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Exploring the Influence of POGIL-Based Instruction on Grade 12 Achievement in the Circular Motion Unit

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Abstract

This research aimed to explore the comparative impact of Process Oriented Guided Inquiry Learning (POGIL)-based instruction and traditional lecture-based instruction on the academic performance of Grade 12 students in the context of the circular motion unit. Employing a quasi-experimental pretest-posttest design, the study assessed students' cognitive outcomes in terms of Knowing, Applying, and Reasoning (KAR). A total of 110 participants were involved, with 54 assigned to the treatment group (25 girls and 29 boys) and 56 to the control group (27 girls and 29 boys). The treatment group received instruction on circular motion through POGIL, while the control group underwent lecture-based instruction. The results revealed statistically significant differences in circular motion performance between the control and treatment groups, with the latter exhibiting superior outcomes. This suggests that POGIL-based instruction positively influences students' understanding of circular motion, emphasizing its efficacy in enhancing learning outcomes in comparison to traditional lecture-based methods.

Keywords: *POGIL-Based Instruction, Lecture-Based Instruction, Unit of Circular Motion, Science Performance*

INTRODUCTION

Science education, with its profound contributions to technological and digital progress, stands as a cornerstone for societal advancement (Pardo, 2017). As Pardo (2017) aptly states, "Science education has tremendous contributions to the technological and digital advancement that serves humanity." This sentiment is relevant for nations worldwide, including the United Arab Emirates (UAE), where the Ministry of Education (MOE) has been at the forefront of science instruction reform since the early 21st century. Aligning with global educational trends, the MOE has underscored the integration of inquiry-based science instruction into school curricula, recognising the need for students to develop competencies rooted in scientific inquiry (Ministry of Education, 2014). The overarching goal is to equip Emirati citizens with critical and creative thinking skills, research capabilities, and the ability to draw reasoned conclusions through scientific inquiry (Gningue et al., 2022; Ministry of Education, 2014).

Moreover, inquiry-based practices have become integral at all levels of science education in the UAE, reflecting the evolving landscape of scientific learning and application (Tairab & Al-Naqbi, 2017). As the Ministry of Education (2014) emphasizes, "The modern, technologically and scientifically advancing world requires Emirati citizens who are able to use critical, creative thinking, research, exploration, and analysis to come to reasonable conclusions about scientific inquiry." However, despite the theoretical underpinnings, the practical implementation of these ideals in the field may present challenges, a discrepancy that this study seeks to address.

This study is based on the framework of constructivism as a conceptual change model of learning. Students create their understanding of the interaction between prior knowledge and new knowledge. It was found out that if the current conception were still functional, it would provide a solution to problems within the existing conceptual schema, and it is important to find out first the existing knowledge of the learner on certain concepts (Canlas, 2016; Wardat et al., 2021).

Research Problem

It has been acknowledged so far that students are not doing well in physics due to traditional instructional methods, as stated by Balfakih (2010) and Ibrahim, Zakiang and Damio (2019), whose results revealed that in physics, students are not where they should be and do not meet the expectations.

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The poor performance of the students in science in general and in the UAE, in particular, could be due to the manifestation of negative attitudes alongside other contributing factors such as poor quality of instructional approaches that are not aligned with the learning needs of the students (Pennington, 2017). Also, the strategies could be unresponsive to the developmental needs of the learners due to outdated content in the curriculum and the lack of support mechanisms to promote learning (Bunce et al., 2008). Moreover, Ibrahim et al. (2019) contend that a majority of students harbour a pessimistic outlook on physics, likely fueled by a dislike for the subject and a struggle to achieve high marks, even when putting forth their best effort (p. 21). Additional research posits that physics is commonly viewed as the most daunting area of study within the broader realm of science, attracting fewer students than other science-related subjects from secondary school through university (Ibrahim et al., 2019). These scholars generally assert that students' negative attitudes towards physics often stem from a lack of interest in the subject matter and the associated curriculum. This viewpoint is corroborated by Guido (2013), who affirms that physics stands out as one of the most formidable and challenging subjects for students in the scientific domain. According to Guido, students perceive physics as a challenging subject during high school and tend to avoid it even more when they enter college.

There are concerns that most students are unwilling to pursue courses in science-related subjects such as physics as they have inner beliefs that they are either unsuited to such courses or incapable of attaining the expected grades to progress or qualify (Watkins & Mazur, 2013).

One may argue that this lower level of performance is related to poor standards and negative perceptions among the learners, which again calls for, among other things, a change in the instructional approaches. This lower level of performance demonstrates the need to study the self-efficacy levels of the students and determine the best approaches that can be used to ensure that self-efficacy levels are increased. Besides self-efficacy, it is also vital to study the nature of attitudes that could contribute to the students' poor performance in science subjects. It is likely that the learners have internalized negative attitudes towards science and mathematics, Al Ahbabi (2017) contends, where they develop inner beliefs and perceptions that they cannot perform excellently in the subjects (Saleh et al., 2023).

Furthermore, situating his study squarely within the UAE, Balfakih (2010) showed a direct link between negative attitudes towards science subjects in general and low achievement in these subjects, including physics. As he put it, education in the United Arab Emirates (UAE) is confronted with significant challenges that could impede its future progress. Key issues encompass low performance in science and a prevalent unfavorable stance towards science subjects, contributing to a substantial rate of student withdrawals from the science track in high school. UAE educators commonly attribute these challenges to the instructional methods employed in teaching science within the country's schools.

More recently, Balfakih's conclusions were supported by Ibrahim et al. (2019), whose arguments were quoted above and who contend that, in the UAE, negative attitudes towards physics contribute directly to students' "dislike" of physics.

The Purpose of the Study

The primary objective of this study is to examine and evaluate the influence of POGIL-based instruction on students' performance in the physics unit, specifically focusing on circular motion. The evaluation of performance revolves around the cognitive outcomes exhibited by the learners. More specifically, the study aims to gauge the effect of POGIL-based instruction on student performance, focusing on three distinct cognitive outcomes: knowing, applying, and reasoning (KAR).

Research Question

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

Are there any significant differences in student performance taught by POGIL instruction and lecturing instruction methods in circular motion unit in physics as measured by the three cognitive outcomes, namely knowing, applying, and reasoning?

Significance of the Study

The present study can be regarded as vital in facilitating an understanding of the benefits of utilizing inquiry-based approaches to learning. Such a strategy is vital in ensuring that learners exploit their abilities in areas like knowing, applying, and reasoning in an explicit manner that guides their acquisition of the recommended skills and competencies. As it will be shown, such competencies are attained due to the effectiveness and the impact of POGIL-based instruction on improving attitudes towards learning science subjects like physics (Pritchard, 2016). The data collected for this study is hoped to guide the inquiry-based and constructivist-oriented practices in science teaching and learning, thereby likely impacting learners cognitively and emotionally. In other words, due to the negative attitudes and apprehension that most students have towards science subjects, the study is hoped to reveal the benefits of adopting POGIL-based instruction when teaching science subjects. Such knowledge reduces the prevalence of negative attitudes towards science subjects and makes science teachers prioritise using POGIL-based strategies. Furthermore, the use of such strategies may enhance the levels of motivation and self-efficacy in students where they develop an inner belief that they are capable of handling science subjects.

The findings of the study can also be used to inform the training and design of professional development activities for teachers to ensure they are acquainted with the use of POGIL-based instructional strategies to improve student learning in science. The training of the science teachers on the suitability of such an approach is pivotal in improving the educational outcomes and enhancing the levels of self-efficacy of students who have negative attitudes towards some subjects. You need references here to support these arguments.

The study may contribute to enhancing students' performance in science in general and physics by focusing on the 21st-century skills that are needed locally and beyond to be in line with the ongoing developmental activities of the UAE, which has started entering the age of space and nuclear civil energy (Zakariya & Wardat, 2023).

Finally, there is a scarcity of previous findings of research studies with regards to POGIL. Thus far, we cannot find any studies regarding POGIL in the UAE. Only limited and few studies were conducted regionally in the Arabian Gulf. Thus, the current study is an attempt to fill in that gap and open an avenue for research to carry out similar research, especially to that of Vishnumolakala et al. (2018), and include the impact of POGIL on performance of students.

LITERATURE REVIEW

Various research studies have focused on understanding students' conceptions and misconceptions in physics, particularly circular motion. Searle (1985) and Ching (2001) delved into students' understanding of circular motion, revealing alternative conceptions related to centripetal acceleration and centripetal force. These studies highlight the challenges students face in grasping fundamental concepts within mechanics.

Moreover, investigations have uncovered widespread difficulties among high school and university students in mastering and applying key physics concepts, including circular motion (Duman et al., 2015; Serhane et al., 2020; Viridi et al., 2013). These difficulties underscore the need for effective instructional strategies to enhance students' comprehension and application of these concepts (Tashtoush, Wardat, & Elsayed, 2023).

In response to these challenges, research supports using inquiry-based learning models, such as Process Oriented Guided Inquiry Learning (POGIL), as effective tools for student-centered learning (Marshall & Alston, 2014). Studies have demonstrated that inquiry-based instructional models, including POGIL, positively impact students' performance on standardized science tests compared to traditional teaching methods (Shemwell et al., 2015; Jackson & Ash, 2012). Additionally, Pritchard (2016) highlights the effectiveness of inquiry-based learning in fostering deeper understanding and knowledge retention.

POGIL, grounded in cognitive and social constructivism theories, engages students actively in learning and emphasizes collaborative learning (Barthlow & Watson, 2014). This approach challenges the traditional teacher-centered, lecture-dominant pedagogy, fostering a shift towards student-centered, inquiry-driven learning experiences.

The theoretical underpinnings of POGIL align with key aspects of cognitive and social constructivism theories, emphasizing active participation of learners, collaborative work, and cycles of learning (Vishnumolakala et al., 2018; Alghamdi & Alanazi, 2020). Teachers in the POGIL model act as facilitators, guiding students through the learning process rather than simply transferring knowledge. This approach resonates with cognitive apprenticeship, discovery learning, and problem-based learning methods.

Research consistently demonstrates the positive impact of POGIL on academic performance (Qureshi & Vishnumolakala, 2018; Vishnumolakala et al., 2018; Alghamdi & Alanazi, 2020). Students exposed to POGIL exhibit not only improved academic outcomes but also positive attitudes toward science and enhanced self-learning and self-teaching strategies (Zgraggen, 2018; Barthlow, 2011).

However, within the Emirati context, Tairab and Al-Naqbi (2018) caution that the adoption of inquiry-based instruction, including POGIL, presents cultural challenges. These challenges include open assessment, group work, resource availability, and the need for in-service training and induction programs for new teachers. Tairab and Al-Naqbi (2018) emphasize that cultural dimensions, including beliefs and values, play a pivotal role in the acceptance and effectiveness of inquiry-based teaching methods.

In conclusion, the literature supports the importance of addressing students' difficulties in understanding physics concepts, particularly circular motion, and advocates for the effectiveness of inquiry-based models like POGIL in fostering meaningful and culturally responsive science education.

Several studies have highlighted the role of various educational factors in student achievement and engagement. For example, Wardat et al. (2022) explored the influence of school factors on students' mathematics achievements in the Trends in International Mathematics and Science Study (TIMSS) in Abu Dhabi Emirate Schools. The study by Jarrah, Khasawneh, and Wardat (2020) implemented pragmatism and John Dewey's educational philosophy in Emirati elementary schools, focusing on mathematics and science teachers. Hidayat and Wardat (2023) conducted a systematic review of augmented reality in science, technology, engineering, and mathematics education, providing insights into its potential and application.

Further research by Wardat, Jarrah, and Stoica (2021) examined middle school students' understanding of the equal sign in the UAE, emphasizing the need for improved mathematical comprehension. Gningue et al. (2022) investigated the relationship between teacher leadership and school climate, revealing significant insights from a teacher-leadership project. The study by Tashtoush et al. (2022) evaluated the effectiveness of a training program based on TIMSS in developing habits of mind and mathematical reasoning skills among pre-service mathematics teachers. Additionally, research by Tashtoush, Wardat, and Elsayed (2023) investigated the impact of mathematics distance learning and learning loss during the COVID-19 pandemic, highlighting teachers' perspectives and challenges.

These studies collectively provide valuable insights into the educational factors influencing student outcomes and teacher practices (Wardat et al., 2022; Jarrah, Khasawneh, & Wardat, 2020; Hidayat & Wardat, 2023; Wardat, Jarrah, & Stoica, 2021; Gningue et al., 2022; Tashtoush et al., 2022; Tashtoush, Wardat, & Elsayed, 2023).

METHODOLOGY

Research Design

The study adopted, a quasi-experimental, pretest-posttest design. This design is used to study the impact of the use of the POGIL-based form of instruction for the students taking a physics subject on their performance that is demonstrated by three outcomes, namely "Knowing", "Applying", and "Reasoning". One of the attributes of the design adopted for the study is that it allowed this researcher to manipulate the independent variable (performance). This design is a good 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.

The study was conducted in two Emirati high schools; one for boys and one for girls. The participating students were pursuing an advanced stream, where physics is one of the subjects; they studied the curriculum of the UAE Ministry of Education (Ministry of Education, 2019c). The students are in Grade 12, whose ages range between 17 to 19 years.

Population, Participants and Sampling

The study sample comprised Grade 12 students aged between 17 and 19 years. Participants were selected from two government secondary schools in Al Ain—one for boys (with a total of 1721 students) and one for girls (with a total of 1880 students). All participants were in Grade 12, totaling 3601 students. Within this group, 702 were boys, and 856 were girls.

Although the two schools were conveniently selected, the two participated classes were selected randomly from each school. One of them is considered to be the experimental group, and the other class is considered to be the control group. Convenient sampling might be vulnerable to selection bias and influences; however, the researcher was aware of this and selected the schools represented in term of size and gender. The researcher used this sampling design because he was teaching in one of these schools and could implement the extermination very well. He also shared his experience with the girls' school teacher, who was knowledgeable and responsive to instruction. Besides, the two schools are the largest and the best high schools in the city of Alain; these two schools got the highest grades according to the last Inspection Reports published by ADEK.

The study's sample size comprised 110 students, 54 of whom were assigned to experimental groups (25 girls and 29 boys) and 56 of whom were assigned to control groups (27 girls and 29 boys).

Instrument (Test of Circular Motion)

A test on "circular motion concepts" was developed using the topic learning outcomes stated in the student textbook and measured the science standards for teaching circular motion. The test was designed in line with external assessment tools (TIMSS and PISA) as well as internal achievement assessment that covers the circular motion unit taught for Grade 12.

Questions were developed for the cognitive domains of knowing, Applying, and Reasoning. There were 6 questions in the "Knowing" domain, 10 questions in the "Applying" domain, and 14 questions in the "Reasoning" domain. Additionally, the test was developed using the TIMSS standardized procedure for test development, which is widely used worldwide and has demonstrated its validity and reliability (TIMSS, 2019). It's used regularly in UAE schools. All the test subscales resemble items of cognitive abilities tested by TIMSS and PISA.

Validity and Reliability

Two university professors, two science supervisors and two experienced science teachers reviewed the test. The expert review suggested increasing the test items to provide a more comprehensive assessment of the performance. For example, the reviewers suggested adding items to "Applying" and "Reasoning" subdomains. They justified doubling the items of "Applying" and "Reasoning" since "Knowing" domain is implicitly included in other domains. Moreover, "Knowing" domain has only three subdomains: (Recall/Recognize, Describe and Provide example). In comparison, the domain of "Applying" has six subdomains: (Compare, Contrast, Classify, Relate, Use Models and Interpret Information) and the "Reasoning" domain has six subdomains: (Analyze, Synthesize, Design Investigations, Evaluate, Draw Conclusions and Generalize). Additionally, the grade level of the participants who are in grade 12 needs to acquire such cognitive levels of Applying and Reasoning. All the items of the test were designed to cover the three domains and subdomains, which were usually covered by TIMSS and PISA standardized tests that have tackled similar learning outcomes in the local curriculum. Furthermore, the 30 items cover all the learning outcomes of the units set by Physics Standards of Grade 12.

The reliability of the test of the Cognitive Outcomes of "Knowing", "Applying", and "Reasoning" (KAR) was measured by the reliability coefficient. The internal consistency coefficient (Cronbach's Alpha) of the entire scale was 0.83, which is considered a high internal consistency. while Cronbach's Alpha coefficient for "Applying" and "Reasoning" were 0.87 and 0.85, respectively, which indicated that these domains have a very good reliability (George & Mallery, 2016).

Both male and female teachers planned the unit of Circular Motion together to ensure that they delivered the unit for both groups in the same way: lecturing for the control group and POGIL-based for the treatment group. The unit was taught in 16 periods, four physics periods a week for four weeks. Each period was 45 minutes.

The researcher and the other female physics teacher who was experimenting by teaching the unit of circular motion challenged themselves to ensure that they were using the two approaches, POGIL and traditional. Both agreed that they exerted personal efforts to be on the right track and ensured that they followed the rules that were congruent with both methods (POGIL vs. traditional).

POGIL-based instruction unfolds in three primary phases. The first phase, exploration, addresses students' challenges in forming concepts (Walsh, 2006). Students enhance their knowledge during this stage by making observations, collecting and analyzing data, and formulating and testing hypotheses to explain and understand information (Hanson, 2005). The second phase, Concept Invention, builds upon the first as students elucidate observations made during exploration, constructing and articulating their understandings. The third phase, "Application," calls for deductive reasoning skills. It's essential to note that "application" in this context extends beyond the third " application " level in Bloom's taxonomy hierarchy, encompassing analyses, syntheses, and evaluations that may arise. Consequently, the use of POGIL is anticipated to have implications for students' cognitive, affective, and psychomotor skills. This could manifest in improved performance in examinations assessing these dimensions of student learning (Mitchell & Hiatt, 2010).

After developing the research instruments, a consent form was sent to parents of the students in the two schools. After receiving the approval, students were assigned to the experimental and the control groups in their intact classes.

(KAR) Pre-Test and Post-Test

The two researchers conducted the pre-achievement test, and the students were informed of the date of the post-achievement test a week before taking it for the students to prepare for it. The two researchers personally supervised the test with the help of other teachers. The two researchers conducted the pre-achievement test, and the students were informed of the date of the post-achievement test a week before taking it for the student to prepare for it, and the two researchers personally supervised the test with the help of other teachers. The researchers devoted the first page to the test instructions and the name of the student, the class, the section, the name of school, and an illustrative example of how to answer the test questions. and the other pages included the test paragraphs of (36) multiple-choice test items. After the test was conducted, the test was marked. One point was given to the correct answer and zero to the incorrect answer. Questions that were left without answers or contained more than one answer were treated as incorrect.

For the resources, students have lessons in a science lab and have their textbooks and laptops; they also use smart boards and all materials and equipment for carrying out their experiments and research. The lesson starts by revealing the learning outcomes and discussing the success criteria with students in experimental group. The teacher revises the previous materials and introduces new concepts and laws. For example, assigning one of the students to write the angular velocity and angular acceleration, reminding students of Newton's second law asking students to write it in a circular motion, and identifying factors Fc depends on. Then, the teacher presents the lesson in tasks and ends with the closure of the lesson.

In each lesson employing the POGIL approach, a brief introductory lecture, lasting no more than ten minutes, provides an overview of one of the highlighted topics. Subsequently, students convene in their groups to discuss the subject introduced in the lecture. After the allotted time for the lesson, the teacher gathers the students' attention to the whole class. Each group then presents their findings or insights from the POGIL activity. Following these presentations, groups resume their work on the activity, with the teacher intervening only upon request while circulating among the groups. The lesson concludes with a brief recap at the outset, offering some background information and providing guided questions to direct the inquiry. Notably, students are accountable for their learning throughout this process.

In contrast, the control group students undergo traditional lecture-based instruction. In this method, students play a passive role, receiving information from the teacher with a primary emphasis on knowledge acquisition rather than developing other skills and competencies.

Data Analysis

Data collection procedures started with the researcher securing the logistics needed to access the identified schools. Logistics included explaining the study's nature and goals and getting the necessary ethical approvals to conduct the study. Participants are also required to sign the ethical forms to ensure they are aware of the study and willingly participate in it without being forced. By signing the consent forms, the participants confirm that they understand their obligations regarding the study.

After teaching the unit of circular motion using POGIL and traditional methods that took four weeks, grade 12 students were given the same post-tests in treatment and control groups. The data collected were coded and given numbers to be ready for analysis.

Data collection procedures took place in two phases: Pre-intervention and post-intervention. In the pre-intervention, the instrument (KAR) was administered before the intervention. In phase two, the same instrument was also administered. Grade 12 students in both schools, control, and treatment groups were given a pre-test. This test was given in 45 minutes. The researcher corrected the exam papers and moderated by another teacher to ensure the correct results.

After teaching the unit of circular motion using POGIL and traditional methods that took four weeks, grade 12 students were given the same post-tests in treatment and control groups. The data collected were coded and given numbers to be ready for analysis.

RESULTS

The data underwent coding and entry into a computer utilising statistical analysis, specifically the Statistical Package for Social Sciences (SPSS) version 27. This program was employed at various stages of data processing to handle both raw data sets (Control and Experimental). The research question underwent analysis through two types of statistical examinations.

Firstly, an independent-sample t-test was computed to compare the mean science achievement scores in the pretest between the treatment group and the control group. Similarly, another independent-sample t-test was performed to compare the mean scores of science achievement in the posttest between the treatment and control groups, as measured by the KAR Achievement Test.

Secondly, a paired-sample t-test was conducted to compare the pretest and post-test scores within each group (treatment group and control group), as assessed by the KAR Achievement Test. The researcher corrected the examination papers and then moderated them by another teacher to ensure accurate results. The same procedures were applied to both the pretest and posttest phases.

Table 1. Independent samples T-test results: comparative analysis of cognitive outcomes in knowing, applying, and reasoning (KAR) variables - pretest phase

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

Table 1 reveals that, on the whole, there is no statistically significant difference in student performance on the total score of the Cognitive Outcomes Test of Knowing, Applying, and Reasoning (KAR) between the control group (M = 13.23, SD = 2.00) and the experimental group (M = 13.91, SD = 2.33). The independent samples t-test results (t = 1.635, DF = 108, p-value = 0.105 > 0.05) indicate that the performance of students in the KAR pre-test was comparable between the two groups. This suggests that the two groups can be considered equivalent in terms of their performance in the pre-test for KAR.

Table 2. Independent samples T-test results for cognitive outcomes in knowing, applying, reasoning, and overall (KAR) variables across two groups - post-test phase.

Scale	Group	N	Mean	Std. Dev.	T	df	Sig.	d
Knowing	Control	56	3.64	1.10	7.98	108	0.000	-1.536
	Experimental	54	5.17	0.88				
	Total	110	4.39	1.26				
Applying	Control	56	5.84	1.35	5.5	108	0.000	-1.043
	Experimental	54	7.70	2.13				
	Total	110	6.75	2.00				
Reasoning	Control	56	3.96	1.39	18.25	108	0.000	-3.479
	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	-3.266
	Experimental	54	21.70	2.96				
	Total	110	17.50	4.84				

Table 2 illustrates notable differences in participants' cognitive abilities between the experimental and control groups. In the experimental group, reasoning ability emerged as the highest (M = 8.83, SD = 1.41), followed by applying ability with a mean of 7.70 (SD = 2.13), and knowing ability was the lowest (M = 5.17, SD = 0.88). Conversely, in the control group, applying ability ranked highest (M = 5.84, SD = 1.35), followed by reasoning ability with a mean of 3.96 (SD = 1.39), and knowing ability was the lowest (M = 3.64, SD = 1.10).

Analysing the total scores on the Cognitive Outcomes Test of Knowing, Applying, and Reasoning (KAR), participants in the experimental group scored significantly higher (M = 21.70, SD = 2.96) than those in the control group (M = 13.45, SD = 2.00).

The independent samples t-test results revealed statistically significant differences between the two groups in knowing abilities (t = 7.98, DF = 108, p-value < 0.05), favouring the experimental group. This suggests that students in the experimental group exhibited significantly higher knowing performance after the intervention than the control group.

Similarly, a significant difference was found in applying abilities (t = 5.50, DF = 108, p-value < 0.05), favoring the experimental group. This indicates that students in the experimental group demonstrated higher applying performance after the intervention compared to the control group.

Furthermore, a highly significant difference was observed in reasoning abilities (t = 18.25, DF = 108, p-value < 0.05), favoring the experimental group. This implies that students in the experimental group displayed significantly higher reasoning performance after the intervention than the control group.

In summary, there was a substantial difference in student performance on the overall KAR test (t = 17.22, DF = 108, p-value < 0.05), favoring the experimental group. The effect size for all differences ranged from (-1.536) to (-3.479), indicating substantial differences between the two groups. Consequently, it can be concluded that students in the experimental group were more likely to achieve high overall KAR performance after the intervention than the control group.

DISCUSSION

The current study's findings demonstrate a positive impact of POGIL-based instruction on the performance of Grade 12 students. These results align with previous research, including the work of Fencl and Scheel (2005), who identified POGIL as having a significant positive influence on students' achievement. Moreover, the outcomes of this study are consistent with other research indicating that students exposed to inquiry-based learning models, such as POGIL, exhibit greater gains in achievement on standardised science tests compared to those taught through traditional methods (Shemwell et al., 2015; Marshall & Alston, 2014; Jackson & Ash, 2012; Banerjee et al., 2010; Wilson et al., 2010).

POGIL operates on the premise that students actively engaged in the learning process comprehend complex concepts at a deeper level than those in passive roles under teacher-centred, lecture-dominant traditional pedagogy. Emphasising student collaboration, POGIL encourages active peer engagement, fostering a learning environment that extends beyond teacher-student interactions (Barthlow & Watson, 2014).

Consistent with the present study, Pritchard (2016) found POGIL-based learning to be more effective than direct instruction in enhancing science achievement. Similarly, Lin and Tsai (2013) reported that POGIL-based instructional approaches improved students' learning capabilities compared to alternative methods. Additionally, Wozniak (2012) observed that using POGIL was instrumental in identifying different conceptions held by students and facilitated their ability to modify or revise such conceptions. These collective findings underscore the efficacy of POGIL in positively influencing student performance and learning outcomes.

In concurrent with the present study, Chase et al. (2013) explain that most students experience improvements in their learning when they are directly involved in creating knowledge. POGIL provides an opportunity for students to construct content knowledge and concepts and apply this knowledge. Moreover, the results of the studies by Devitri et al. (2019) and Zamista & Rahmi (2019) showed positive results of using POGIL in improving students' literacy ability in science.

On the other hand, the results of this study regarding the positive impact of using POGIL-based instruction in improving students' science performance contradicted the findings of other research studies. For example, Barthlow (2011) contrasted these findings as Barthlow's study found that the learners taught using POGIL did not have any different or alternative conceptions compared to the learners taught using the traditional forms of instruction. Furthermore, Walker and Warfa (2017) found that POGIL had a small effect on science achievement outcomes. On his part, Geiger (2010) carried out a study to examine the effects of POGIL implementation in health courses at Gaston College. His results showed that POGIL was less successful. The results are different, which may be due to some factors, including contexts, levels, methods of implementation and students' readiness and interests.

The results of various studies indicate that several factors, including context, level, methods of implementation, and students' readiness and interests, can influence educational outcomes. For instance, Tashtoush et al. (2023) examined the impact of ICT-based education on mathematics academic enthusiasm, revealing significant positive effects on student engagement. Similarly, Jarrah, Wardat, and Gningue (2022) addressed misconceptions in the addition and subtraction of fractions among seventh-grade students, identifying key areas for instructional improvement.

Zakariya and Wardat (2023) explored job satisfaction among mathematics teachers, highlighting the contributions of teacher self-efficacy and motivation to teach. Their findings emphasize the importance of these factors in enhancing teacher satisfaction and performance. Moreover, Wardat et al. (2024) investigated mathematics teachers' perspectives on artificial intelligence in education, discussing the potential benefits and challenges of integrating AI into teaching practices.

Further research by Jarrah et al. (2022) assessed the impact of digital games-based learning on students' performance in learning fractions using the ABACUS software application. This study found that digital games can be an effective tool for enhancing students' understanding and engagement with mathematical concepts.

These studies collectively suggest that while there may be variations in outcomes due to different contexts and implementation methods, the integration of innovative teaching strategies and technologies generally has positive effects on student learning and teacher satisfaction (Tashtoush et al., 2023; Jarrah, Wardat, & Gningue, 2022; Zakariya & Wardat, 2023; Wardat et al., 2024; Jarrah et al., 2022).

Despite some studies showing moderate to no effect of POGIL, the present research demonstrates that POGIL had positive effects on Grade 12 students' abilities in knowing, applying, and reasoning. This success is attributed to POGIL's practical engagement of students in constructing and applying scientific knowledge in real-life situations, which improves cognitive and higher-order thinking skills (Walker & Warfa, 2017). The active and independent learning promoted by POGIL enhances students' self-efficacy and positive attitudes toward learning, further contributing to their academic success.

CONCLUSION

Major points that could be concluded from this research study are that, first, POGIL-based instruction has more positive effects than traditional methods. This study is especially true regarding Grade 12 students' performance and cognitive outcomes of knowing, applying and reasoning (KAR) to learning physics. Second, Grade 12 students taught using POGIL-based instruction performed better than their counterparts taught using traditional methods.

Thus, the major conclusion is that POGIL-based instruction positively improved Grade 12 students' scientific performing abilities of reasoning, applying and knowing. Thus, one would confidently say that POGIL is the core factor that positively impacts students' science performance.

IMPLICATIONS & RECOMMENDATIONS

The study's finding suggests that there is a need to adapt effective strategies such as POGIL to maximized student learning in line with the new science education reforms related to the acquisition of 21st-century skills. In science teaching and learning, students should be trained to be independent learners by enhancing discovery learning and inquiry learning. Using POGIL-based instructional methods brings the UAE closer not only to the international benchmark when it comes to science but also to meeting its ambitious future projects.

A central aspect of POGIL which makes it unique is its materials. Three characteristics make POGIL materials unique: 1) POGIL materials are designed for self-managed teams that interact with the instructor as a facilitator of learning rather than as a source of information.

2) POGIL materials guide students through an exploration to construct understanding.

3) POGIL materials use discipline content to facilitate the development of higher-level thinking skills and the ability to learn and apply knowledge in new contexts. To conclude, pre-service as well as in-service teachers should be introduced to these materials.

Educational decision-makers and schools need to shift towards inquiry-based instruction as well as POGIL-based instruction that enhances students' performance, so it is recommended to shift from the teacher-centred approach of science teaching into a student-centred approach since lecture-based instruction has been found ineffective in enhancing students' performance. Furthermore, the physics curriculum should be introduced and presented in a way that improves the students' performance. This can be done by simplifying the curriculum through learning by doing through inquiry and relating physics to real-life contexts. In addition, academic counselling programs should be provided to choose career in science for Grade 12 students to explain the importance of physics for their future career, the digital age, and the age of artificial intelligence.

Limitations and Future Research Opportunities

This study addressed POGIL-based instruction and how it might have impacted Grade 12 students' performance. Some limitations are to be acknowledged. For instance, the study only sampled 110 Grade 12 students in two high governmental schools in one emirate in the UAE and was restricted to the period of the academic year 2019-2020. Future research studies are needed to investigate this theme in a larger sample that may include other grades, schools, educators, emirates, and other science subjects. Future research studies using a mixed-method approach are also recommended to conduct triangulation and ensure the causal relationship between the independent variable (the use of POGIL) and the other dependent variables.

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Data Availability Statement**:** The data for this study is not publicly available; however, it can be

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