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The Impact of Pogil-Based Instruction versus Teacher versus Lecturning Based Instruction on Grade 12 Performance in Circular Motion Unit

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Abstract: The aim of this study was to investigate the impact of Process Oriented Guided Inquiry Learning (POGIL)-based instruction versus lecture-based instruction on Grade 12 students' performance in circular motion unit. A quasi-experimental, pretest-posttest design, 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). 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 unit of circular motion in physics using POGIL-based instruction while the control group was taught the unit using lecture-based instruction. The findings of the study showed statistically significant differences between students of the control group and the treatment group in favor of the later regarding their circular motion performance, suggesting the superiority of the POGIL in enhancing student understanding of the circular motion.

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

Introduction

Science education in general and physics have tremendous contributions to the technological and digital advancement that serves the humanity (Pardo, 2017). Thus, science education has become a vital necessity for the progress and advancement of all the nations. The United Arab Emirates is not an exception. The Ministry of Education (MOE) of The United Arab Emirates (UAE) has been starting reform science instruction since the beginning of the 21st century. The MOE emphasized the inclusion of inquiry-based science instruction in the school science curriculum and programs so that scientific inquiry needs to be a part of the students' learning competencies, which are based on global trends of reforms. Moreover, the goals of improving science education should enable students to apply scientific inquiry in a way that could lead to development of science thinking skills (Ministry of Education, 2014). Moreover, inquiry-based instruction has been emphasized. According to the Ministry of Education (2014), *"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"*. Thus, inquiry-based practices have become an integral part of science teaching and learning at all the science instruction levels (Tairab & Al-Naqbi, 2017).

Research studies have supported the use of inquiry-based learning models such as POGIL in the classroom as one practical way to reinforce a student-centered learning (Marshall & Alston, 2014). Additionally, results from research found that inquiry-based instructional model have had positive effects on students' attainment on standardized science tests than those who were taught using the traditional methods. Moreover, marginally related to this current study, teaching models of inquiry-based learning had been shown to be effective at closing the racial gap in achievement scores (Shemwell, Chase, & Schwartz, 2015; Jackson & Ash, 2012). Furthermore, Pritchard (2016) added that inquiry-based learning was more effective in acquisition of deeper understanding and retention of knowledge.

One of the most popular methods of inquiry in science education is Process Oriented Guided Inquiry Learning (POGIL). By using POGIL students are actively engaged in the learning process, eventually leading to understanding complex concepts to a profound level while fostering collaboration among students (Barthlow & Watson, 2014). One way of reforming science education is inquiry-based learning, including POGIL, in which students need to find solutions to problems by asking scientific questions; designing plans and carrying explanations; finding out and analyzing evidence and information; offering interpretations and drawing explanations; and communicating results and findings (Marx et al., 2004).

POGIL works on the basis that students who are actively engaged in the learning process understand complex concepts to a deeper level than those students who remain passive in the learning process such as with the teacher-centered, lecture-dominant traditional pedagogy (Barthlow & Watson, 2014).

POGIL bases its theoretical and practical conceptions upon the major concepts of the cognitive and social constructivism theories. Some of these aspects stemmed from these theories are aligned with a POGIL-based instructional approach: For instance, learners are active participants in the learning process, and they are the core of the instruction. Then, teachers are facilitators and guide not lecturers who transfer knowledge to students. Next, students work collaboratively and learn through a process of cycles. Also, cognitive apprenticeship, learning, discovery learning, and problem-based learning are the most distinctive methods of instruction and inquiry learning is a major aspect of the process of teaching and learning (Vishnumolakala et al., 2018; Alghamdi & Alanazi, 2020)

POGIL proved to have a positive effect in academic performance (e.g., Qureshi & Visnumolakala, 2018; Vishnumolakala et al., 2018; Alghamdi & Alanazi, 2020) Students who are taught using POGIL have positive attitudes toward science, tend to perform well in science and are equipped with strategies for self-learning and self-teaching (Zgraggen, 2018; Barthlow, 2011). Within the Emirati context, Tairab and Al-Naqbi (2018) found that inquiry-based instruction and POGIL is no exception, that is, they challenge science education students. Beside not offering simple answers, for Tairab and Al-Naqbi (2018), inquiry-based instruction has proved to be culturally challenging, especially when it comes to teaching constructively; its open assessment; group work; availability (or the lack thereof) resources and in-service training; and its requirement for induction programs for new teachers. Tairab and Al-Naqbi (2018) added that these cultural dimensions have proved to be most challenging precisely "because beliefs and values are so central to it includes the textbook issue, views of assessment and the "preparation ethic," i.e., an overriding commitment to "coverage" because of a perceived need to prepare students for the next level of schooling" (pp. 400-401).

Research Problem

It has been acknowledged so far the 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.

The poor performance of the students in the 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 to 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, Havanki & Vanden, 2008). Furthermore, as Ibrahim et al. (2019) have argued, "most students tend to have a negative attitude towards physics presumably because they dislike the subject, do not obtain high marks in examination even though they have tried their best" (p. 21).Other researchers suggest that, for students, physics is considered as 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 (Ibrahim 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. Guido (2013) also supported this position by stating that "*Physics is considered as one of the most prevailing and problematic subjects by the students in the realm of science. Students perceived physics as a difficult subject during high school days and become more evasive when they reach college*" (p.2087).

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).

This lower level of performance, one may argue, 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 be contributing to the poor performance of the students 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.

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) faces major problems which may hinder its future development. These include low achievement in science and a negative attitude toward science subjects, which have resulted in a high number of student dropouts from the science track in high school. It is believed among UAE educators that the main reason is the way science has been taught in its schools. (p. 605).

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 are contributing directly to students' "dislike" of physics.

The Purpose of the Study

The purpose of the study is primarily to investigate and then assess the impact of POGIL-based instruction on the performance of students in physics unit, namely circular motion. Such performance is measured through the cognitive outcomes of the learners. Specifically, to assess the impact of POGIL-based instruction on student performance as measured by three types of cognitive outcomes namely: knowing, applying, and reasoning (KAR).

Research Question

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

- How much impact does POGIL based instruction have on student performance 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 a vital endeavor 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 the levels of 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, and thereby it is likely to impact 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

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attitudes towards science subjects and makes science teachers prioritize the use of 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 study can be considered as a basis for informing policy makers in the education about the need to adopt POGIL-based instruction when teaching subject areas like sciences where most of the students have negative attitudes towards them. The policy makers can use the findings of the current study to make radical changes and adjustments to the instructional strategies that are in use today in subject areas where students appear to perform below expectations. Moreover, 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 in the 21st century skills that are needed locally and beyond to be in line with the ongoing developmental activities of the UAE that has started entering the age of space and nuclear civil energy.

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.

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 of the independent variable (performance,). This design is a good approach in evaluating the forms of causality that will be evident amongst the variables in the study. Such design, Creswell (2012) explains further, is the most beneficial method in the field of education since little interference occurs. It is also appropriate to the nature of the study that compares between pre and post intervention, including the study's dependent variables.

Context

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

Population, Participants and Sampling

The sample for the study consisted of Grade 12 students whose age ranged between 17 to 19 years. The participants were drawn from two governmental secondary schools in Al Ain. One school was for the boys (with a total 1721students) and one for the girls (with a total 1880 students). All participants were Grade 12 students (N= 3601). Of these 3601 students, 702 boys and 856 girls.

Although the two schools were conveniently selected, the two participated classes were selected randomly from each school. One of them considered to be the experimental group and the other class 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

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size and gender. What made the researcher used this sampling design was that he was teaching in one of these schools and could implement the extermination very well and as well share his experience with the girls' school's 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 sample size consisted of 110 students. Up to 54 were assigned to experimental groups (25 girls and 29 boys), while up to 56 students 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. All together questions were developed for the cognitive domains, Knowing, Applying and Reasoning. There were 6 questions in "Knowing" domain, 10 questions in "Applying" domain, and 14 questions in "Reasoning" domain. Additionally, the test was developed using TIMSS standardized procedure for test development widely used over the world and has demonstrated its validity and reliability (TIMSS, 2019). That's used regularly in the UAE schools. All the test subscales resemble items of cognitive abilities tested by TIMSS and PISA.

Validity and Reliability

The test was reviewed by two university professors, two science supervisors and two experienced science teachers. The review by experts resulted in a suggestion to increase the test items to provide a more comprehensive assessment of the performance. For example, the reviewers suggested the addition of items to subdomains "Applying" and "Reasoning". 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 "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 test of the Cognitive Outcomes of "Knowing", "Applying", and "Reasoning" (KAR) was measured by 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).

Instructional Methodology & Procedures

Both male and female teachers planned unit of Circular Motion together to ensure that they were delivering 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 method. Both agreed that they exerted personal efforts to be in the right track and ensured that they follow the rules that congruent to both methods (POGIL vs. traditional).

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 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 conduction the test, 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 the lessons in science lab, have their textbooks, 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; remind students Newton's second law and ask students to write it in a circular motion; identify factors Fc depends on it. Then, the teacher presents the lesson in tasks and ends with the closure of the lesson.

A POGIL for every lesson begins with a short introductory lecture of no more than ten minutes about one of the topics highlighted above. Students then meet with their groups to discuss the topic introduced in the brief lecture. After a prescribed period for that lesson, the teacher calls the students' attention to the whole class. Each group reports on what they have learned or discovered regarding the POGIL activity. Groups then return to their work on the activity. The teacher circulates among the groups to help only when requested. The lesson concludes with the lesson by supplying a little background at the beginning and guided questions to steer the inquiry; the students are responsible for their learning. On the other hand, the control group students were taught using lecture-based instructional method.

Data Collection and Analysis

Data collection procedures started with the researcher securing the logistics needed to access the identified schools. Logistics included explanations of the nature of the study and its 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 are willingly participating in it without being forced. Also, by signing the consent forms, the participants are confirming that they understand their obligations regarding the study.

After completing teaching the unit of circular motion using POGIL and traditional methods that took four weeks, grade 12 students were then given the same post-tests both 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 exam papers were corrected by the researcher and moderated by another teacher to ensure the correct results.

Analysis

Data were coded and entered a computer using of statistical analysis namely Statistical Package for Social Sciences (SPSS) version 27. This program used in different stages of data processing to process the raw data (Control and Experimental). The research question was analyzed by two kinds of analysis. Firstly, an independent-sample t-test was calculated to compare the mean scores of the science achievement in the pretest between the treatment group and control group. Similarly, another independent-sample t-test analysis was calculated to compare the mean scores of the science achievement in the posttest between the treatment group and control group as measured by the KAR

Achievement Test. Secondly, a paired-samples t-test was conducted to compare the scores of the pretest and posttest within each group (treatment group and control group) separately as measured by the KAR Achievement Test.

Results of Research Question

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

Table 1 shows that 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) about 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 pre-test of KAR was the same and showed that the two groups are equivalent.

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 2 showed that participants' reasoning ability was the highest in experimental group (M = 8.83, SD = 1.41), then applying ability came with mean of 7.70 (SD=2.13), while participants' knowing ability was the lowest (M = 5.17, SD = 0.88). About the control group, participants' applying ability was the highest in (M = 5.84, SD = 1.35), then reasoning ability came with mean of 3.96 (SD=1.39), while participants' knowing ability was the lowest in control group (M = 3.64, SD = 1.10). In the total score of the cognitive outcomes Test of (KAR), participants scored higher in the experimental group (M= 21.70, SD =2.96) than the control group (M= 13.45, SD = 2.00).

Table 2. 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.	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	5.50	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				

Std. Dev.= Standard Deviation.

The results of T- test for independent samples showed that statistically there was a high significant difference between the control group and experimental group about students' knowing abilities in favor of 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 high significant difference found between the control group and experimental group about students' applying abilities in favor of 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 t-test test for independent samples showed that statistically there was a high significant difference between the control group and experimental group about students' reasoning abilities in favor of 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 high significant difference found between the control group and experimental group about student performance in the total score of the cognitive outcomes of (KAR) Test ($t = 17.22, DF = 108, p - value < 0.05$) in favor of 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, comparing to control group. Effect size was found very large in all the differences ranging from (-1.536) to (-3.479) and that showed the magnitude of differences between the two groups were very large.

Discussion of Results

The results of the current study found that POGIL-based instruction affected Grade 12 students' performance positively. These findings are in line with other results such as hose reported by Fencl and Scheel (2005) who found that POGIL had the greatest positive impact on students' achievement. Furthermore, the results of this study are also in the same line with some studies whose results indicate that students who learn through an inquiry-based learning model have greater achievement gains on standardized science tests than those students who are taught using the traditional method (Shemwell et al., 2015; Marshall & Alston, 2014; Jackson & Ash, 2012; Banerjee et al., 2010; Wilson et al., 2010).

POGIL works on the basis that students who are actively engaged in the learning process understand complex concepts at a deeper level than those students who remain passive in the learning process such as with the teacher-centred, lecture-dominant traditional pedagogy. POGIL also emphasizes collaboration among students (Barthlow & Watson, 2014). This means that students usually learn by actively engage with other students than with the teacher.

Like the results of the present study, Pritchard (2016) found that POGIL-based learning to be more effective than direct instruction at science achievement. In addition, Lin and Tsai (2013) found that POGIL-based instructional approach enhanced the ability of the students to perfect their learning capabilities in comparison to other approaches. Furthermore, Wozniak (2012) found similar results that using POGIL was instrumental in identifying the different conceptions by students and facilitated their ability to change or alter such conceptions.

In concurrent to the present study, Chase et al., (2013) explain that most of the students experience improvements in their learning when they are directly involved in the creation of knowledge. POGIL provides such opportunity for students to construct the content knowledge and

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concepts, apply and 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 literacy ability of students' 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 when compared to the learners that have been 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 that may be due to some factors including contexts, levels, methods of implementation and students' readiness and interests.

In sum, despite the studies cited above which show moderate to no effect of POGIL, in this research, POGIL had shown positive effects on Grade 12 students' abilities of knowing, applying and reasoning due to its practical engagement of the students in constructing their scientific knowledge and demonstrating it in real life situations. It enabled students to improve their cognitive skills and higher thinking skills and, hence, reflected in better performance in physics content as measured by KAR (Knowing, Applying and Reasoning). Indeed, according to these findings as well as those of Zamista and Rahmi (2019), learning by doing through POGIL increases students' motivation and engagement to learn better, and develop better understanding. Additionally, students do not tend to construct concepts well unless they practice, since POGIL-based instruction increases students' performance and understanding. In general, such a context increases students' self- efficacy and their positive attitudes. It is worth reiterating that success generates success and as such, students' success certainly enhances their self -efficacy and their positive attitudes toward learning (Walker& Warfa, 2017).

Conclusions

Major points could be concluded from this research study is that, first, POGIL-based instruction has more positive effects than traditional methods. Within this study, this especially true when it comes to Grade 12 students' performance and cognitive outcomes of knowing, applying and reasoning (KAR) to learning physics. Second, Grade 12 students who were taught using POGIL-based instruction performed better than their counterpart students who were 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 impacted positively students' science performance.

Implications & Recommendations

The finding of the study suggests that there is a need to adapt effective strategies such as POGIL to maximize 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. Clearly, using POGIL-based instructional methods bring the UAE closer not only to the international benchmark when it comes to science but to meeting its ambitious future projects.

A central aspect of POGIL which makes it unique is its materials. Three characteristics that make POGIL materials unique:

1) POGIL materials are designed for use with 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 enhanced 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 had been found ineffective in enhancing students' performance. Furthermore, 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

Though this study had 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 restricted to the period of one 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 and emirates as well as other science subjects. Future research studies using a mixed-method approach are also recommended to conduct triangulation and ensuring the causal relationship between the independent variable (the use of POGIL) and the other dependent variables.

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