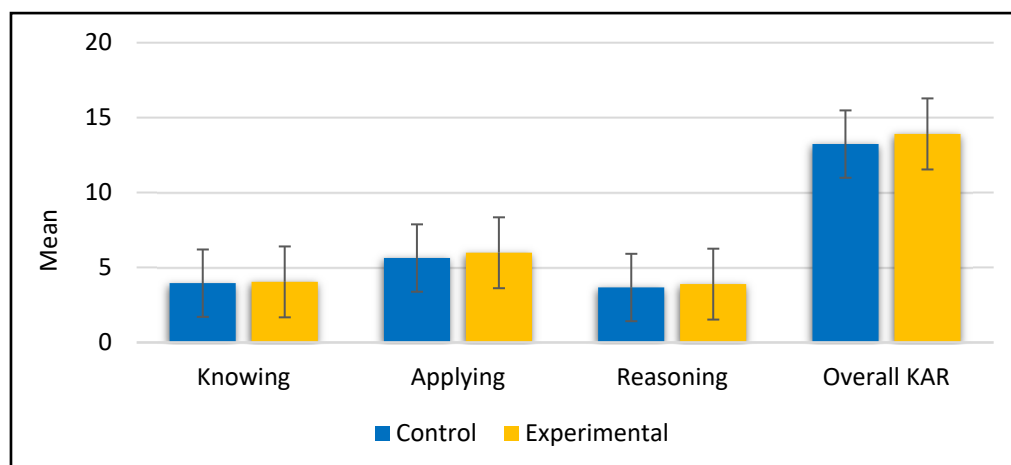


Figure 1. Profile of the Cognitive Outcomes of (KAR) Test –Pretest.

As presented in Table 2, the participants' applying ability for the control group was the highest ($M = 5.84$, $SD = 1.35$), followed by their reasoning ability ($M = 3.96$, $SD = 1.39$). However, participants' knowing ability was reported as the lowest ($M = 3.64$, $SD = 1.10$). In the total score of the cognitive outcomes of (the KAR) test, participants scored a mean of 13.45 ($SD = 2.00$). To deduct whether there were statistically significant differences between the means of the scores of the Knowing, Applying and Reasoning, and overall (KAR) in the pretest and post-test for the control group, the researcher ran Paired sample T- test for related samples. Results of Paired sample T-test indicated no significant difference in means of the students' knowing scores in the pretest and post-test for the control group ($t = 1.29$, $DF = 55$, $p - value > 0.05$). No significant difference was shown in means of the students' applying scores ($t = 0.97$, $DF = 55$, $p - value > 0.05$), and no significant difference was shown in means of the students' Reasoning scores ($t = 1.16$, $DF = 55$, $p - value(0.524) > 0.05$). Overall, no significant difference in means of total scores of the Cognitive Outcomes of the (KAR) in the pretest and post-test for the control group ($t = 0.641$, $DF = 55$, $p - value > 0.05$). We can conclude that the student's performance in the cognitive outcomes of the (KAR) in the pretest

and post-test for the control group 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.

Table 2. Results of Paired Sample T-Test for the Cognitive Outcomes of the (KAR) Test in the Pretest and Post-Test for the Control Group.

Scale	Test	Mean	Std. Deviation	Mean Diff.	t	df	Sig.
Knowing	Pretest	3.93	1.10	0.286	1.29	55	0.203
	Post-test	3.64	1.10				
Applying	Pretest	5.63	1.46	0.214	0.792	55	0.432
	Post-test	5.84	1.35				
Reasoning	Pretest	3.66	1.07	0.304	1.608	55	0.114
	Post-test	3.96	1.39				
KAR	Pretest	13.21	2.00	0.232	0.641	55	0.524
	Post-test	13.45	2.00				

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

Table 3 above and Figure 2 showed that participants' reasoning ability was the highest in the experimental group ($M = 8.83$, $SD = 1.41$). Applying ability came with a mean of 7.70 ($SD = 2.13$), while participants' knowing ability was the lowest ($M = 5.17$, $SD = 0.88$). Concerning the control group, participants' applying ability was the highest ($M = 5.84$, $SD = 1.35$). Reasoning ability came with a mean of 3.96 ($SD = 1.39$), while participants' knowing ability was the lowest in the control group ($M = 3.64$, $SD = 1.10$). In the total score of the cognitive outcomes Test (KAR), participants scored higher in the experimental group ($M = 21.70$, $SD = 2.96$) than in the control group ($M = 13.45$, $SD = 2.00$). Independent Samples T-test was conducted to find if there were statistically significant differences between the mean scores of the post-test measured in this study in the circular motion unit in the physics curriculum of grade 12 in both control and experimental groups after the intervention.

Table 3. Results of Independent Samples T-Test of the Cognitive Outcomes of the Variables of Knowing, Applying, Reasoning, and Overall (KAR) for the Two Groups-Post-Test.

Scale	Group	N	Mean	Std. Dev.	T	df	Sig.
Knowing	Control	56	3.64	1.10	7.98	108	0.000
	Experimental	54	5.17	0.88			
	Total	110	4.39	1.26			
Applying	Control	56	5.84	1.35	5.50	108	0.000
	Experimental	54	7.70	2.13			
	Total	110	6.75	2.00			
Reasoning	Control	56	3.96	1.39	18.25	108	0.000
	Experimental	54	8.83	1.41			
	Total	110	6.35	2.81			
Overall KAR	Control	56	13.45	2.00	17.22	108	0.000
	Experimental	54	21.70	2.96			
	Total	110	17.50	4.84			

Std. Dev.= Standard Deviation.

The results of T- the test for independent samples showed that statistically, there was a highly significant difference between the control group and experimental group regarding students' knowing abilities in favour of the experimental group ($t = 7.98$, $DF = 108$, $p - value(0.00) < 0.05$), which indicated that the students in the experimental group were more likely had a high knowing performance after the intervention, comparing to control group. In addition, statistically, there was a

highly significant difference found between the control group and experimental group regarding students' applying abilities in favour of the experimental group ($t = 5.50, DF = 108, p - value < 0.05$), which indicated that the students in the experimental group were more likely to had a high applying performance in applying after the intervention, comparing to control group.

The results of the t-test test for independent samples showed that statistically, there was a highly significant difference between the control group and experimental group regarding students' reasoning abilities in favour of the experimental group ($t = 18.25, DF = 108, p - value (0.00) < 0.05$), which indicated that the students in the experimental group were more likely to had a high reasoning performance reasoning after the intervention, comparing to control group.

Statistically, there was a highly significant difference found between the control group and experimental group regarding student performance in the total score of the cognitive outcomes of (the KAR) Test ($t = 17.22, DF = 108, p - value < 0.05$) in favour of the experimental group. We can conclude that the students in the experimental group were more likely to have a high performance in the overall KAR after the intervention 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 (.05/4) since four tests were conducted.

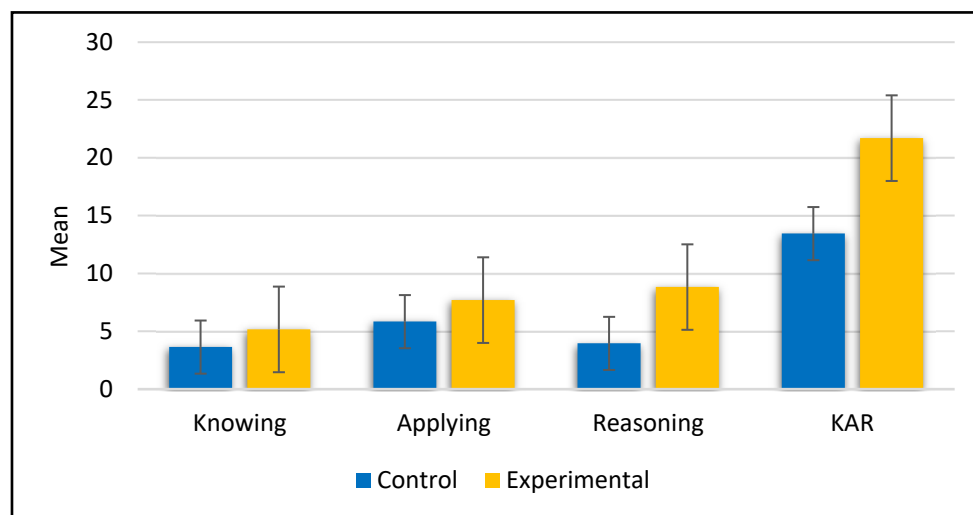


Figure 2. Profile of the Students in the Cognitive Outcomes of (KAR)-Post-Test.

The results in Table 4 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.

Table 4. 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.

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.

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.

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 11, 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.

The effect size of the POGIL approach for reasoning scores for the experimental group will be:

$$D = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{4.94}{1.66} \times 100 = 2.98 \times 100 = 298\%$$

The effect size calculated above shows that the percentage of the POGIL approach for reasoning scores for the experimental group is 298%. This percentage indicates that this tool effectively elevates reasoning ability among the students in the experimental group by approximately 2.98 level of standard deviation. Further, Cohen's effect size value ($d = 2.98$) suggested a very high 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 3).

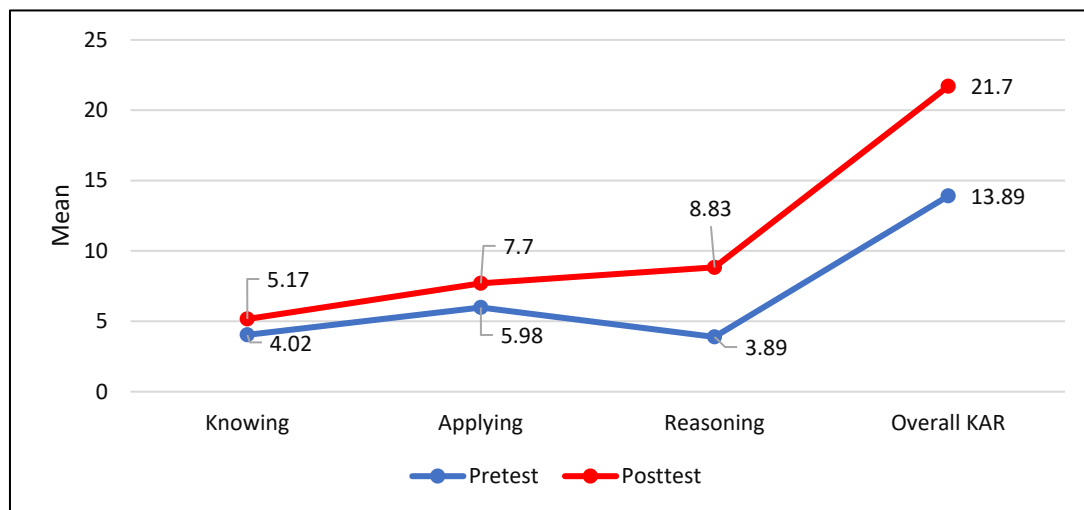


Figure 3. Profile of the cognitive outcomes Test of (KAR)-Pretest vs Post-test.

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 5 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 5. 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 Self-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 5 and Figure 4 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 $= 0.0125 (0.05/4)$ since four tests were conducted.

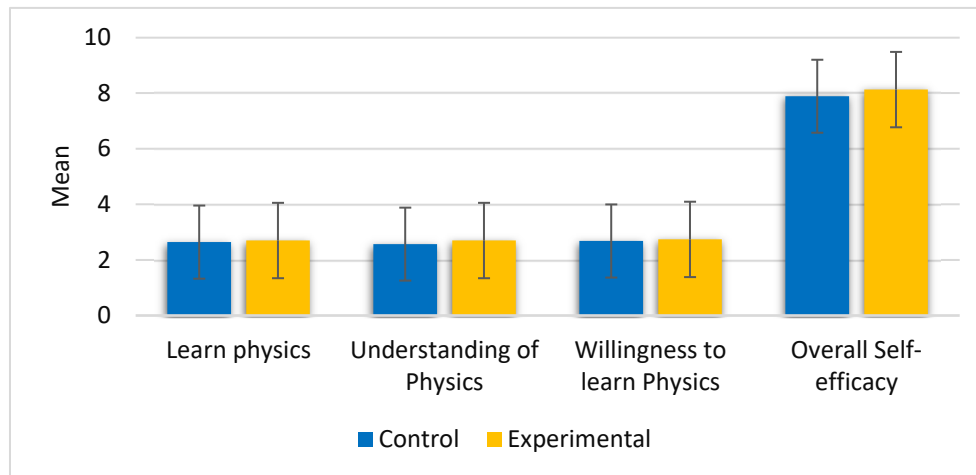


Figure 4. Profile of the Students in the Pretest for the Subscales and Whole Test of Self-Efficacy.

As presented in Table 6, 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.

Table 6. 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	Pretest	2.57	0.68	0.13	0.98	55	0.33
	Post-test	2.70	0.63				
Willingness to learn Physics	Pretest	2.68	0.61	0.02	0.16	55	0.87
	Post-test	2.66	0.61				
Overall Self Efficacy ¹	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.

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.

Table 7 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).

Table 7. 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 Self-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.

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.

The results presented in Table 8 and Figure 5 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 understanding 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.

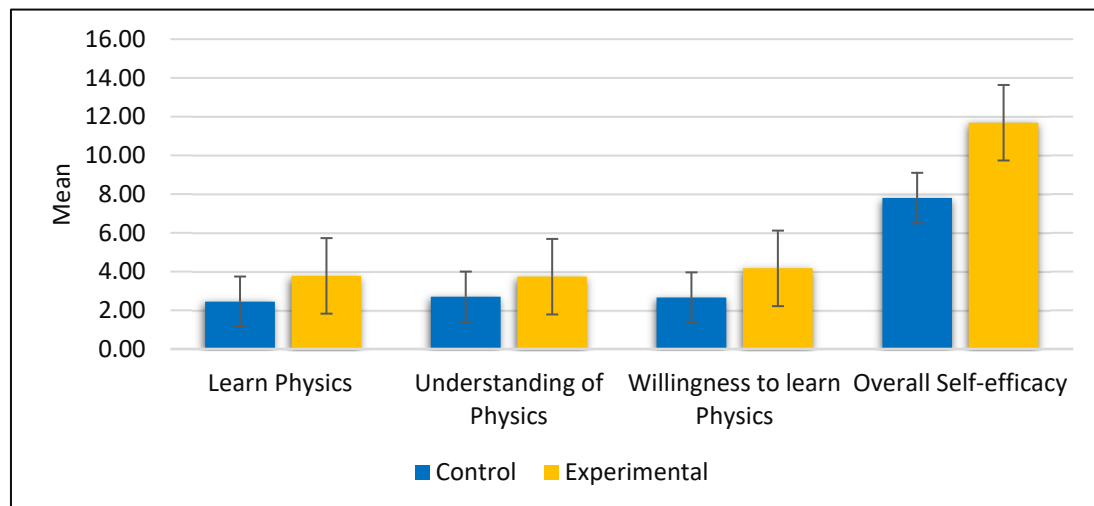


Figure 5. Profile of the Students in the Post-Test for the Subscales and Whole Test of Self-Efficacy.

Table 8. 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.

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 5 below). Using the data presented in Table 8, 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. Further, Cohen's effect size value ($d = 1.40$) suggested a high practical significance. In addition, the effect size of the POGIL approach for the understanding Physics scores for the experimental group will be:

$$D = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{1.04}{0.73} \times 100 = 1.42 \times 100 = 142\%$$

The effect size calculated above shows that the percentage of the POGIL approach for understanding Physics scores for the experimental group is 142%. This percentage indicates that this tool effectively elevates the understanding of Physics ability among the students in the experimental group by approximately 1.42 level of standard deviation. Further, Cohen's effect size value ($d = 1.42$) suggested a high practical significance. Likewise, the effect size of the POGIL approach for willingness to learn Physics scores for the experimental group will be:

$$D = \frac{\text{Mean difference}}{\text{SDdiff}} \times 100 = \frac{1.43}{0.98} \times 100 = 1.46 \times 100 = 146\%$$

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 6).

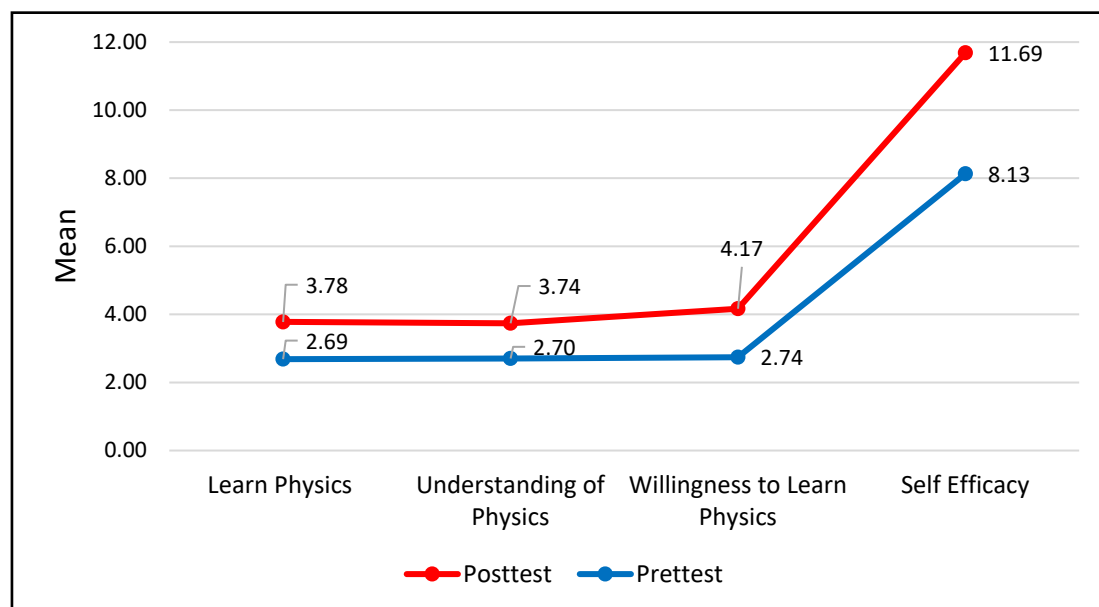


Figure 6. Profile of the Experimental Group in the Subscales of Self-Efficacy Survey: Pretest vs Post-Test.

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 9. Correlation between Grade 12 Students' Performance in KAR, Self-Efficacy and Attitudes in Control Group: Pearson's Correlation Coefficient.

	Scales	KAR	Self-Efficacy	Attitudes
KAR	Correlation Coefficient	1.000		
	P-value			
	n	56		
Self-Efficacy	Correlation Coefficient	0.076	1.000	
	P-value	0.579		
	n	56	56	
Attitudes	Correlation Coefficient	0.037	0.194	1.000
	P-value	0.786	0.153	
	n	56	56	56

Table 10. Correlation between Grade 12 Students' Performance in KAR, Self-Efficacy and Attitudes in Experimental Group: Pearson's Correlation Coefficient.

	Scales	KAR	Self-Efficacy	Attitudes
KAR	Correlation Coefficient	1.000		
	P-value	.		
	N	54		
Self-Efficacy	Correlation Coefficient	0.704**	1.000	
	P-value	0.000	.	
	N	54	54	
Attitudes	Correlation Coefficient	0.565**	0.569**	1.000
	P-value	0.000	0.000	.
	N	54	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 ($r = 0.704, p - \text{value} (0.00) < 0.05$) 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 ($r = 0.565, p - \text{value} (0.00) < 0.05$), 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 ($r = 0.569, p - \text{value} (0.00) < 0.05$), 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 11. Model Summary: Relationship between Students' Performance, Self-Efficacy and Attitudes 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

The prediction model contained two predictors: Self-Efficacy and students' attitudes towards science inquiry, used to predict Students' performance in KAR. As Tables 12 and 13 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 12. ANOVA for the Relationship between Students' Performance, Self-Efficacy and Attitudes 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			

Table 13. Model Coefficients for the Relationship between Students' Performance, Self-Efficacy and Attitudes 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
Students' Attitudes towards science inquiry	0.63	0.30	0.24	2.10	0.041

Dependent Variable: Students' Performance.

The raw and standardized regression coefficients of the predictors are shown in Table 13. 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 ($\beta = 0.57, t = 4.88, p - \text{value} (0.00) < 0.05$). In addition, students' attitudes towards science inquiry statistically have a positive effect on student's performance since ($\beta = 0.24, t = 2.10, p - \text{value} (0.04) < 0.05$). Overall results of the fourth question showed no correlations between the variables: students' performance and, Self-efficacy and Attitudes 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 and their Attitudes towards Scientific Inquiry after the intervention. In addition, the results showed that students' Self-Efficacy and attitudes 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.

As previously said, teams in POGIL have defined roles which 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.

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.

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.

References

- Aiman, U., Hasyda, S. and Uslan, U. (2020), "The Influence of Process Oriented Guided Inquiry Learning (POGIL) Model Assisted by Realia Media to Improve Scientific Literacy and Critical Thinking Skill of Primary School Students", *European Journal of Educational Research*, Vol. 9 No. 4, pp. 1635–1647.

- Al-Naqbi, A.K. and Alshannag, Q. (2018), "The status of education for sustainable development and sustainability knowledge, attitudes, and behaviors of UAE University students", *International Journal of Sustainability in Higher Education*, Vol. 19 No. 3, pp. 566–588.
- Anam, S. and Stracke, E. (2016), "Language learning strategies of Indonesian primary school students: In relation to self-efficacy beliefs", *System*, Vol. 60, pp. 1–10.
- Artino Jr., A.R. (2012), "Academic self-efficacy: from educational theory to instructional practice", *Perspectives on Medical Education*, Vol. 1 No. 2, pp. 76–85.
- Assem, H.D., Nartey, L., Appiah, E. and Aidoo, J.K. (2023), "A Review of Students' Academic Performance in Physics: Attitude, Instructional Methods, Misconceptions and Teachers Qualification", *European Journal of Education and Pedagogy*, Vol. 4 No. 1, pp. 84–92.
- Bandura, A. (1977), "Self-efficacy: Toward a unifying theory of behavioral change.", *Psychological Review*, Vol. 84 No. 2, pp. 191–215.
- Barthlow, M.J. and Watson, S.B. (2014), "The Effectiveness of Process-Oriented Guided Inquiry Learning to Reduce Alternative Conceptions in Secondary Chemistry", *School Science and Mathematics*, Vol. 114 No. 5, pp. 246–255.
- Brown, S.D. (2010), "A Process-Oriented Guided Inquiry Approach to Teaching Medicinal Chemistry", *American Journal of Pharmaceutical Education*, Vol. 74 No. 7, p. 121.
- Daubenmire, P., Frazier, M., Bunce, D., Draus, C., Gessell, A. and Van Opstal, M. (2015), "Research and Teaching: During POGIL Implementation the Professor Still Makes a Difference", *Journal of College Science Teaching*, Vol. 44 No. 5, available at: https://doi.org/10.2505/4/jcst15_044_05_72.
- Easterbrook, M.J. and Hadden, I.R. (2021), "Tackling Educational Inequalities with Social Psychology: Identities, Contexts, and Interventions", *Social Issues and Policy Review*, Vol. 15 No. 1, pp. 180–236.
- Frey, R.F., McDaniel, M.A., Bunce, D.M., Cahill, M.J. and Perry, M.D. (2020), "Using Students' Concept-building Tendencies to Better Characterize Average-Performing Student Learning and Problem-Solving Approaches in General Chemistry", edited by Davidesco, I.CBE—Life Sciences Education, Vol. 19 No. 3, p. ar42.
- Guido, R.M. (2013), "Attitude and Motivation towards Learning Physics", *International Journal of Engineering Research & Technology (IJERT)*, Vol. 2 No. 11.
- Haleem, A., Javaid, M., Qadri, M.A. and Suman, R. (2022), "Understanding the role of digital technologies in education: A review", *Sustainable Operations and Computers*, Vol. 3, pp. 275–285.
- Hassan Al Marzouqi, A.H., Alameddine, M., Sharif, A. and Alsheikh-Ali, A.A. (2019), "Research productivity in the United Arab Emirates: A 20-year bibliometric analysis", *Heliyon*, Vol. 5 No. 12, p. e02819.
- Hu, H.H. and Shepherd, T.D. (2013), "Using POGIL to help students learn to program", *ACM Transactions on Computing Education*, Vol. 13 No. 3, pp. 1–23.
- Idul, J.J.A. and Caro, V.B. (2022), "Does process-oriented guided inquiry learning (POGIL) improve students' science academic performance and process skills?", *International Journal of Science Education*, Vol. 44 No. 12, pp. 1994–2014.
- Kaleva, S., Pursiainen, J., Hakola, M., Rusanen, J. and Muukkonen, H. (2019), "Students' reasons for STEM choices and the relationship of mathematics choice to university admission", *International Journal of STEM Education*, Vol. 6 No. 1, p. 43.
- Knight, J.K., Wise, S.B., Rentsch, J. and Furtak, E.M. (2015), "Cues Matter: Learning Assistants Influence Introductory Biology Student Interactions during Clicker-Question Discussions", edited by Momsen, J.CBE—Life Sciences Education, Vol. 14 No. 4, p. ar41.
- Le, H., Janssen, J. and Wubbels, T. (2018), "Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration", *Cambridge Journal of Education*, Vol. 48 No. 1, pp. 103–122.
- Lin, T.-J. and Tsai, C.-C. (2013), "A MULTI-DIMENSIONAL INSTRUMENT FOR EVALUATING TAIWANESE HIGH SCHOOL STUDENTS' SCIENCE LEARNING SELF-EFFICACY IN RELATION TO THEIR APPROACHES TO LEARNING SCIENCE", *International Journal of Science and Mathematics Education*, Vol. 11 No. 6, pp. 1275–1301.
- Lin, T.-S.C.W.M.Y.-G. (2009), "Faculty Perceptions of Teaching Support and Teaching Efficacy in Taiwan", *Springer*, Vol. 59, pp. 207–220.
- De Loof, H., Boeve-de Pauw, J. and Van Petegem, P. (2022), "Engaging Students with Integrated STEM Education: a Happy Marriage or a Failed Engagement?", *International Journal of Science and Mathematics Education*, Vol. 20 No. 7, pp. 1291–1313.

- Nipa Deora, Nathalie Rivera, Sheila Sarkar, Marcos Betancourt, L.W. (2020), "Combining Flipped Classroom with POGIL in an Urban Community College Setting: A Pilot Study", Vol. 10 No. 1, pp. 19–23.
- Osborne, J., Simon, S. and Collins, S. (2003), "Attitudes towards science: A review of the literature and its implications", *International Journal of Science Education*, Vol. 25 No. 9, pp. 1049–1079.
- Pintrich, P.R., Smith, D.A.F., Garcia, T. and McKeachie, W.J. (1993), "Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (Mslq)", *Educational and Psychological Measurement*, Vol. 53 No. 3, pp. 801–813.
- Qureshi, S., Vishnumolakala, V.R., Southam, D.C. and Treagust, D.F. (2017), "Inquiry-Based Chemistry Education in a High-Context Culture: a Qatari Case Study", *International Journal of Science and Mathematics Education*, Vol. 15 No. 6, pp. 1017–1038.
- Sakellariou, C. and Fang, Z. (2021), "Self-efficacy and interest in STEM subjects as predictors of the STEM gender gap in the US: The role of unobserved heterogeneity", *International Journal of Educational Research*, Vol. 109, p. 101821.
- Soltis, R., Verlinden, N., Kruger, N., Carroll, A. and Trumbo, T. (2015), "Process-Oriented Guided Inquiry Learning Strategy Enhances Students' Higher Level Thinking Skills in a Pharmaceutical Sciences Course", *American Journal of Pharmaceutical Education*, Vol. 79 No. 1, p. 11.
- Tairab, H. and Al-Naqbi, A. (2017), "Provision of Inquiry Instruction and Actual Level of Practice as Perceived by Science Teachers and their Students", *EURASIA Journal of Mathematics, Science and Technology Education*, Vol. 14 No. 1, available at: <https://doi.org/10.12973/ejmste/80320>.
- Talanquer, V. (2022), "The Complexity of Reasoning about and with Chemical Representations", *JACS Au*, Vol. 2 No. 12, pp. 2658–2669.
- Trevathan, Jarrod, and Myers, T. (2013), "Towards online delivery of process-oriented guided inquiry learning techniques in information technology courses", *Journal of Learning Design*, Vol. 6 No. 2, pp. 1–11.
- Vishnumolakala, V.R., Southam, D.C., Treagust, D.F., Mocerino, M. and Qureshi, S. (2017), "Students' attitudes, self-efficacy and experiences in a modified process-oriented guided inquiry learning undergraduate chemistry classroom", *Chemistry Education Research and Practice*, Vol. 18 No. 2, pp. 340–352.
- Walker, L. and Warfa, A.-R.M. (2017), "Process oriented guided inquiry learning (POGIL®) marginally effects student achievement measures but substantially increases the odds of passing a course", edited by Tractenberg, R.E. *PLOS ONE*, Vol. 12 No. 10, p. e0186203.
- Wozniak, B.M. (2012), "Effect of Process-Oriented Guided-Inquiry Learning on Non-Majors Biology Students' Understanding of Biological Classification", [Master's Thesis, Minnesota State University, Mankato].
- Yadav, A., Subedi, D., Lundeborg, M.A. and Bunting, C.F. (2011), "Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course", *Journal of Engineering Education*, Vol. 100 No. 2, pp. 253–280.
- Yadav, A., Vinh, M., Shaver, G.M., Meckl, P. and Firebaugh, S. (2014), "Case-based instruction: Improving students' conceptual understanding through cases in a mechanical engineering course", *Journal of Research in Science Teaching*, Vol. 51 No. 5, pp. 659–677.
- Young, T., Macinnes, S., Jarden, A. and Colla, R. (2022), "The impact of a wellbeing program imbedded in university classes: the importance of valuing happiness, baseline wellbeing and practice frequency", *Studies in Higher Education*, Vol. 47 No. 4, pp. 751–770.
- Zamista, A.A., Rahmi, H. and Juni. (2019), "Development of Physics Module based on Process Oriented Guided Inquiry Learning as a Tool to Increase Student Science Process Skills", *Journal of Physics: Conference Series*, Vol. 1233 No. 1, p. 012067.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.