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INVESTIGATING THE IMPACT OF POGIL-BASED INSTRUCTION VERSUS LECTURING BASED INSTRUCTION ON GRADE 12 PERFORMANCE IN CIRCULAR MOTION UNIT, SELF-EFFICACY, AND ATTITUDES

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Under the Supervision of Professor Hassan Tairab

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Declaration of Original Work

I, Saif Saeed Salem Al Neyadi , the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this dissertation entitled "*Investigating the Impact of POGIL-Based Instruction Versus Lecturing Based Instruction on Grade 12 Performance in Circular Motion Unit, Self-Efficacy, and Attitudes*" hereby, solemnly declare that this dissertation is my own original research work that has been done and prepared by me under the supervision of Professor Hassan Tairab in the College of Education at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my dissertation have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this dissertation.

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Abstract

This dissertation aims 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, self-efficacy, and attitudes. Four research questions guided the study. A quasi-experimental, pretest-posttest design was adopted as a methodology 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 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 with regard to their science performance, their self-efficacy and science related attitudes. However, there was no statistically significant difference between students' performance that can be attributed to gender. Moreover, positive correlations were found between participants' performance at 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, self-efficacy and attitudes. 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, unit of circular motion, science performance attitude, self-efficacy.

Title and Abstract (in Arabic)

تأثير التعلم المبني على عملية التقصي الموجه (POGIL) مقابل التدريس المبني على المحاضرات والتلقين على أداء طلاب الصف الثاني عشر في، وحدة الحركة الدائرية، والكفاءة الذاتية، والاتجاهات

الملخص

هدفت هذه الأطروحة إلى التحقيق في تأثير التعلم المبني على عملية التقصي الموجه (POGIL) مقابل التدريس المبني على المحاضرات والتلقين على أداء طلاب الصف الثاني عشر في موضوع الحركة الدائرية، والكفاءة الذاتية، والاتجاهات. تم استخدام أربع أسئلة بحثية لتوجيه الدراسة. تم اعتماد تصميم شبه تجريبي للاختبار القبلي والبعدي لتقييم تأثير التدريس المبني على (POGIL) مقابل التدريس المبني على المحاضرات على أداء الطالب كما تم قياسه بثلاثة أنواع من النتائج المعرفية: المعرفة والتطبيق والاستدلال. سيتم اختيار مدرستين ثانويتين حكوميتين في العين كعينة مريحة لإجراء الدراسة، واحدة لمدرسة الأولاد والأخرى لمدرسة البنات. كان العدد الإجمالي للمشاركين حوالي 110 طالبًا وطالبة (العدد = 110)؛ 54 مخصصًا للمجموعة التجريبية (25 طالبة و 29 طالب) و56 مخصصًا للمجموعة الضابطة (27 طالبة و 29 طالب). تم تعليم كلا المجموعتين وحدة الحركة الدائرية في الفيزياء. تم تعليم المجموعة للمجموعة التجريبية وحدة الحركة الدائرية من خلال التعلم القائم على عملية التقصي الموجه (POGIL) بينما تدرس المجموعة الضابطة الوحدة في التدريس المبني على المحاضرات التقليدية. أظهرت نتائج الدراسة فروق ذات دلالة احصائية بين طلاب المجموعة الضابطة وطلاب المجموعة التجريبية في صالح المجموعة الأخيرة فيما يتعلق بالأداء العلمي لطلاب الصف الثاني عشر وكفاءتهم الذاتية واتجاهاتهم العلمية. وعلاوة على ذلك لا توجد فروق ذات دلالة احصائية بين أداء الطلاب يمكن أعزاءه للنوع (الجنس). كما أظهرت نتائج الدراسة وجود الارتباطات إيجابية بين أداء المشاركين في اختبار KAR وكفاءتهم الذاتية واتجاهاتهم في المجموعة التجريبية. أوصيت الدراسة بالتحول نحو التدريس باستخدام POGIL نظرًا لتأثيره الإيجابي على أداء الطلاب والكفاءة الذاتية والاتجاهات. كما اقترحت الدراسة بإجراء مزيد من البحث لتشمل فصولاً أخرى ومراحل أخرى من التعليم بما في ذلك المراحل الابتدائية والثانوية في المدارس الخاصة والحكومية. بالإضافة إلى ذلك ، يجب أن توسع عينات من اصحاب المصلحة كالمعلمين والموجهين .

مفاهيم البحث الرئيسية: التعلم المبني على عملية التقصي الموجه، التدريس المبني على المحاضرات والتلقين موضوع الحركة الدائرية أداء الطلاب، الكفاءة الذاتية، الاتجاهات.

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First and above all, I thank God, the almighty for providing me this chance and giving me the ability to proceed successfully, at the end of this dissertation, I would like to take some time to thank all the people without whom this study would never have been possible. Although it is, just my name appears on the cover, many people have contributed to the research in their own specific way and for that, I want to give them special thanks.

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Dedication

To my beloved parents and family

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List of Abbreviations

ADEK	Abu Dhabi Education Department of Education and Knowledge
I-BI	Inquiry-based learning
IEA	International Association for the Evaluation of Educational Achievement
KAR	Knowing, Applying and Reasoning
POGIL	Process Oriented Guided Inquiry Learning
SEC	Scientific inquiry, enjoyment of lesions and care interest
SSRA	Survey Science Related Attitude
TIMSS	Trends in International Mathematics and Science Study
TOSRA	Test of Science Related Attitudes
U.A.E	United Arab Emirates

Chapter 1: Introduction

1.1 Overview

This dissertation is meant to investigate the effects of employing the Process Oriented Guided Inquiry Learning (POGIL)-based instruction and its impacts on students' performance in science, self-efficacy, and attitude. Chapter 1 introduces the research problem of this study and its major themes including POGIL, students' performance in science, self-efficacy, and attitude. The research study begins by describing the context of science education within the United Arab Emirates (UAE), the research purpose, and the research questions are addressed. Furthermore, the significance of the study in relation to the education system of the UAE and the limitations of the study are also discussed. The chapter concludes with a description of the overall organization of the study.

1.2 Emirati Context

In striving for a better education, the UAE government is working with the assumption that the nature and quality of education offered in the UAE is not where it should or could be. For instance, the rankings by the Global Competitiveness Index shows that the quality of education in the UAE is falling, thus pointing to the need for the adoption of suitable and responsive strategies to address this downward trend (Al Ahbabi, 2017). The government of the UAE, however, is committed to investing more funds in education as it is considered one of the most critical areas that will enhance the shift from an oil economy to a human resource economy (AlGhawi, 2017).

The provision of high-quality education is considered as one of the most critical missions of the UAE government. For the UAE government, such an investment in education would rank the UAE amongst the elite nations of the world, (AlGhawi, 2017). To demonstrate its commitment, the government of the UAE has committed additional budget allocations where 14.8% of the national budget is directed towards the education sector. For instance, the government allocated AED 10.41 billion to the education sector for fiscal year 2020, (UAE Ministry of Finance, 2021). The UAE emphasized the need for increased investments in education as it will enhance the productivity of its human resources and enhance economic stability based on recent trends where products such as oil that has been the mainstay of the economy is experiencing increased competition from other energy sources like renewable energy (Yousef, 2017).

In line with this commitment, the Ministry of Education in the UAE has developed the 'Education 2020 Strategy' that highlights that education for the UAE citizens should be provided free of charge from kindergarten to higher education levels. Such an offer will ensure a high number of UAE nationals access education opportunities without being limited by financial constraints. Education 2020 Strategy also enumerates the plans that the government is ensuring that the quality of the education service offered in the UAE should surpass others offer around the globe. For instance, through strategies like benchmarking and focus on areas like curriculum education, continuing education, and adult literacy programs, the government aims at ensuring that the education being offered is of the best quality and is available to all (Yousef, 2017).

Keeping these front and center as 21st century aims, the education strategy adopted by the UAE government also prioritizes the introduction of smart education programs and improvements in the pedagogical strategies adopted by teachers. Revising the curriculum where major emphasis is being given to the teaching of science and mathematics, is another 21st century goal (Yousef, 2017). These efforts are meant to ensure that the graduates from the UAE education system are marketable globally as their skills have been benchmarked with the best in the world (Badry & Willoughby, 2016).

1.3 Overview of Education in Abu Dhabi

Education in the UAE is highly prioritized by the government and through entities such as the Abu Dhabi Department of Education and Knowledge (ADEK), the government is playing a crucial role in ensuring education is available to every learner free of charge (TAMM, 2019). The government makes the first six years of school compulsory as this phase is considered critical in ensuring all learners have a minimum formal education and a level of literacy.

Following the successful completion of the six years, the students then enroll for three years at a middle education facility. The education at this level is also compulsory and marks the end of the mandatory education. From here the learner proceeds to secondary school. At the secondary school level, there are two types of schools. There are ‘ordinary’ secondary schools where one studies for three years. The UAE focus on teaching academic subjects to facilitate one’s pursing academic study in university. The other category of secondary schools is the ‘technical’ school that primarily focuses on equipping students with specific skills based on their preferences and strengths, for example, technical skills such as electric or mechanic. Here, one studies for three years at these technical schools and upon completion, one acquires a diploma in this specific skill area (TAMM, 2019).

Zaman (2017) argues the Emirati school model raises standards of teaching and learning and “enable[s] all schools across the country to operate under a standardized framework that is developed on the best international practices" (p. 1). Achieving this goal is being closely monitored by H. H. Shaikh Mohammad Bin Rashid, the Vice-President, and Prime Minister of the UAE, who considers it "essential to establish and support a well-informed education system capable of keeping up with future changes and developments" (Zaman, 2017). Interestingly enough, Zaman (2017) explains this Emirati model unifies the curriculum in all private and government schools in using one curriculum, which aims at elevating the education system to the global benchmark to produce aspiring generations and boost educational outcomes to be aligned with the comprehensive development in the UAE (Morgan, 2018).

Prior to 2015, students used to choose either the scientific or the literary stream. However, MOE abolished this system and instead introduced four streams: General Stream, Vocational Stream, Advanced Stream and Elite Stream (Advanced Science Program-ASP). The key difference between the general stream and the advanced stream is the range of scientific subjects. Students in the advanced track receive more in-depth instruction in mathematics and sciences than those in the general track. The elite stream is developed for academically outstanding students. The stream will admit students from Grade 6 until they finish Grade 12. Elite curriculum focuses on mathematics and science in a way that enhances the skills in analysis, reasoning and problem-solving (Ministry of Education, 2021).

Vocational education is also available and is offered through vocational institutes and training centers. The national qualification authority coordinates the provision of education at the different vocational training centers. These institutions are crucial in ensuring the programs under implementation in the vocational training centers adhere to the predetermined quality standards and best practices. These efforts enhance the marketability of the skills and competencies acquired, as such skills are considered critical in boosting the productivity levels in the economy, (TAMM, 2019). There is also tertiary education that is offered through various universities and colleges where the learners acquire skills in their respective areas of competency based on their qualifications. It demonstrates that the education system in Abu Dhabi in particular (the site of this research) and the UAE in general is well-developed and suited in meeting the educational needs of the various student categories (TAMM, 2019).

1.4 Science Instructional Practices

The UAE Ministry of Education has started transformation procedures to reform science instruction since the beginning of the 21st century. For instance, science standards have been initiated to meet the local context and to be in line with international practices. The science standards of the curriculum documents were created through the analysis of Next Generation of Science Standards of the United States of America 2011 and Singaporean Science Standards 2014. The Standards were constructed to identify the recent trends in its construction, so that the best global practices are reached while maintaining national originality and identity (Framework & Standards Documents, 2018).

The UAE Ministry of Education emphasizes the inclusion of inquiry-based science instruction in the school science curriculum and programs since, it is argued, 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 developing science thinking skills (Ministry of Education, 2014). Moreover, inquiry-based instruction has been emphasized. According to the Ministry of Education (2014), "[t]he 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).

The UAE participated for the first time in the Trends in International Mathematics and Science Study (TIMSS) in 2007 to join 57 other countries. This globally comparative assessment was carried out under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). TIMSS is designed to contribute in the process of improving teaching and learning in mathematics and science for students through evidence-based results. In addition, TIMSS results aim at informing educational policy making and highlighting similarities and differences between countries so that participating countries share experience and expertise in relation to quantity and quality of student learning (Alshannag, Tairab, Dodeen, & Fattah, 2012).

1.5 Physics Education

Science education in general and physics in particular have tremendous contributions to the technological and digital advancement that serves the humanity (Pardo, 2017). Yet, judging from the results of international exams like Program for International Student Assessment (PISA) and TIMMS, learners performed low in science including physics in many countries. For the purpose of this research, in the UAE, for example, the results in physics are not where they should be (Balfakih, 2010; Ibrahim, Zakiang, & Damio 2019). This study will discuss later in this introduction, despite infrastructure develop by the UAE government, the UAE was ranked 23 amongst the 63 countries that conducted TIMMS exam. These results are directly linked to students' attitudes and self-efficacy towards physics, which are not encouraging and may even be problematic. Talking about these attitudes, particularly about physics, Guido (2013) writes, "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). 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.

To make for these negative attitudes, Bug-os & Caro (2019) argued that "These motivate educators to use variety of strategies to put student's performance in physics on a pedestal. Also, to address the demand to produce learners who knew not only how to write, read and do arithmetic but learners who are able to perform process skills", (p. 31).

1.6 Process Oriented Guided Inquiry Learning (POGIL)

A popular method 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).

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). Results from these studies found that students who were taught through an inquiry-based instructional model have had greater achievements on standardized science tests than those who were taught using the traditional method. Moreover, marginally related to my research, 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; Banerjee, Banerji, Duflo, Glennerster, & Khemani, 2010; Wilson, Taylor, Kowalski, & Carlson, 2010).

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. As already indicated, POGIL also emphasizes collaboration among students (Barthlow & Watson, 2014).

In the traditional model, students are taught a concept, mostly in a lecture atmosphere; then presented with a problem; and finally instructed to use what they know to form a hypothesis about the concept or the experiment. These types of science lab activities are easy to create since the outcomes are known and the procedures are consistent every time the lab is performed. This type of lab uses deduction since students use logic to confirm or refute their hypothesis from data gathered. The students start with the outcome and work backwards (Shemwell et al., 2015).

Research has shown inquiry-based learning to be more effective than direct instruction at not only raising science achievement, but also closing the gender achievement gaps in science education (Pritchard, 2016). Inquiry-based learning is also effective in acquisition of deeper understanding and retention of knowledge. Learning through inquiry leads to greater levels of engagement which, according to Pritchard's research, is directly linked to higher achievement in science.

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).

It is worth noting that, for the benefit of this research, attitude is approached as a person's perspective on inquiry, which is most often attained from experience or observation (Dibiase & Mcdonald, 2015). Attitude is an important factor that affects learning and increases their achievement. Furthermore, attitude towards science is defined by Al-Naqbi (2007) as "the beliefs, feelings, and values thought about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves" (p. 2). Al-Naqbi adds that attitudes toward science are simply known as specific feelings that indicate to what extent a learner likes or dislikes science. It is very important to study learners' attitudes towards science since attitudes are believed to impact their learning behaviors, such as supporting scientific inquiry and pursuing their study in science stream. Here, as Bloom (1976) and Bandura (1986) have shown, there is a strong positive correlation between attitudes and achievement; and the opposite is also true, where students who have negative attitudes toward science tend to have lower scores on attainment measures, (Al-Naqbi, 2007).

Self-efficacy, on the other hand, represents a student's belief that s/he performs in a certain task in physics, the focus of this research. That is to say, to use Bandura's (1994) language, self-efficacy is the sum of "people's beliefs about their capabilities to produce levels of performance that exercise influence over events that affect their lives" (p. 71). Self-efficacy then is a self-motivated construct that can impact and be impacted by an internal or external feedback.

For Lindstrøma and Sharmaa (2011), self-efficacy was found to be a good predictor of academic attainment and success in future career. Thus, constituting a hypothesis for this research study, there is a link between students' science self-efficacy and confidence in their abilities to complete the actions required in particular fields, physics in the case of this study. Nonetheless, from the existing literature, a strong link can be seen between physics self-efficacy and success (Cavallo, Potter, & Rozman, 2004; Shaw, 2003). Self-efficacy is a dynamic factor that can be impacted and changed by feedback. For instance, if a student masters a task, s/he will certainly gain confidence in his/her abilities to achieve and succeed (Bandura, 1997).

Since self-efficacy is known to influence one's own confidence and ability to perform a task, students with high self-efficacy will have high expectations towards performing the assigned task and likely to succeed in science at school and to choose majors that can be aligned with their self-beliefs about personal competencies and abilities (Sawtelle, Brewe, Goertzen, & Kramer, 2012).

1.7 Problem Statement

The performance of the UAE students in science and mathematics subjects has been below expectations in comparison to other countries globally. For instance, according to the results in the Trends in International Mathematics and Science Study (TIMSS) the UAE was ranked at position 42 in Grade 4 mathematics out of 63 countries (TIMSS, 2019). In Grade 8 science, UAE was ranked at position 23 amongst the 63 countries (TIMSS, 2019). Such trends demonstrate there is a need, among other things, for a change in the instructional strategies to ensure the learning needs of the students are addressed in a proactive manner. Furthermore, 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.

The poor performance of the students in the science and mathematics subjects 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).

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.

In addition to negative attitudes, self-efficacy was found to be low. This was reflected in the results of the UAE students in TIMSS 2015. Here, it was noted that the students’ confidence and attitudes towards learning science was lower than the average international benchmarks (TIMSS, 2015). It was also observed in TIMSS 2015 that only 26% of students tended to study science in the UAE. This percentage is nearly similar to a report of official sources from the UAE Ministry of Education that reported only 28% of the student joined science stream in secondary school (Ministry of Education, 2014). Moreover, Abu Dhabi Emirate had the lowest science achievement score of all international benchmarking participants in TIMSS 2011, well below the international average of 500 (461) (TIMSS, 2015). Building on the researcher's observation as a physics teacher in two schools in Al Ain, UAE, only one third of the students joined the science stream.

From the researcher's experience and based on the statistics of the academic year 2020/2021 from two schools where the current study was carried out, the following table shows the frequency and percentage of students who joined both general and advanced steams.

Table 1: Frequency and Percentage of High School Students' Enrollment in Science

Stream	School 1			School 2		
Grade	Advanced Stream	General Stream	Total	Advanced Stream	General Stream	Total
Grade 12	75	153	228	43	112	155
Grade 11	58	191	249	45	98	143
Grade 10	66	208	274	43	61	104
Grade 9	36	185	221	48	82	120
Total	235	737	962	179	353	522
Percentage	24%	76%	100%	34%	66%	100%

It is clear from Table 1 that the percentage of students' enrollment in Advanced Steam in high school ranged between 24% to 34% out of the total schools' population.

Thus, most students prefer General Stream and a lot less prefer Advanced Stream, which includes science subjects.

Another focal point that highlights the significance and points to the importance of this research study is the sacristy of research in the field of science inquiry education in the UAE. “In the UAE,” writes Al-Naqbi (2019), “research is limited regarding whether science teachers who graduate from science teacher education programs teach according to scientific inquiry principles” (p. 143). Furthermore, the research thus far could not find any studies that tackled POGIL the UAE.

Due to students’ poor performance in physics, this research contends that POGIL may provide a solution to enhance their performance and improve their attitude and self-efficacy towards physics. Furthermore, the low performance and negative attitude of students towards physics call for a shift in instructional strategies, strategies that implement inquiry-based pedagogy and enhance students’ performance, self -efficacy and attitude.

1.8 Purpose of 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 science subjects, namely physics. Such performance is measured through the cognitive outcomes, self-efficacy and attitudes of the learners. Specifically, the following are the main areas that will be addressed by the study:

1-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).

2-To determine the impacts of POGIL-based instruction on students' self-efficacy as measured by variable of physics learning, understanding of physics, and the willingness to learn it in their future careers.

3-To assess the impact of POGIL-based instruction on students’ scientific attitudes, namely student attitudes to scientific inquiry, enjoyment of lessons and care interest (SEC) in physics.

1.9 Research Questions

To achieve the purpose of the study, the following research questions were addressed:

1. How do grade 12 students perform in POGIL-based instruction versus lecture-based instruction in circular motion unit in physics as measured by cognitive outcomes of the test defined by the variables of Knowing, Applying and Reasoning (KAR)?
2. How does POGIL-based instruction versus lecture-based instruction affect Grade 12 students’ self-efficacy as asset by the variable of learning, understanding, and the willingness to learn circular motion unit of physics in their future careers?
3. How does POGIL-based instruction versus lecture-based instruction affect the students’ scientific attitudes toward Scientific inquiry, Enjoyment of lessons and Career interest (SEC) in physics?
4. Are there any correlation between Grade 12 students’ performance, self-efficacy and scientific attitudes when they learn by POGIL-based instruction and lecture-based instruction?
5. What is the effect of interaction, if any, between students’ gender and the type of instruction (POGIL-based instruction and lecture-based

instruction) on physics performance, their self-efficacy and scientific attitudes?

1.10 Significance of the Study

First of its kind in the UAE, the present study is vital in facilitating an understanding of the benefits of utilizing 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 that 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 it will be shown, such competencies are attained due to the determination of the impact of POGIL-based instruction on improving the levels of self-efficacy and attitudes towards learning science subjects like physics. The data collected for this study is hoped to guide the field practices in science teaching and learning. 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 teachers prioritize the use of POGIL-based strategies. The use of such strategies enhances 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 as a basis 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 methods to improve performance. The training of the 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.

1.11 Limitations of the Study

The main limitations of the study are that only government schools are selected and the students involved are only in Grade 12. For future studies, it is suggested to utilize a mixture of students from government and private schools in different grades. Cross-referencing of these schools, may give us a more accurate image of the findings and the suitability of the conclusions reached in the study. Another limitation is that only physics as a subject is used to test the suitability of the POGIL-based strategy. It would have been beneficial to use other science subjects like chemistry and biology and other subjects like mathematics. Again, such a broad nature of disciplines would have enhanced the quality of the results obtained and reveal the suitability of the intervention in diverse subject areas. Also, the study did not consider other factors that could impact on the levels of comprehension or enthusiasm demonstrated by the students when engaging in the survey. There are other factors, language competency for example, that could impact on the levels of self-efficacy demonstrated by the students when carrying out the assigned tasks and such factors could influence the nature of the conclusions made in the study.

1.12 Identification of Variables

The independent variable for all the research questions is POGIL-based instruction. The first dependent variable for research question #1 is the students' performance as measured by a test including cognitive outcomes of Knowing, Applying and Reasoning (KAR) in circular motion unit in physics curriculum of Grade 12. The second dependent variable for research question #2 is Grade 12 student's self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers as measured by self-efficacy survey.

The third dependent variable for research question #3 is Grade 12 students' attitude toward Scientific inquiry, Enjoyment of lessons and Career interest (SEC) in physics as measured by (SEC) attitude survey.

1.13 Operational Definitions

1.13.1 Process Oriented Guided Inquiry Learning (POGIL)

It is one of the main approaches of inquiry-based learning; it entails students working collaboratively on assigned tasks to understand complex concepts in areas like science and mathematics. Through the approach, the students are engaged in process-led inquiry where they answer set of questions and handle assigned tasks and, in the process, they intuitively acquire the desired skills in the relevant subject area. It implies that through the use of POGIL, the teachers play a supplemental role where rather than serve as sources of information, the act as facilitators (Bunce et al., 2008).

1.13.2 Students' Scientific Performance

For the purpose of this study, scientific performance is defined as the score obtained by students as measured by the Achievement Test including cognitive outcomes of knowing, applying and reasoning (KAR) in circular motion unit in physics curriculum of Grade 12.

1.13.2.1 Knowing

It refers to students' knowledge of scientific facts, information, concepts, and tools. A factual knowledge enables students to engage successfully in the more complicated cognitive activities essential to the scientific enterprise. This variable includes the following sub-variables: "Recall, Recognize" in which the learners recall or recognize accurate science statements; possess knowledge of vocabulary, facts, information, symbols, and units; and select appropriate apparatus, equipment, measurement devices, and experimental operations to use in conducting investigations. Then, students provide definitions of scientific terms, vocabulary, symbols, abbreviations, units, and scales in relevant contexts. Next, students describe physical materials, science processes and knowledge of properties, structure, function, and relationships. Also, students provide appropriate examples to illustrate knowledge of concepts. The last one is demonstration of knowledge about the use of equipment, tools, measures, and scales that are similar to other standardized tests (TIMSS, 2011).

1.13.2.2 Applying

It involves in the process of applying scientific knowledge and understanding of science in real-life situations. This application requires students to be able to compare/ contrast/ classify/ identify/ describe similarities and differences between groups of materials, or processes. Also, the students have to use models to demonstrate understanding of a science concept, structure, relationship, process, physical system or cycle. Then, students can relate knowledge of an underlying physical concept to an observed or inferred property, behavior, or use of objects, or materials. Next, students can interpret information using a scientific method; in addition to finding solutions and providing an explanation for natural phenomenon (TIMMS, 2011).

1.13.2.3 Reasoning

It is involved in "the more complex tasks related to science. A major purpose of science education is to prepare students to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions, and extend their knowledge to new situations" (TIMSS, 2011). Students need to find solutions to infrequent problems. This can be done by "analyzing problems to determine the relevant relationships, concepts, and problem-solving steps; develop and explain problem-solving strategies" (TIMMS, 2011). Here, students also need to integrate and synthesize by "providing solutions to problems that require consideration of a number of different factors or related concepts; make associations or connections between concepts in different areas of science'' (TIMMS, 2011). To hypothesize and predict, students need to combine ''knowledge of science concepts with information from experience or observation to formulate questions that can be answered by investigation; formulate hypotheses, make predictions about the effects of changes in conditions in light of evidence and scientific understanding." (TIMMS, 2011). Furthermore, students can do other steps such as design or plan investigations appropriate for answering scientific questions or testing hypotheses; make general conclusions that go beyond the experimental or given conditions; evaluate and weigh advantages and disadvantages to make decisions about alternatives; and justify and use evidence and scientific understanding to justify explanations and problem solutions (TIMMS, 2011).

Related to KAR are “achievement test” and “academic performance.” For the purpose of the current study, an Achievement Test (AT) is an assessment of developed cognitive knowledge, skills or competencies to be measured in a given grade level, usually through planned instruction, such as training or classroom instruction (Brookhart & Nitko, 2014). Whenever and wherever I am using Academic Performance (AP) in this research study, I am usually referring to a set of goals, attainments and learning objectives set in the course or unit that students attend (Caballero, Abello, & Palacio, 2007). Such performance is expressed through grades which are the result of an assessment that involves passing or not certain tests and subjects. Academic performance can also be defined as the level of knowledge shown in a subject compared to the norm, and it is generally measured using the grade point average (Hoyos, 2011). In this research study, students’ performance was measured by a cognitive KAR test after studying a unit about circular motion.

1.13.3 Self-efficacy

Self-efficacy is defined by Bandura (1994) “people’s beliefs about their capabilities to produce levels of performance that exercise influence over events that affect their lives*”* (p. 71). For Said, Al-Emadi, Friesen and Adam (2018), self- efficacy is seen as *“*the task-specific belief that one has the potential to learn and achieve” (p. 3). It is, simply put, the confidence in one’s own ability to perform a particular task. For the purpose of this research, it is operationally defined as the score obtained by students as measured by the scale of self-efficacy survey. When it comes to physics learning, the focus of this study, self-efficacy refers to a student's confidence in his/her abilities to successfully perform academic activities at a desired level (Schunk, 1991). For Schunk and Zimmerman (1995), this involves self-regulated learning, which helps a student to use their own resources to plan, control and analyze the execution of tasks, activities and the preparation of learning products.

For physics understanding, self-efficacy is defined "as people's findings of their abilities to organize and effect courses of action required to attain chosen types of performance" (Sander & Sanders, 2005). POGIL can promote such self-efficacy since students are engaged primarily in concept invention which helps them to facilitate/promote their own understandings (Ibid.). Here, Lindstrøma and Sharmaa (2011) argue, related to willingness to learn physics for future careers, self-efficacy is a good predictor of academic attainment and success in future career.

1.13.4 Scientific Attitude

An attitude is defined as "a set of emotions, beliefs, and behaviors toward a particular object, person, thing, or event" (Said et al., 2018). In addition, attitude towards science is defined as "the beliefs, feelings, and values thought about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves" (Al-Naqbi, 2007). For the purpose of the study, scientific attitude is operationally defined as the score obtained by students as measured by the Scale of Attitude (SEC) survey. This survey involves three subscales. The first level shows students' acceptance of using scientific enquiry, the second level demonstrates students' enjoyment of science learning experiences and development of interests in science and scientific activities, and the third level points to students' development of interest in pursuing future career in science or relevant science work.

Further to what is cited above, for Eagley and Chaiken (2007), the term attitude, is “a psychological tendency that is stated by assessing a particular entity with some degree of favor or disfavor” (p. 583). Attitude, Koballa and Glynn (2007) explain, is a general evaluation of a highly specific behavior that is defined in terms of action, target, context, and time. Generally, social psychologists refer to a three-component model to define the psychological nature of attitudes: (1) cognitive (belief-based); 2) affective (emotion-based); and (3) behavioral (observable reaction). The cognitive and affective components can be determined using psychometric tests, however, the behavioral component is achieved over observations. For instance, in a POGIL class, the instructor detects students’ behavior through (a) students’ active engagement in small group discussions, and (b) students exploring models or data obtainable in the POGIL worksheets (Eagly & Chaiken, 1993; Engel, Blackwell, & Miniard, 1995).

In sum, these definitions will be extremely useful and I will make use of them throughout this research study. In most cases, I will take for granted that the reader heretofore is familiar with them and their definitions will serve as a frame of reference if they are needed.

1.14 Organization of the Study

The–study started with the first chapter that introduced the statement of the problem that stemmed from the low scientific performance of the UAE students resulting from methods of teaching and learning, students’ unsatisfactory levels of attitudes and self-efficacy towards physics. Furthermore, this chapter tackles also the study background and context. It also stated the purpose of the study that aimed to assess the impact of POGIL-based instruction on student scientific performance, attitude and self-efficacy towards physics in general and circular motion theme in particular. Additionally, four research questions were stated to guide the research. Then, the significance of the study and its contribution to the field of instruction and research were discussed.

The second chapter addresses the theoretical framework of the study, including cognitive and social constructivism theories, that would participate in discussing the findings and results of the study as well as reviews of the recent global, regional and local studies in different contexts.

The third chapter describes the methods and materials for data collection and analysis. It also encompasses a description of the employed quasi-experimental design, the sample of the study and how participants were selected. The three instruments (KAR Cognitive Test, Survey of Attitude and Self-efficacy Survey) were described and their validation was discussed. Then, data collection procedures employed to implement the research are explained, how collected data is analyzed by the use of different methods such as descriptive statistics, independent sample T test and correction coefficients and the ethical considerations followed in this research.

The fourth chapter presents the results of the four research questions in tables, graphs and descriptions for each question. This chapter concludes with a summary of the major results.

The fifth chapter concludes the study with a discussion of the results in light of the theoretical framework, literature review and relevant studies. It also offers some practical implications and recommendations based on the results. Lastly, the limitations and opportunities for further research are discussed and suggested.

Chapter 2: Literature Review and Theory

2.1 Overview

This chapter tackles both the theoretical framework as well as the literature relating to the study, including the applicable theories and the previous studies that have been conducted on the topic. Most of the studies assessed are those that cover the main aspect of the research which is evaluating the impact of POGIL-based instruction on the levels of self-efficacy and attitudes demonstrated by students towards learning of science topics. The information will enhance the levels of understanding of the impact of POGIL on the levels of self-efficacy and attitudes developed by students towards learning physics. The chapter concludes with a clear indication of the relevance of both the theory and literature reviewed to this research study and its pedagogical implications.

2.2 Theoretical Framework

Learning theories are beneficial for enhancing teaching and learning since they enable educators construct insightful ideas about the process of learning. Learning theories shed light on different aspects of the learning process (Eggen & Kauchak, 2007). The spectrum of learning theories can be categorized into three main areas: behaviorism, cognitivism, and constructivism (Yilmaz, 2011). The proper theoretical framework of this research stemmed from cognitive theory and social constructivism. POGIL bases its theoretical and practical conceptions upon the major concepts of these two theories; cognitivism, and social constructivism (Kuhn, 2008).

For the current study, a theoretical framework that combines social constructivism and cognitive theory is used. Both theories are premised on the idea that learning is a cognitive process which is situated in a social, cultural, and linguistic context (Piaget, 1976; Vygotsky, 1978). To explain, social constructivism is a theory that is conceived first by Piaget and then further developed by Vygotsky puts forth that, first, learning is an individual act but, second, this act is socially impacted by our identity (who we are) and where we find ourselves (country, history, culture, gender, social class, language, and many other social factors). This theory has proved to be helpful for the current research as it helped this researcher to situate the research itself (being in the UAE) research participants (a group of Emirati high school students) and the subject of the research (science education, physics, POGIL).

On its part, the cognitive theory contends that a) there are different mental processes that have to take place to facilitate learning and b) it is necessary for these mental processes to work in unison as any failure by the processes to work as designed leads to a loss of interest by the learner and failure of the learning process (Compernolle & Williams, 2011). From its inception, cognitive theory is conceived as a counter theory to behaviorism. For cognitive theory, there were three main problems behaviorism. First, behaviorism failed to explain how learners make sense of and process information (Alexander, Schallert, & Reynolds, 2009). Second, behaviorism emphasized observable behaviors and almost totally neglected cognitive and mental process of learning (Slavin, 2006). Third, behaviorism assumed that prior knowledge played a bigger role than stimuli in orientating the learning process (Deubel, 2003).

In responding to these three assumptions, among others, cognitive theory was able to emerge as a modern theory and hence proved its utility for the research carried for this dissertation, especially POGIL. Cognitive theory has the following assumptions. First, it argues that people are neither animals nor machines to only respond to environmental stimuli in the same way (Matlin, 1994). Second, cognitive theory describes learning and acquisition of knowledge as a mental activity involving internal coding and structuring by the learner (Slavin, 2006; Derry, 1996). Third, cognitive theory puts an emphasis on "what learners know and how they come to acquire it than [on] what they do" (Yilmaz, 2011). Fourth, it focuses "on making knowledge meaningful and helping learners organize and relate new information to prior knowledge in memory" (ibid). Fifth and finally, when it comes to teaching, cognitive theory contends that, "Instruction should be based on a student's existing mental structures or schema to be effective" (p. 215). That is to say, learning will have a lasting impact if it builds on and makes use of what students already know.

This last point is significant for this study. Contrary to behaviorism, for cognitive theory, learning is seen as an active process "involving the acquisition or reorganization of the cognitive structures through which humans process and store information" (Simon & Klandermans, 2001). Here, the learner is no longer a passive receiver of information but "an active participant in the process of knowledge acquisition and integration" (Good & Brophy, 1990); and knowledge acquisition becomes "a mental activity involving internal coding and structuring by the learner" (Yilmaz, 2011). In sum, only in seeing learning from this cognitive theory lens can learning be effective.

For the dissertation, these arguments are important, especially when it comes to POGIL and how POGIL approaches teaching and learning. POGIL makes direct use of cognitive learning theory and this is how. First, emphasis is placed on the active involvement of the learner in the learning process and in POGIL, the learner is the center of learning and the role of the teacher is a guide in the side and the teacher is only a facilitator. Second, POGIL centralizes metacognitive training, which includes self-planning, monitoring, and revising techniques (Jensen, 2005). Here, third, an emphasis is put on structuring, organizing, and sequencing information to facilitate optimal processes (Wiggins & McTighe, 2005). In sum, these three insights are clearly highlighting the different aspects of POGIL, which include: a) clarifying the role of each member in the group to monitor what members are doing; b) achieving the tasks on time; c) participating in the activities and understanding the concepts and d) how well the group operates (Trevathan & Myers, 2013).

To explain further, POGIL-based instruction emphasizes discovery and problem-based learning, both of which fall under cognitive theory, especially that of Vygotsky's (1978) 'Zone of Proximal Development' (ZPD). It is significant to note that ZPD has five stages: modeling, coaching, articulation, reflection, and exploration (Wilson, Jonassen & Cole, 1993). These five stages are a faithful description and correspond one-to-one to the POGIL phases, which are:

1) The lesson begins with short introductory presentations by teachers of no more than ten minutes.
2) Students meet with their groups to discuss the topic introduced in the brief lecture.
3) After a prescribed period for that lesson, the teacher calls the students' attention to the whole class.
4) Each group reports on what they have learned or discovered regarding the POGIL activity.
5) Groups then return to their work on the activity. The teacher circulates among the groups to help only when requested; and 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 (Barthlow & Watson, 2014).

Inquiry-based learning that is a major aspect of POGIL that grew out of Piaget's (1976) theory of cognitive development, a theory that aimed at developing students' higher thinking skills and engage them in investigating an issue and formulating and testing a hypothesis in order to find solutions to a problem (Saskatchewan Education, 2009). Such assumption was shown clearly in POGIL method in which students need to find solutions to problems by asking scientific questions; designing plans and carrying explanations; finding out and analyzing evidences and information; offering interpretations and drawing explanations; and communicating results and findings (Marx et al., 2004; Barthlow & Watson, 2014).

Some of the main cognitive processes that facilitate learning are synonymous with the strategies that are implemented in POGIL-based instruction. They include aspects like observing the diverse phenomena, categorizing and then forming generalizations on what has been observed either through inductive or deductive processes (Compernolle & Williams, 2011). Figure 1 shows the interconnection between cognitive learning theory and POGIL.

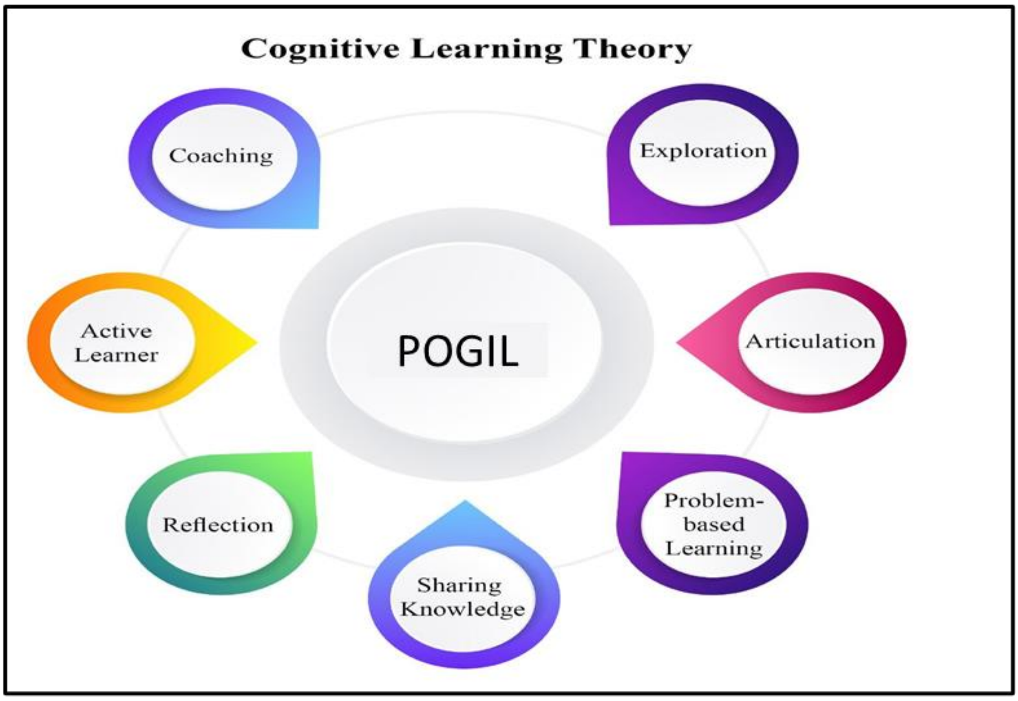

Figure 1: Nterconnection between Cognitive Learning Theory and POGIL

Somewhat of a similar framework to cognitivism, social constructionism has also proven to be extremely useful as a theoretical framework, especially as an inquiry-based framework (Kuhn, 2008). Linking cognitive process to the social aspects of learning (see discussion above), social constructivism highlights the role of culture and social context in comprehending what occurs in nature and in constructing knowledge (Derry, 1999). Social constructivism builds on specific assumptions about reality, knowledge, and learning. Regarding reality, especially for students, it is believed that it is constructed in and through student activity, projects and tasks. Collectively, students discover the properties of the world around them (Kukla, 2000). Regarding knowledge, it is a purely human product and it is culturally and socially constructed (Ernest, 1999). Individuals create meaning through their interactions with each other and with the environment they live in. It is viewed as a social process that occurs cooperatively among students. As for learning, it does not happen only within an individual nor is it a passive development of behaviors that are shaped by external forces. Significantly, social constructivism argues that meaningful learning usually takes place when individuals are engaged in social activities through interaction (McMahon, 1997).

Doolittle and Camp (1999) argue that constructivist philosophy provides the theoretical basis for POGIL (Halpern, 2003). This argument, Doolittle and Camp (1999) explain, are built on three contentions. First, knowledge is not passively constructed, but rather is the result of active participation and engagement of the learner. Second, knowing has roots in biological and neurological construction, and in social, and cultural based interactions between the learners and instructor. Third, to use Ricketts, Duncan and Peake's (2006) language, cognition is viewed as "an adaptive process that functions to make an individual's behavior more viable given a particular environment" (p. 49). That is, cognition is the process that organizes and makes sense of one's real life experience and representation of reality.

In addition to these three tenets of constructivism, there are other factors of essential constructivist pedagogy that are important for understanding POGIL instruction of science (Doolittle & Camp, 1999). These factors include: a) learning should occur in authentic, real life environments; b) learning should encompass collaborative negotiation and mediation among students and learners; c) content knowledge skills should be made relevant to the learner's needs, interests, and readiness and within the framework of the learners' prior knowledge; d) students should be assessed formatively and encouraged to become self-regulatory, self-mediated, and self-aware and e) teachers become guides and facilitators of learning, not instructors (Hanson, 2006). Such tenets and factors are major components of instructional models of science instruction in general and POGIL in particular and

POGIL is viewed as the platform of constructive learning theory (Doolittle & Camp, 1999).

POGIL is a student-centered teaching method that was developed by science educators in the 1990s. It is also based on social constructivist learning theory since it involves learners' developing their conceptual understanding collaboratively and working in groups on carefully designed activities of the learning cycle (Guessoum, 2012). The first section of POGIL-based lesson plan, as already explained, is called orientation section in which students are provided with instructions and prerequisites about the activity learning objectives and the success criteria by a facilitator. The second is the exploration section in which students work collaboratively to explore a model and form a concept through a series of questions that help them develop an understanding and think critically about the model. The third section is the application in which students extend their understanding by finding answers for the questions and solving in-depth problems. The fourth and final section is evaluation in which students share their group results with other students' groups and the facilitator and reflect on their performance. It is beneficial to clarify that such practice implementation may differ from classroom to another according to the context, subject, resources and instructors (Chase, Pakhira, & Stains, 2013; Hanson, 2006).

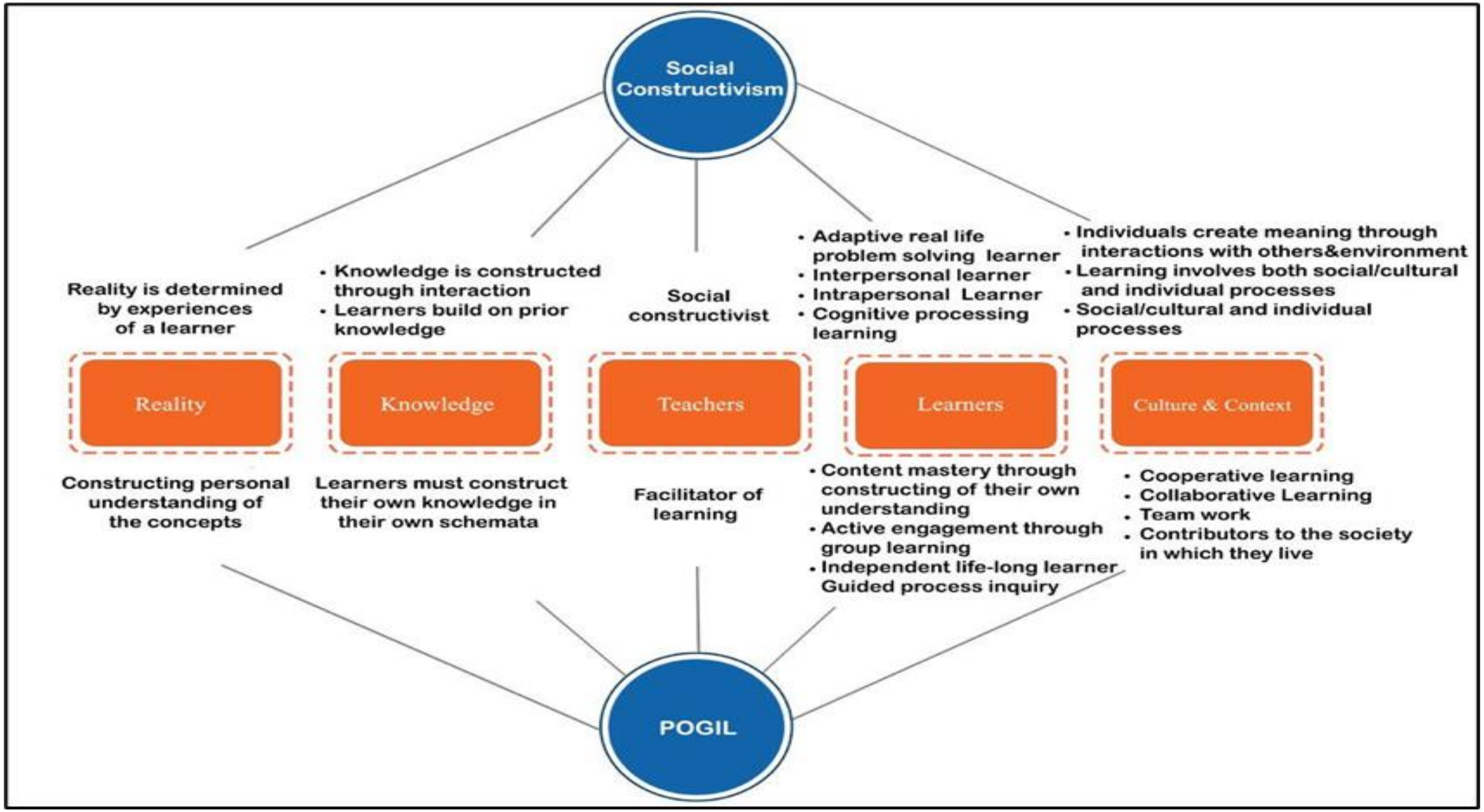

Figure 2: Model of Relationship between the POGIL and Social Constructivism

As is shown in Figure 2, instructional models such as POGIL are based on the social constructivist perspective that emphasizes the need for collaboration among learners and with practitioners in the society (McMahon, 1997). Lave and Wenger (1991) confirmed the importance of practical knowledge that resulted in relations among practitioners, the practices, and the social organization and economy of communities of practice. If this is the case, then learning has to involve such knowledge and practice (Gredler, 1997). Social constructivist approaches can include reciprocal teaching, collaborative learning, cognitive apprenticeships, problem-based instruction, cooperative learning and other methods that involve learning with others (Schunk, 2000).

Instructionally speaking, interactions among learners are central to POGIL-based teaching. As already noted, most of the learning is undertaken in groups where the learners are exposed to environments where they can confidently exchange ideas with their colleagues and enhance their critical thinking and problem-solving skills through such interactions. In such an environment, the learners exchange ideas with their contemporaries confidently as they have equitable thinking capabilities hence the increased ability to learn from one another (Bell, Urhahne, Schanze, & Ploetzner, 2010).

Because of such an amicable environment, where students feel comfortable to take risks, the reason for further exploration increases (O'Dwyer & Childs, 2014). Through such explorations, it becomes likely that the students will discover new concepts or come up with ideas that shape the concepts being learned for ease of understanding. The teacher provides the students with questions and concepts that evoke their critical thoughts to ensure that they demonstrate analytical capabilities on the ideas they have gained during the exploration. The questions provided by the teacher are also necessary in guiding the process of developing cognitive capabilities through mental images of the concepts in the students (Hanson, 2006). The questions guide the students to specific information areas that they should prioritize and the appropriate relationships amongst various concepts that they should consider in arriving at conclusions.

Similar to the cognitive theory, constructivism is directly related to POGIL. To explain, I will refer to Hein (2012). For Hein, the constructivist learning process starts with the evolution stage where the learners are supposed to make meaning with the observations made during the exploration stage. Here, their ability to draw meaning is crucial as it demonstrates that their cognitive processes are engaged and keen towards the impeding learning processes. Their levels of understanding, Hein (2012) explains, are revealed when the teacher requests them to make presentations of the observations. It is during such presentations that the learners reveal their levels of understanding of the concepts that are evident in the observed phenomena. The teacher plays the facilitating role and guides the learners during such presentations where new ideas emerge. Through the presentations, moreover, each of the learners makes distinct observations and tries to draw linkages amongst the variables observed in order to identify relationships. The learners are usually grouped in various groups and their presentations facilitate the identity of oversights or errors by one group when the presented content differs from that of the others (Chase et al., 2013).

Due to these differences, it becomes easier for the learners to envisage the presented observations from the points of view of their other colleagues where they utilize the additional information to either correct or enrich their initial observations and conclusions. It demonstrates that the observation phase exploits the deductive reasoning capabilities of the students through series of interactive processes that facilitates the deeper embedding of knowledge (Prince & Felder, 2007).

Through the process of deductive reasoning, the learners apply the ideas and knowledge acquired in new settings. It draws on the learner that the learned ideas can be conceptualized in new settings thereby enhancing their enthusiasm of applying the learned concepts in other settings or situations (Orphanos & Orr, 2014). Such capabilities are crucial as the application of concepts and ideas successfully in new situations imparts higher levels of self-confidence in the learners. It also leads to higher retention rate of the learned concepts as the learner makes more meaning with the said concepts. During the application phase, evaluations and syntheses are conducted of the learned concepts and how they can be applied in various scenarios (Jin & Bierma, 2013). The phase is essential as it demonstrates to the learners how the concepts they have learned can be applied to different situations thereby demonstrating acquisition of new levels of skills and knowledge.

In regard to the application of the constructivist approach in the POGIL-based instructional approach, it imparts quality skills in the learners in how to think and learn about the process rather than focusing on aspects such as memorization. It implies that according to constructivism, learning should be done through creating, constructing and inventing one's personal understanding of the concept. It then becomes easier for one to correlate the different forms of meanings of the concept with those of others that facilitate deeper understanding and application of the learned concept in diverse situations (Piaget, 1976; Wiggins & McTighe, 2005). Furthermore, the learners must construct their own knowledge in their own schemata not to transfer such knowledge from the teacher's schema to that of the student. As demonstrated by Vygotsky (1978), social interaction is vital in the cognitive development of the child as it promotes learning through observing and inquiry that later form the basis of knowledge. Through social interaction, the learner finds it easier to acquire knowledge and link it to real-life situations. In the following model, it will be shown clearly how POGIL borrowed some basic principles from this theory regarding the role of students as knowledge producer and teachers as facilitators; students learn collaboratively in organized teams and in cycles in addition to inquiry-based learning as a basic aspect of learning.

POGIL model is based upon theoretical and practical conceptions of cognitive learning theory and social constructivism. Some of these aspects are summed up in the following points, which have also been summarized above:

(1) Learners are active participants of the learning process and they are the core of instruction.

(2) The role of teachers is facilitators and guide not lecturers who transfer knowledge to students.

(3) Students also work collaboratively and learn through a process of cycles.

(4) Cognitive apprenticeship, learning, discovery learning, and problem-based learning are the most distinctive methods of instruction.

(5) Inquiry learning is a major aspect of the process of teaching and learning.

Before moving to the literature review, it is worth noting that cognitivism and constructivism have proved to be important theoretical frameworks as both are dealing with not only the cognitive processes but situating these processes in and with a social context. Cognitivism refers to the internal processes that are happening in the learner's mind but which can be accessed by observing the learner's performance (Piaget, 1976). Here, what is performed tells us what and how the learner is thinking. On the other hand, constructivism argues that learners do not just absorb information, they construct it (Vygotsky, 1978). For the purpose of this research, it will be interesting to analyze, first, learners' academic performance as signaling what the learners are thinking and, second, how they construct what they learn. In reviewing existing literature, which is what I do next, the ideas embedded in these theories can be discussed further.

Finally, Eberlein et al. (2008) argued that when POGIL is concerned the difference between the constructivist ideas of Piaget and Vygotsky is that although the Piaget emphasized the necessity of engaging students with new challenging experiences then guide them to build and construct their own meaning and understanding, Vygotsky emphasized the social aspects of learning. Such social dimension can bridge the gap between isolated learning outcomes and the level of potential development achieved through collaboration to bring students closer to the ZPD (Figure 3).

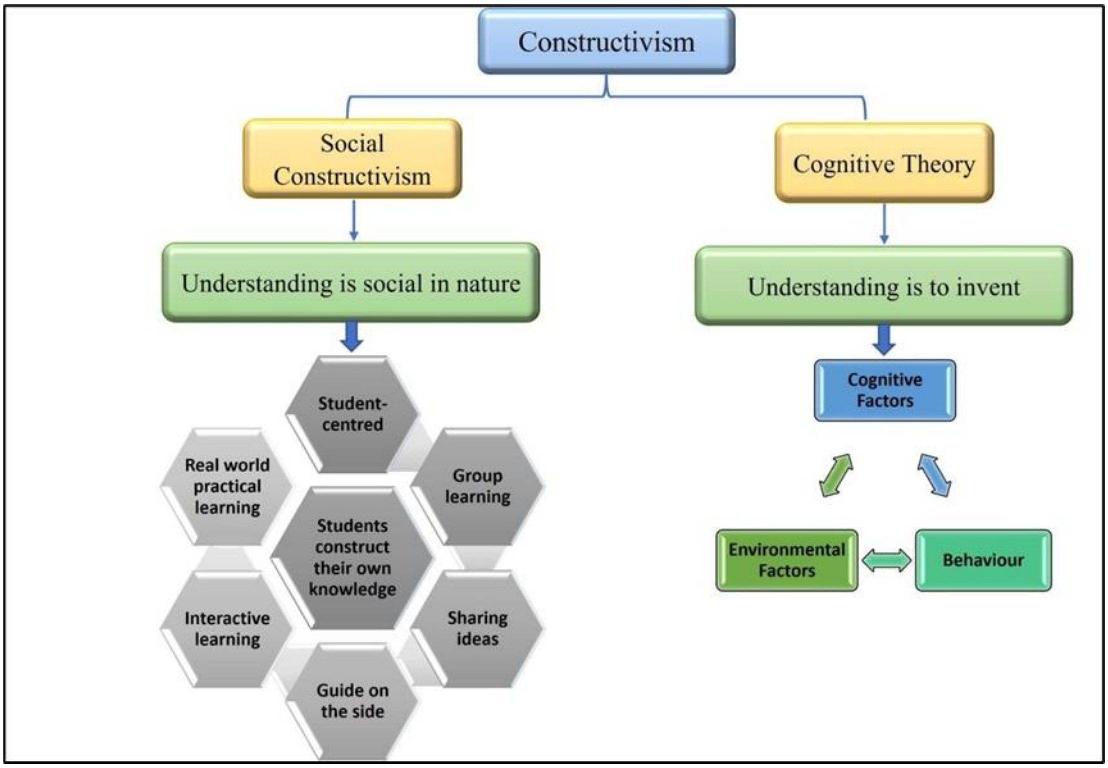

Figure 3: Vygotsky's Social Constructivism & Piaget's Cognitive Theory

2.3 Literature Review

2.3.1 Inquiry-Based Learning (I-BL)

I-BL is an instructional approach by which learners are actively engaged and progressing towards becoming literate about the nature of science, how to do science and how to communicate science (Guessoum, 2012). Additionally, inquiry is a way to enable students to apply the process of science in real life situation (Cianciolo, Flory, & Atwell, 2006). The National Research Council (1996) added that inquiry grants students opportunities for doing various processes of science such as observing, questioning, examining resources, using tools and equipment, interpreting data, connecting results and communicating results. For Tairab and Al-Naqbi (2018), I-BL is a tried-and-tested way of instruction that engages in the scientific practices so that students can construct and produce their own scientific knowledge through active learning. According to this perspective, students have become knowledge producers not consumers (National Research Council, 2000). Inquiry-based learning also assumes that students need to find solutions to problems by asking scientific questions; designing plans and carrying explanations; finding out and analyzing evidences and information; offering interpretations and drawing explanations; and communicating results and findings (Marx et al., 2004). Hence, I-BL includes a wide range of science teaching approaches such as hands-on and project-based science activities; guided discovery; experimental investigations; laboratory works; problem-solving; designed-based approaches; and conducting actual research (Wilhelm & Wilhelm, 2010).

Put otherwise, I-BL includes any method in which students discover knowledge implicitly either inductively or deductively. According to Prince and Felder (2007), I-BL is when students are exposed to some kind of challenge and they achieve the desired learning in the process of responding to that challenge. I-BL is thus a student-centered learning method in which students explore and make discoveries while the teacher's role is turned into a facilitator of content knowledge. Indeed, for Shemwell et al. (2015), the teacher's role boils down to designing proper inquiry experiences.

I-BL works in the opposite direction of the traditional instruction, which is lecture-based and teacher-centered. As already indicated, in the I-BL, students are presented with a problem and instructed to use what they know to form a hypothesis about what the experiment will show. Such types of instruction use deduction since the students use logic to approve or refute their hypothesis from data gathered. The students start with the outcome and work backwards (Spencer & Moog, 2008). Such types of instruction, moreover, pose challenges for teachers and learners since learning by inquiry needs new methods and strategies to deal with this trend from different perspectives (Krajcik, Mamlok, & Hug, 2001).

As one type of I-BL, and for the purpose of this study, process-oriented guided-inquiry learning's (POGIL) main components can be summarized in Figure 4

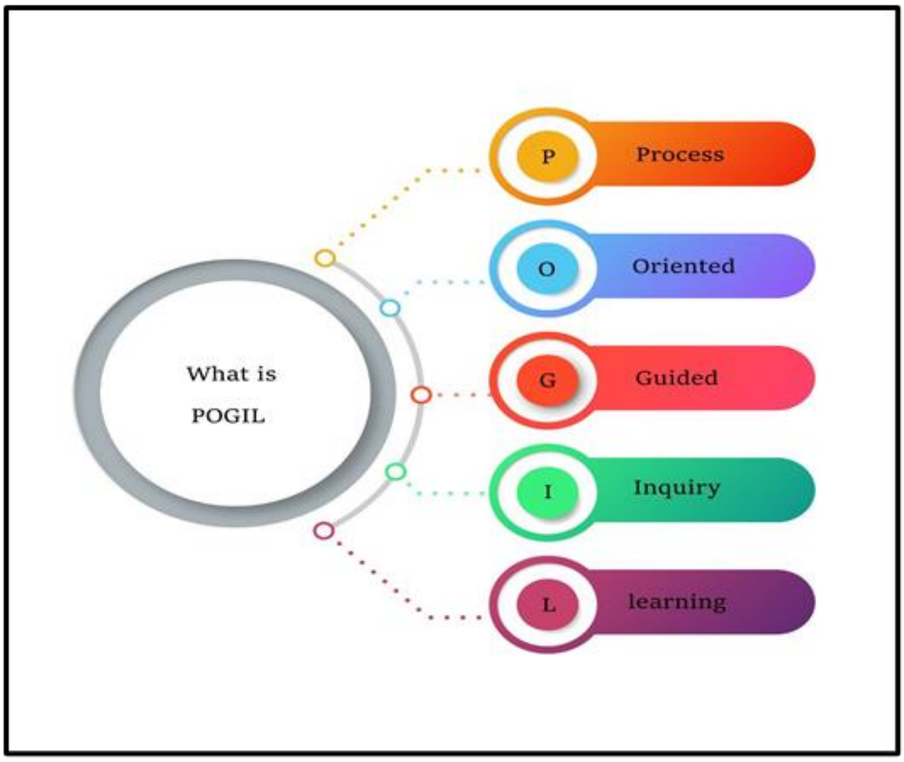

Figure 4: Process-oriented Guided-inquiry Learning (POGIL) Model

2.3.2 Process-Oriented Guided-Inquiry Learning (POGIL)

As shown in Figure 4, POGIL is not only a strategy but also 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 (Twigg, 2010).

Based on social constructivist learning theory, POGIL is a student-centered teaching method that was developed by science educators in the 1990s. Here, learners develop their own conceptual understanding collaboratively and work in groups on carefully designed activities of the learning cycle (Nielsen, 2015). To be absolutely sure, the first section of the lesson is called orientation section in which students are provided with instructions and prerequisites about the activity learning objectives and the success criteria by a facilitator. The second is the exploration section in which students work collaboratively to explore a model and form a concept through a series of questions that help them develop an understanding and think critically about the model. The third section is the application in which students extend their understanding by finding answers for the questions and solving in-depth problems. The fourth and final section is evaluation in which students share their group results with other students' groups and the facilitator and reflect on their performance. It is beneficial to clarify that such practice implementation may differ from classroom to another according to the context, subject, resources and instructors (Chase et al., 2013).

What is beneficial about POGIL, Hanson (2006) argues, is that it helps students construct their own scientific understanding based on their prior knowledge, experiences, skills, attitudes, beliefs and self-efficacy. The students, Hanson explains, also experience a learning cycle of exploration, concept formation, and application. Besides, students using POGIL module are connecting and visualizing concepts and multiple representations as well as discussing and interacting with one another. They also reflect on progress and assess performance (Yoon, Joung, & Kim, 2012).

In sum, POGIL requires students to do the tasks as a group and play different roles within the group: Manager, Recorder, Presenter and Reflector. Such a process of distributing roles reinforces accountability of each student and ensures that all students work within the group and, as a team, they depend on each other's roles (Bell et al., 2010).

2.3.3 POGIL Instructional Implementation

To shed some lights 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 important 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, behavior and performance and may report to the group (or the class) about how well the group operates (Twigg, 2010).

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 (2013) explain, learning is achieved though fun exercises that prove effectively to students the benefits of shared information and collaborative learning. The students also learn the rules and roles of the "highly structured" group sessions, and the expectations for each session. Once the POGIL learning culture has been established, the authors add, students come to class prepared for POGIL group work. While there are numerous formats for how POGIL lessons can be structured, a common approach is to have a ten-minute lecture, then a breakaway POGIL session for five minutes. Through POGIL, Trevathan and Myers (2013) conclude, the students work on an exercise related directly to the lesson content. The teacher mingles amongst the groups to measure how the students are performing. At the end of the lesson, two or more groups are called on to report back to the class. The teacher then typically reviews and adds to the students' answers.

Making use of these steps, Hanson (2006) carried out a research study to develop physics modules based on POGIL models. These modules were developed with a developmental model consisting of analysis, design, development, implementation, and evaluation stages. These stages included: (1) formulating the hypothesis; (2) designing the experiment; (3) writing data and analyzing the results of the experiment; (4) applying the concept (related to the problem presented at the beginning of the worksheet) and (5) communicate.

Discussing Hanson's study, among others, Slavich and Zimbardo (2012) argue that, for POGIL-based instruction to be successful, learners at the initial phase should utilize various tools like models and experiments to raise inquiries into the phenomena being observed. Learners will be required to work collaboratively and thus, for Slavich and Zimbardo (2012), develop positive social attitudes to enhance their levels of collaboration and engagement with their colleagues, which is vital in the perfection of the meta-cognitive skills. Using POGIL-based instruction, Slavich and Zimbardo (2012) conclude, it is easier for learners and educators to create pleasant classroom environments as most of the learning activities are student-centered, and the teacher only acts as a facilitator or guide.

A study by Walker and Warfa (2017) established that students that taught using POGIL-based instructional strategy registered higher levels of achievement and developed positive attitudes towards the use of the approach. On the other hand, Lin and Tsai (2013) established that the use of the POGIL-based instructional approach enhanced the ability of the students to perfect their learning capabilities in comparison to other approaches. Further, Wozniak (2012) found that using POGIL was instrumental in identifying the different conceptions by students and facilitated their ability to change or alter such conceptions. However, a study by Barthlow (2011) contrasts these findings as the study found that the learners that 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. For the purpose of this research, in sum, one has to keep an open mind when doing the analysis later on in the research study and be cautious with the conclusions one reaches.

Nonetheless, the suitability of the POGIL-based approach to learning is due to its ability to adhere to the learning cycle through the stages of exploration, the discovery of concepts and the application of such concepts (Bell & Banchi, 2008). These stages require the student to demonstrate creativity and collaboration in exploring different thought patterns to identify or discover the concepts and how they can be applied in contemporary settings. The requirement of students to think means that the students must demonstrate high levels of confidence to follow the taught concepts and identify their inter-linkages and applicability in real-life situations.

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. This conception contravenes the widely held opinion that improved learning is only attained through instructional approaches that are teacher-centered. However, it has been proved that students will learn better when they are directly involved in thinking in class. In such a way, they are directly involved in the construction of knowledge and analysis of data and work collaboratively with their peers (Chase et al., 2013). Such involvements where they work in groups and teams is crucial in increasing their levels of enthusiasm and motivation that results in increased retention of the ideas being learned.

A study by Al-Balushi, Ambusaidi, Al-Shuaili and Taylor (2012) highlights how the use of constructivist approach through the deployment of the POGIL-based instruction facilitates discovery. Through discovery, the authors argue, students perfect their critical thinking skills as they explore new phenomena and cause-and-effect relationships that are critical in understanding the interrelationships amongst diverse concepts in a subject area. The students then reinforce their understanding by answering questions that are related to the topic. The students can then develop the ability to address in-depth problems that opens new lines of knowledge on the topic. The different groups can then exchange information on the learned concepts with the guidance of the teacher where needed thereby guaranteeing high level of retention of the learned concepts.

2.3.4 Relevant Global Studies

Deora, Rivera, Sarkar, Betancourt and Wickstrom (2020) conducted a research in the U.S. to examine the impact of the flipped classroom along with POGIL methods in chemistry of college students. The results revealed positive trends favoring POGIL students. Similar to Barthlow's (2011) study, however, no significant differences were found between students' overall grades that learnt by POGIL and their counterpart students learnt by traditional instruction, but there was an increase in passing grades.

Following an earlier study, Barthlow and Watson (2014) conducted a study in the U.S. comparing the achievement of secondary chemistry students from four high schools to determine the effectiveness of using POGIL to reduce alternate conceptions related to the particulate nature of matter. The results showed significant differences on standardized tests between students using POGIL and those taught using the traditional pedagogy in favor of the first group.

Always in the U.S., Walker and Warfa (2017) carried out a study to explore if coupling process skills to content teaching impacted academic success measures. They meta-analyzed twenty-one studies involving 7876 students who were taught using POGIL-based instructions compared to standard lecture-based instructions. The findings suggested that providing opportunities to improve process skills during class instruction did not inhibit content learning but enhanced conventional success measures. Overall, the results found that POGIL had a small but notable effect on science achievement outcomes.

In the same context, Chase et al., (2013) carried out a study to explore the effects of the implementation of POGIL in sections of a general and organic chemistry course on students' grades, retention, attitude and self-efficacy toward chemistry. The results revealed little to no impact on most measures, namely on students' grades, retention and self-efficacy but positive attitudes favoring POGIL students were observed.

In the Australian context, Vishnumolakala, Southam, Treagust, Mocerinoa and Qureshi (2017) conducted a mixed method study to investigate the attitudes, self-efficacy, and experiences of undergraduate chemistry students in modified POGIL classes. The results of the study showed statistically significant positive and high perceptions of students' attitudes, self-efficacy and experiences. The study found that POGIL-based instruction created positive experience for to new students who had limited prior chemistry knowledge.

A quasi-experimental research was conducted by Bug-os and Caro (2020) in the Philippines to explore the impact of Process-Oriented Guided Inquiry Learning (POGIL) on Grade 12 students' performance and attitudes. The research compared students' performance and attitudes in POGIL classes and non-POGIL Classes, especially in physics in general and geometric in particular. The results showed that students leaning by POGIL preformed higher academically and in attitudes compared to non-POGIL students.

Roller and Zori (2017) carried out a qualitative study to explore the impact of POGIL in a fundamental nursing course at Adelphi University, a mid-size, private university in the northeastern United States This study aimed at examining differences in final course grades and course satisfaction in 2 groups of fundamentals nursing students where one group experienced Process Oriented Guided Inquiry Learning as a teaching strategy and one group did not. Satisfaction with performing in the varied roles used during POGIL was also examined. The results of this study revealed that students who experienced POGIL had significantly higher final grades and course satisfaction compared with students who did not experience POGIL. The active learning and teamwork experienced during POGIL were pointed to as significant factors in students' attitudes and transition to satisfactory practicing nurses.

Hahn, Judd, Hirsh, and Blair (2014) conducted a study aimed at comparing the secondary school chemistry students' ACT Science Test scores between students taught by POGIL method versus students taught by traditional, teacher-centered pedagogy. This study also found no significant difference in the mean difference of scores in regard to the three different types of questions on the ACT Science Test.

On their part, Soltis, Verlinden , Kruger, Carroll and Trumbo (2015) conducted a study to determine the impact of the POGIL teaching strategy on student performance and engagement in higher-level thinking skills of first-year pharmacy students at Adelphi University, College of Nursing and Public Health. The results of the study showed that the use of the POGIL strategy increased student overall performance on examinations, improved higher-level thinking skills, and provided an interactive class setting.

In the Indonesian context, Zamista and Rahmi (2019) found in their study that students had difficulties in learning physics in Indonesia as physics learning process focused on the many cognitive aspects mastered by students without regard to the process of how cognitive aspects are built by students. That is, the common physics learning, the authors argue, does not provide opportunities for students to be trained in various skills since it focuses primarily on memorization. Such a style of learning does not facilitate for students to have balanced knowledge, skills and positive attitudes (Heck & Ellermeije, 2010; Mun, Hew, & Cheung, 2009).

Always within the Indonesian context, Devitri, Syafriani and Djamas (2019) carried out a study aiming at determining the validity of physics model modules, modules that were taught using POGIL. The results showed positive results in improving literacy ability of students' science. Like Devitri et al. (2019), Zgraggen (2018) carried out a study also in Indonesia. The study explored the effects of using POGIL pedagogy in high school chemistry classes compared to that of an independently designed guided inquiry method. The results showed no statistically significant differences in outcome between the POGIL and other models of inquiry. It will be interesting to see the differences as well as similarities between these studies and mine.

This last study is significant because it shows negative results when using POGIL. In his study, Geiger (2010) examined the effects of POGIL implementation in health courses at Gaston College, U.S. The results showed that POGIL was less successful, due to lack of student readiness for a challenging learning environment. So, Geiger concluded that POGIL modules must have sufficient cognitive, affective, and team skills embedded in them to succeed, especially if the desired result is to reach a higher cognitive level. This study is significant to keep in mind as I do the analysis later in the research study as POGIL is an acquired and a learned competency, which is not commonly used in the UAE; so here the cultural angle needs more attention.

2.3.5 The Impact of Application of POGIL on Self-Efficacy

Self-efficacy is defined as the learners' belief in their ability to accomplish tasks in specific situations; that is, their competencies to organize and complete courses of action required in achieving selected types of performances (Bandura, 1986). Since self-efficacy is the confidence in one's own ability to perform, it will be reflected in the actions students pursue. Students with high self-efficacy for performing a certain task will have high expectations towards performing this task and likely to succeed, for example, in science at school and to choose majors that align with their self-belief about personal competencies and abilities (Sawtelle et al., 2012).

Situated within the social cognitive theory, self-efficacy indicates behavior can be best understood in terms of a reciprocal system including reasoning, behavior and context. This reciprocal system, Chang, McKeachie and Lin (2010) explain, refers to perceived ability to carry out the task, behavior, performance, and environment setting. Within this reciprocal system, moreover, self-efficacy becomes a vital construct for learners to monitor their performance as it attracts their attention on beliefs about the effectiveness of their learning methods (Zimmerman, Kramer, McNair, & Malila, 2006). For Zimmerman et al. (2006) the major aim of self-efficacy monitoring is to improve students' ability in predicting their learning accurately.

Keeping these ideas in mind, Suprapto, Chang and Ku (2017) carried out a research that aimed at exploring the correlation between students' conception of learning physics and their physics' self-efficacy. A total of 279 students who were majoring in physics education participated in this research and were invited to complete two instruments: the conception of learning physics and the physics learning self- efficacy. The results showed a moderate correlation between students' conception of learning physics and their physics' self-efficacy.

Suprapto et al. (2017) study concludes that the suitability of the POGIL-based approach is due to its ability to enhance the psychomotor and cognitive skills of the learners. An improvement in these skill sets leads to improved levels of self-efficacy and the acquisition of positive attitudes toward learning, thereby improving the ability of the learner to experience improvements in performances in learning activities (Nihalani, Wilson, Thomas, & Robinson, 2010). POGIL-based learning, Nihalani et al. (2010) add, increases the levels of self-efficacy in the learners as the approach promotes peer-to-peer interactions during the learning process that facilitates the ability of the student to make meaning with the concepts being learned. According to Kuhn, Black, Keselman and Kaplan (2000), the use of POGIL facilitates the ability of the student to apply content knowledge where real-world problems are solved through the use of peer collaborations thereby facilitating the acquisition and perfection of cognitive skills across the entire hierarchy of Bloom's Taxonomy, and this will more likely lead to improve self-efficacy. Researchers such as Britner (2008), Lin and Tsai (2013), Caprara et al., (2008) and Chiou and Liang (2012) have found that the development of higher levels of self-efficacy by students in science subjects impacts positively on their levels of achievement and cognitive skills.

The ability of POGIL to enhance the levels of self-efficacy is evident in stages such as the exploration phase when the learner becomes critical towards the presented data and concepts. In this stage, the learner is likely to develop deeper insights into the presented information and concepts and through such criticism, s/he improves the personal knowledge as s/he obtains insights from the group members with the teacher acting as a facilitator (Chase et al., 2013). Further, due to the ability of the POGIL-based approaches to improve the self-confidence of the student, it is easier for the learner to internalize the belief that he or she has the capability of understanding the presented information and concepts. As Vacek (2011) contends, such interest and enthusiasm to know personally and also from others is critical to the formation of suitable mental models that enhance the levels of reflection of the concepts due to enhanced levels of self-efficacy. These capabilities, Vacek explains further, are vital in enhancing the levels of performance of the student due to a better understanding of the required course content in the relevant subject area. Also, POGIL impacts positively on self-efficacy due to the involvement of the learners in the stages of concept invention. To enhance their participation, the learners demonstrate interest and motivation towards understanding the required concepts to ensure they are also active participants in the process (Lin & Tsai, 2013).

In Bandung, Indonesia, Ardiany, Wahyu and Supriatna (2017) carried out a mixed method research that used experimental design to study the high vocational school students' self-efficacy in learning physics using guided inquiry instructional method. The study sampled a group of physics teachers to explore their opinion about guided inquiry learning. The results of the study showed improvement in students' performance and self–efficacy of their learning via guided inquiry learning. The results also showed a significant relationship between self-efficacy and guided inquiry learning. The study concluded that guided inquiry learning is fun, interesting and challenging so that students can expose their ideas and opinions without being forced or feeling fearful of exposing themselves (in case of a mistake). The participating teachers and students in this study thought that guided inquiry learning increased students' active engagement, positive attitudes and self-efficacy towards learning.

In their study, Lin and Tsai (2013) used a multidimensional scale that measures students' science learning self-efficacy beliefs. The authors found that their science learning self-efficacy impacted a) the students' abilities to use advanced cognitive skills, b) their use of scientific knowledge and skills in their daily life situations and c) to communicate scientific concepts and ideas with other people.

Lindstrøm and Sharma (2011) carried out a study in Australia aimed to study the relationship between self-efficacy and science academic achievement. They investigated whether gender and prior formal physics instruction mattered to students' physics self-efficacy. They found that both showed a significant effect. Females reported lower self-efficacy than males, and males with no prior formal physics instruction showed the highest self-efficacy. They concluded that gender and prior formal instruction in physics did matter when studying physics self-efficacy, which may have important consequences both for the study of self-efficacy and for the way tertiary physics was taught.

On their part, Caprara et al. (2008) carried out a longitudinal research study to investigate the development of students' academic self-efficacy from middle school to high school. The authors found that over the transition from middle school to high school, students' self-efficacy levels decreased. They concluded that students face more complicated and demanding subjects which in turn decrease their self-efficacy beliefs. However, they found positive relationships between students' self-efficacy and grades or achievement in science. They also found out that female students considerably increased in their self-efficacy than male students.

Before moving to the next section, it is worth summarizing what is discussed so far. First, the three areas that are relevant to this study are discussed, namely self-efficacy, attitude and academic performance. It is clear that POGIL has proved to be, by and large, more positive as an instructional approach. All the studies discussed above show that students who are taught using POGIL have positive attitude towards science in general and physics in particular. This is the case globally. POGIL also proved to be an important contributing factor in improving students' academic performance and in their sense of self and self-efficacy. It introduced students to strategies developing their sense of responsibility and how to manage their own learning.

2.3.6 The Impact of Application of POGIL on Attitudes

It is important to examine student's attitude toward using POGIL in teaching physics. This can help us better understand the impact of POGIL on students' attitude and their science learning achievement. For the purpose of 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, Simon, & Collins, 2003). This definition includes the majority of Klopfer's (1971) attitude components that constitute the bases of Test of Science Related Attitudes (TOSRA) developed by Tajfel and Fraser (1978), to measure the seven science related attitudes among secondary school students. To be sure, TOSRA consists of seven attitude scales, namely: Social Implications of Science; Normality of Scientists; Attitude of Scientific Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; Leisure Interest in Science; and Career Interest in Science.

TOSRA was based on what Klopfer (1971) called "manifestation of favorable attitudes towards science and scientists" and was based on the following premises:

> "It is reasonable to see whether the student will speak, write, and act in ways which show that he [or she] places a positive value on the role of science in

furthering man’s [sic] understanding and that he [or she] give due acknowledgement to scientists for their past and potential future contributions in their quest.” (p. 577).

There has been a group of research studies determining attitudes of students for science and examining its relation with other variables. Some of these studies found positive or moderate relationships between attitudes and students’ achievement in primary and secondary schools (Genç, 2001; Tepe, 1999; Turhan, 2003). Additionally, some of the studies aimed at researching the factors on the attitude towards science. Here, it was found that students’ attitude towards science learning increased as their grade increased (Alkan, 2006; Çakır, ùenler, & Taúkın, 2007; Ilgaz, 2006). In contrast, other studies’ results showed that students’ attitude towards science lessons increased as their grade decreased (Geroge, 2006; Külçe, 2005; Weinburgh, 2000).

When it comes to the gender differences in attitudes toward science, the studies had different results. Some studies showed that attitudes towards science lesson did not vary between genders (Çakır et al., 2007; Ilgaz, 2006; Külçe, 2005; Neathery, 1997; Turhan, 2003). In contrast, Neathery (1997) showed that male students rated science as a subject more exciting than female students in elementary and secondary schools. Similarly, Weinburgh (2000) found that male students were more positive than female in their enjoyment of science, motivation, and self-concept while the females are more positive in their perception of the science teacher and the value of science to society.

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 extremely relevant and important to this study. The same relevance can be seen in the studies discussed in the following paragraphs.

In the Philippines, a quantitative study was conducted by Guido (2013) to analyze and evaluate the relationship between engineering and technology students' attitude and motivation towards learning physics. The results of the study found no significant difference in the attitude and motivation of students towards learning physics. Furthermore, most of the students participating in the study felt good when they were successful in physics. 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 found it enjoyable studying physics since they could see its utility in everyday life situations.

In Malaysia, Ibrahim et al. (2019) carried out a quantitative research study to explore secondary schools students' learning attitude in physics and challenges towards learning force and motion. The results of the study found favorable attitudes in learning physics by majority of students, though most students had poor scores in physics test. This result was a strong indicator that there was no relationship between students' attitude and their scientific achievement in physics. The results also revealed that the topics of motion and forces were challenging and difficult for most of participants.

In the Turkish context, Kaya and Boyuk (2011) also carried out a quantitative study to examine high school from Grade 9 to Grade 11 students' attitudes towards physics lessons and physical experiments. The students were divided into two groups having both positive and negative attitudes towards physics lessons and physical experiments. It was found also the grade and age affected their attitudes towards physics lessons and physical experiments but not gender.

In their study, Oh and Yager (2004) found that students who were taught using traditional lecture-based instruction developed negative attitude towards science learning whereas students who were taught by constructivist science instruction like POGIL had positive attitudes towards science learning. Oh and Yager (2004) thus recommended to enhance the learning environment to allow students to attain scientific knowledge and gain a more positive attitude toward science. Other studies stated that the classroom learning environment that is based on process and inquiry is a strong factor in determining and predicting students' attitudes toward science (Simpson & Oliver, 1990; Goh & Fraser, 1997; Fraser, Aldridge, & Adolphe, 2010).

In the Australian context, Vishnumolakala et al., (2017) carried out a study investigated the chemistry students' attitudes, self-efficacy, and experiences in modified POGIL classes. They found statistically significant differences in favor of students' attitudes, self-efficacy and experience. They also reached the conclusion that POGIL intervention provided positive affective experiences for students who are new to chemistry or have limited prior chemistry knowledge.

In Bandung, Indonesia, Ardiany et al. (2017) carried out a mixed method research that used experimental design to study the high vocational school students' self-efficacy in learning physics using guided inquiry instructional method. Furthermore, the research also sampled a group of physics teachers to explore their opinion about guided inquiry learning. The results of the search study showed improvement in students' performance and self - efficacy of their learning via guided inquiry learning. The results also showed a significant relationship between self-efficacy and guided inquiry learning. The results found out that guided inquiry learning is fun, interesting and challenging so that students can expose their ideas and opinions without being forced. The participating teachers and students in this study thought that guided inquiry learning increased students' active engagement, positive attitudes and self-efficacy towards learning.

2.3.7 The Relationship between Application of POGIL and Gender

Spencer and Moog (2008) throughout their detailed report about the best practices of POGIL, recommended diverse groups when applying POGIL. In some contexts where classes have either male or female students, following such recommendation would be impossible. In fact, there are few studies that tackled gender differences in the application of POGIL. Alghamdi and Alanazi (2020) investigated Grade 10 (male and female) students' perceptions of POGIL approach in chemistry classes. There were no gendered differences in overall students' scores.

Marshman, Kalender, Schunn, Nokes-Malach & Singh (2018) conducted a longitudinal analysis of students' motivational characteristics in introductory physics courses. They focused on gender differences. They measured gender differences in relation to four factors: (1) Factor 1. Learning tool characteristics (internal) – pertaining to features embedded in the learning tools that help students learn; (2) Factor 2. Student characteristics (internal); (3) Factor 3. Learning tool characteristics (external) – pertaining to how the tool is implemented in a particular course and (4) Factor 4. Student characteristics (external) - pertaining to the student-environment interaction. They focussed in their study on Factor 2. They found that there are evident differences in gender where female students underperform male students. In specific areas, women had lower gains on the than men such as "Force Concept Inventory". They also mentioned that prior research found gender differences with regard to motivational characteristics. In addition, there were gender differences in self-efficacy in middle school and throughout high school where female students scored low scores than male students in self-efficacy scales. However, they reached the conclusion that such differences in gender are associated with the societal stereotypes and biases.

Making use of POGIL in other subjects, like Computer Sciences, showed that pass rates increase for female students but not males, (Hu, Kussmaul, Knaeble, Mayfield & Yadav, 2016). In a Chemistry course that made use of POGIL, Zgraggen (2018) argued that there were statistically significant differences in performance between males and females with and females performed better than males overall but there were no interaction effects between group and gender. Similarly, Akpinar, Yildiz, Tatar, & Ergin (2009) argued that there was a significant difference between female and male students in terms of “interest in science” in favor of female. As for other factors such as (enjoyment of science, anxiety”, enjoyment of science experiments); compared with boys, girls tend to have positive attitudes toward science course. Akpinar et al. (2009) reached the conclusion that girls develop more positive attitudes towards science when compared to the boys.

Finally, David et al. (2020) conducted a study to investigate the effect of POGIL in improving undergraduates' academic achievement in science education, they reached the conclusion that “gender has no significant influence on the students’ academic achievement in science subjects when teachers utilize active learning strategies such as, the POGIL, that encourage collaboration, cooperation, and communication”, (p.4025).

2.3.8 Studies Related to the UAE and Arabian Gulf Context

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 lack of studies that involve high school students pertaining to the use of inquiry-based instruction, especially the use of approaches such as POGIL in the UAE context.

An instrument-based survey conducted in the UAE by Tairab and Al-Naqbi (2018) that evaluated the effectiveness of the use of constructivist pedagogical strategies established unanimity between students and teachers that most of curriculum materials require the use of inquiry-based instructional strategies to enhance effectiveness. Constituting a rare research on the topic, the study highlighted the various challenges that could be experienced if such an approach is adopted. Tairab and Al-Naqbi’s study is similar to mine in that their study is looking at POGIL-based instruction, investigating the teaching of physics, and is conducted in a high school context in the UAE.

A study by Al-Naqbi (2007) showed significant differences in the nature of perceptions of high school students towards chemistry as a subject, chemistry research and jobs related to chemistry. In the scale of self-efficacy, the main differences amongst the students were found in their performance and their scores and the percentiles of the secondary schools. However, in terms of gender, nationality and matriculation, there were no significant or notable differences amongst the students on the self-efficacy scale. Further, the results of the study indicated there were notable differences amongst the students on the basis of their learning experiences in chemistry. The main similarity between this study and the one conducted by Al-Naqbi (2007) is that both have similar variables of self-efficacy and attitudes in addition to being conducted in the UAE.

A recent mixed method research study was carried out in Qatar by Treagust, Qureshi, Vishnumolakala, Ojeil, Mocerino and Southam (2020) investigated how to implement POGIL in government schools in Qatar. POGIL intervention was found to be helpful for Grade 10 science students as it improved their perceptions of chemistry in particular. The study stated that POGIL could participate in the enhancement of teachers' training in science education.

Another quasi-experimental study carried out by Qureshi and Visnumolakala (2018) to explore Qatari Foundation first year students' understanding of chemistry concepts in a POGIL context. The results of the study found positive effects of POGIL on students' understanding of chemistry concepts. The authors thus concluded that student-centered pedagogical practices like POGIL enhanced students' understanding in the field of science.

Always in Qatar, a mixed method research study was carried out by Vishnumolakala, Qureshi, Treagust, Mocerino, Southam and Ojeil (2018) to follow-up foundation-year chemistry students taught in POGIL to evaluate their attitudes, experiences and self-efficacy in chemistry. The findings of this study indicated that "inquiry-based chemistry learning experience improves the students' intellectual accessibility and emotional satisfaction as well as develops their self-efficacy levels" (p. 1). The results showed that POGIL experience enabled the students succeed in rigorous pre-medical chemistry courses and gained some process skills required in the medical program. Also, POGIL had a long-term positive impact on the attitudes, self-efficacy and learning experiences of chemistry students. The findings of this study provided further evidence on the benefits of POGIL in pre-medical education in Qatar.

A research study in Saudi Arabia conducted by Alghamdi and Alanazi (2020) investigated Grade 10 (male and female) students' perceptions of POGIL approach in chemistry classes. The results of the study showed that POGIL increased their engagement and reflected effective on their academic performance and positively on their learning experience. POGIL also enriched students' affective traits such as cohesiveness and personal relevance. Alghamdi and Alanazi (2020) recommended training teachers in POGIL implementation due to its appropriateness to the Saudi educational context.

2.4 Chapter Summary

This chapter provided insights into the topic of this research study, both in terms of theory and literature review. It identified gaps where a POGIL-based study is needed in the UAE. This research thus far cannot find any studies regarding POGIL in the UAE 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, self-efficacy and attitude of students.

From a theoretical point of view, the chapter discussed cognitive and social constructivism theories as its foundation. POGIL bases its theoretical and practical conceptions upon the major concepts of these two theories. Some of these aspects are summed up in the following points, which are aligned with a POGIL-based instructional approach: a) learners are active participants in the learning process and they are the core of the instruction; b) teachers are facilitators and guide not lecturers who transfer knowledge to students; c) students work collaboratively and learn through a process of cycles; d) cognitive apprenticeship, learning, discovery learning, and problem-based learning are the most distinctive methods of instruction and e) inquiry learning is a major aspect of the process of teaching and learning.

In sum, this chapter is divided into two parts: theory and literature review. In the theory section, I introduced cognitivism and constructivism as two guiding theoretical frameworks that help me conceptualize this study, the questions asked in the research study, choosing the appropriate methodology, collecting and analyzing the data collected and the conclusions reached. The second part of the chapter reviewed the literature regionally, nationally and internationally. Focusing on POGIL and its contributing factor in relation to performance, self-efficacy and attitude, this section of the chapter looked at a substantial number of studies from across the world (including GCC). Except for one study which found POGIL to be a challenge for students (because students were not prepared for what it took to learn using this method of teaching), POGIL proved to have a positive effect in academic performance (e.g., Qureshi & Visnumolakala, 2018; Vishnumolakala et al., 2018; Alghamdi & Alanazi, 2020) self-efficacy (students take their own responsibility and learning seriously) (Devitri et al., 2019; Zamista, & Rahmi,, 2019; Walker & Warfa, 2017; Barthlow &Watson, 2014; Lin & Tsai , 2013; Britner, 2008; Caprara et al., 2008; Chiou & Liang, 2012; Chase et al., 2013; Vacek, 2011) and positive attitude toward science in general and physics in particular (the focus of this research) (Wozniak, 2012; Nihalani et al., 2010; Hanson, Fuchs, Aisenbrey, & Kravets, 2004; Kuhn et al., 2000). 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; Genç, 2001; Tepe, 1999; Turhan, 2003; Alkan, 2006; Çakır et al., 2007; Ilgaz, 2006; Simpson & Oliver, 1990; Goh & Fraser, 1997; Fraser et al., 2010; Neathery, 1997; Weinburgh, 2000).

Finally, the chapter found that, except for two studies marginally related to this research topic, no other studies were conducted on POGIL in the UAE. So, this research study is hoped to fill in that gap and the recommended pedagogical and curricular implications may prove to be useful for teachers and policy makers.

Chapter 3: Methodology

3.1 Overview

This chapter describes the methodologies used to collect data for the study. The chapter encompasses a description of the employed design, the sample of the study and how they were selected, the instruments used to collect data, procedures employed to implement the research, how collected data was analyzed, and the ethical considerations followed in this research.

3.2 Research Design

The study adopted a cause-effect, pre-test post-test 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, self-efficacy and scientific attitudes. performance demonstrated by three outcomes, namely “Knowing”, “Applying”, and “Reasoning”. Self-efficacy 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 each of the three independent variables (performance, self-efficacy and scientific attitudes). Per Creswell (2012), this design is the best 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.

3.3 Variables of the Study

The study employs the following variables:

3.3.1 Student Science Performance in Circular Motion

This independent variable consists of three levels, thus creating what is known as KAR (Knowing, Applying and Reasoning):

3.3.1.1 Knowing

Knowing refers to students' knowledge base of circular motion information, concepts, tools, and procedures. Accurate and broad-based factual knowledge of circular motion enables students to engage successfully in the more complex cognitive activities essential to the scientific enterprise. "Students are expected to recall or recognize accurate circular motion statements; possess knowledge of vocabulary, facts, information, symbols, units, and procedures; and select appropriate apparatus, equipment, measurement devices, and experimental operations to use in conducting investigations. Describe physical materials and processes demonstrating knowledge of properties, structure, function, and relationships" (TIMSS, 2015).

3.3.1.2 Applying

Applying involves the application of knowledge of physics facts, concepts, and procedures in problem situations and applying an understanding of physics concepts and principles to find a solution or develop an explanation. Items aligned with this cognitive domain will involve the application or demonstration of relationships, equations, and formulas in contexts likely to be familiar in the teaching and learning of physics concepts. Both quantitative problems requiring a numerical solution and qualitative problems requiring a written descriptive response are included. In providing explanations, students should be able to use diagrams or models to illustrate structures and relationships and demonstrate knowledge of circular motion concepts (TIMMS, 2015).

Applying also involves the following: 1) relating knowledge of an underlying physical concept to an observed property, behavior, or use of objects or materials; 2) using models to demonstrate an understanding of a physics concept, structure, relationship, process, or system; 3) finding solutions, and explaining the reasoning involve in solving problems, developing explanations, drawing conclusions, and extending their knowledge to new situations; applying scientific reasoning to understand a phenomenon. Here, students may analyze a problem to determine what underlying principles are involved; devise and explain strategies for problem-solving; select and apply appropriate equations, formulas, relationships, or analytical techniques; and evaluate their solutions. This level involves analyze/solve problems, generalize, synthesize/integrate, justify, hypothesize/ predict, draw conclusions (TIMMS, 2015).

3.3.1.3 Reasoning

Reasoning domain involves unfamiliar or more complicated contexts that require students to reason from scientific principles to provide an answer. Students may analyze a problem to determine what underlying principles are involved; devise and explain strategies for problem-solving; select and apply appropriate equations, formulas, relationships, or analytical techniques; and evaluate their solutions. It includes analyze/solve problems, generalize, synthesize/integrate, justify, hypothesize/ predict, draw conclusions (TIMMS, 2015).

3.3.2 Students' Self-Efficacy Variable

The second independent variable is students' self-efficacy. Students' self-efficacy defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986; Suprapto et al., 2017). Self-efficacy is a significant concept in Bandura's social cognitive theory that indicates that behavior is best understood in terms of a triadic reciprocal system: cognition, behavior, and environment. The notion of reciprocal determinism in social cognitive theory means perceived ability to perform the task, behavior, performance, and environment setting (Chang et al., 2010). Self-efficacy is a significant construct that helps students monitor their performance since it focuses attention on their beliefs about the effectiveness of their learning methods (Zimmerman et al., 2006).

Self-efficacy variable has three constructs; physics learning, understanding physics and willingness to learn physics for future careers. The first and second ones are related to knowledge and comprehension level skills, but the third is related to desire and self- assessment (Suprapto et al., 2017).

3.3.3 Scientific' Attitudes Variable

The third variable and the dependent variable at same time is students' attitudes. Students' attitudes is defined as "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, Simon, & Collins, 2003). This definition includes the majority of Klopfer's attitudes components that constitute the bases of Test of Science Related Attitudes (TOSRA) developed by Fraser (1978), to measure seven related attitudes among secondary school students. Three constructs; attitudes to scientific inquiry, enjoyment of science lessons, career interest in science have been selected from the original TOSRA (Ali, Mohsin, & Iqbal, 2013) as these constructs are the most appropriate to POGIL method of teaching.

The objective evaluation of the variables forms the most cogent basis for identifying the nature of conclusions made during the study. Additionally, the study design is also the most suitable based on the context of the study as it guarantees minimal interference with the learning environment of the students (Morgan & Winship, 2016). Furthermore, quasi-experimental studies are appropriate in educational settings and have been applied in these contexts for a long time due to their suitability to natural settings (Creswell, 2012). Such environment makes it easier to identify the different trends from the observations made in the outcomes amongst each of the variables examined. Also, the use of a quasi-experimental approach in the study is cost-effective, as pre-screening and randomization are not required (Creswell, 2012).

3.4 Population, Participants and Sampling

The study was conducted in 2019 and the participants were drawn from two government high 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 were pursuing advanced stream, where physics is one of the subjects, they studied ministry of education (Ministry of Education, 2019c).

The study utilized two government schools in Alain, where one of the schools is for boys and the other for girls. Easy access to the schools, prompted the researcher to utilize convenient sampling in determining the classes that were involved in the study as the focus grade is already known. One of the attributes of using convenient sampling is that the targeted subjects for the research are easily accessible and within the proximity of the researcher and the researcher does not have to invest massive resources to access the subjects (Creswell, 2012). Further, the use of convenient sampling is cost-effective as only the selected class in each school is involved and not the entire population is being studied.

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. 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 for the study consisted of Grade 12 students whose age ranged between 17 to 19 years. Two classes were selected randomly from each group. One of them considered to be the experimental group and the other class considered to be the control group. 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), as presented in Table 2.

Table 2: Sample Size of the Two Groups

Group		**Gender**		**Total**
		Boys	**Girls**	
Control	n	29	27	56
	%	51.8%	48.2%	100%
Experimental	n	29	25	54
	%	53.7%	46.3%	100%
Total	**n**	**58**	**52**	**110**
	%	**52.7%**	**47.3%**	**100%**

As shown in the Table 2, boys represent 51.8% (n=29) of the total of control group, while they represent 53.7% (n=29) of the second group. On the other hand, girls represent 48.2% (n=27) of the total of control group, while they represent 46.3% (n=25) of the second group.

3.5 Instrument

3.5.1 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 are similar to items of cognitive abilities tested by TIMSS and PISA (Table 3, which shows the distribution of test questions of KAR test per domain and subdomain).

3.5.2 Validity and Reliability of Test of Circular Motion

A test on "Circular motion" was initially developed using 18 items; 6 items for each subdomain; Knowing, Applying and Reasoning. The test was reviewed by two university professors, two science supervisors and two experienced science teachers, see Appendix A. 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. TIMSS and PISA have been widely used all over the world, and the UAE is not an exception. The final version of the test consisted of 30 items; two items covered each subdomain as shown in Table 3. Furthermore, the 30 items cover all the learning outcomes of the units set by Physics Standards of Grade 12.

Table 3: Distribution of test Questions of KAR Test Per Domain and Subdomain

Question	**Learning outcomes**	**Cognitive Variable**	**Sub Variable**
1, 2	To recognize basic knowledge of circular motion	Knowing	Recall/ Recognize
3, 4	To describe concepts and principles	Knowing	Describe
5, 6	To give example and solve real time problems	Knowing	Provide example
7, 8	To compare the ideas of circular motions and dynamics	Applying	Compare
9, 10	To understand the application of forces and its effects	Applying	Contrast
11, 12	To classify the categories of forces and other parameters	Applying	Classify
13, 14	To relate the ideas of circular motion in real world applications	Applying	Relate
15, 16	To use force diagram and models for problem solving	Applying	Use models
17, 18	To interpret and solve problems using circular motion	Applying	Interpret Information
19, 20	To analyze the properties of the objects in circular motion	Reasoning	Analyze
21, 22	To construct solution for studying the circular motion	Reasoning	Synthesize
23, 24	To investigate circular motion designs and frames	Reasoning	Design investigations
25, 26	To evaluate results using formulae	Reasoning	Evaluate
27, 28	To interpret and draw conclusion based on information provided	Reasoning	Draw Conclusions
29, 30	To get a generalized idea about circular motion.	Reasoning	Generalize

After modifying the test some items were added and the test reached its final version, see appendix B. The reliability of the test was measured through the split-half reliability as shown in Table 4.

Table 4: Reliability Coefficients for Test of the Cognitive Outcomes of Knowing, Applying and Reasoning (KAR)

Variable	Cronbach's Alpha	Items No.
Knowing	0.78	6
Applying	0.87	12
Reasoning	0.85	12
Whole Test Items	0.83	30

The reliability of test of the Cognitive Outcomes of “Knowing”, “Applying”, and “Reasoning” (KAR) was collected by measuring split-half reliability coefficient. Cronbach's Alpha coefficient for “Knowing” was 0.78 which indicted that this domain has a good reliability, while Cronbach's Alpha coefficient for “Applying” and “Reasoning” were 0.87 and 0.85 respectively, which indicated that these domains has a very good reliability (George & Mallery, 2016). The internal consistency coefficient (Cronbach’s Alpha) of the entire scale was 0.83, which is considered a high internal consistency.

The students (N=110) were given a test involving 30 multiple-choice questions that measure the performance of the students in the circular motion. The data calculated by the test used to compare the results of the intervention on the three domains or variables that were being tested which included Knowing, Reasoning and Applying.

3.5.3 Self Efficacy

Self-efficacy: first developed in the late 1970s as part of the social cognitive theory (Bandura, 1977), researchers have been trying to utilize this theoretical construct to explore differences in teaching practice and learning achievement. In this study, self-efficacy is used to assess POGIL approach on the participants self-efficacy.

Enochs and Riggs (1990) also worked to show that teachers' efficacy was both a context and subject matter specific construct. In developing this theory that was consistent with Bandura's (1977) formulations, Riggs and Enochs (1990) developed the 'Science Teaching Efficacy Belief Instrument' (STEBI). The idea of student self-efficacy was taken from the research of science teachers' self-efficacy. For the purpose of this research, Survey of Self- efficacy was modified to tackle the students' sense of self-efficacy. The researcher distributed the survey to the students who participated in the study, in order to investigate their self- efficacy, after the intervention (taught by POGIL-based instruction).

Lin, Liang and Tsai (2015) showed that self-efficacy – which they see from the students' perspective as the ability to perceive self-capability – impacted the students' abilities to use advanced cognitive skills; to use their scientific knowledge and skills in their daily life situations and to communicate scientific concepts and ideas with other people (Vacek, 2011; Lin et al. 2015).

In this research, self-efficacy is defined using three constructs namely: 1) learning of physics, 2) understanding physics, and 3) willingness to learn physics in their future careers. These three constructs of self-efficacy are essential to the learners since they include learning, understanding and their desire for the future. They prepare students not only for school but also for life and higher education. Constructs were developed in ways that reflect their relationship to cognitive domine of the participant. Its assume that:

1. The construct of learning physics is a level of Knowing.
2. Understanding physics is needed for Applying and Reasoning.
3. The construct of willingness to learn physics in their future careers.

Data of the test of self-efficacy were collected before and after the implementation of POGIL-based instruction. For the benefit of the reader, a reiteration of the data collection process is needed. First, the total number of students before whom the survey was administered was 20 students. The survey itself has a total of 30 questions. First, the survey was piloted before these 20 students to ascertain the clarity of the questions, hence the idea of 'piloting.' After the survey, it was found that some questions needed modification or rephrasing. The number of questions stayed the same, but some questions were rephrased to make them clearer. Second, an exam was administered to verify students' level of competency. Third, students were then taught using POGIL-based instruction. Fourth, a final exam was administered to see the impact of POGIL. Finally, the updated survey was then administered.

The main objective of the survey was to identify the levels of self-efficacy for each of the students in learning physics and determining whether the students were interested in pursuing physics in their future careers.

3.5.4 Validity and Reliability of Self Efficacy Survey

The construct and content validation of the survey was done by experts, including two science education professors, two science education advisers "Academic Quality Improvement" and two experienced physics teachers, see appendix C. They provided their input and opinions and suggestions on the constructs being measured by the instrument. They also provided some comments and suggestions that helped in improving the survey and added some comments about the aim and instruction as well as simplifying some items to make them readable (Appendix D). They deleted some repeated items and the survey reached its final version (Appendix E). The jury advised the researcher to have a bilingual version in

Arabic to avoid language barrier, and suggested to simplify the academic language to be within the understanding of the students (Appendix F).

The items were translated into Arabic to reduce any language barriers for the students and ensure they understand the different items found in the survey. The Arabic version was reviewed by two science education professors, two science education supervisors, two experienced physics teachers and translators who provided some comments regarding modifying some phrases to make it readable correctly by students. After reviewing made, two items were added to the construct of learning Physics, and four items were added to the construct of Willingness to learn physics in the students' future careers. The modified version was reviewed again by the experts mentioned before, and they provided minor comments and suggestions.

In order to find out the levels of the reliability of the results obtained in the survey Cronbach's Alpha coefficient was measured (Table 5).

Table 5: Reliability Coefficients for Survey of Grade 12 Students' Self-Efficacy

Variable	Cronbach's Alpha	Items No.
Learning Physics	0.96	10
Understanding Physics	0.74	8
Willingness to learn physics in the future careers	0.78	12
Whole Survey Items	0.90	30

The reliability of test of the Students' Self-Efficacy was calculated through split-half reliability coefficient. Cronbach's Alpha coefficient for “Learning Physics” was 0.96 which indicted that this domain has excellent reliability, while Cronbach's Alpha coefficient for “Understanding Physics” and “Willingness to learn physics in the future careers” were 0.74 and 0.78 respectively, which indicated that these domains has a good reliability (George & Mallery, 2016). The internal consistency coefficient (Cronbach's Alpha) of the entire scale of students' Self-Efficacy was 0.90, which is considered a high internal consistency.

3.5.5 Survey of Physics Related Scientific Attitudes

This survey is based upon the Test of Science Related Attitudes (TOSRA) (Fraser, 1981). TOSRA has been constructed to assess science-related attitudes along seven dimensions: social implications of science, normality of scientists, attitude toward scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. The TOSRA includes 70 items, each measured on a 5-point Likert scale; these items comprise seven subscales with ten items each.

The study selected three constructs from the Test of Science Related Attitudes (TOSRA) due to the proven reliability of the scales and their suitability for this study (Fraser, 1981). The constructs selected focused on the areas of scientific inquiry (10 items), enjoyment of lessons (10 items) and career interest (10 items). These three scales were selected as they were in line with POGIL and the survey of self-efficacy. These constructs were developed to be in line with the performance test that measures Knowing, Applying and Reasoning.

Overall, the three selected scales seem to be in sync with other instruments; they are also in line with the nature of POGIL approach that is inquiry-based and prepares students for future and independence in their inquiry.

The three scales were used in measuring the effects of POGIL based instruction on student attitudes to scientific inquiry, enjoyment of lessons, and career interest in physics. The validity of this form of survey has been evaluated in other countries settings like Australia and USA (Welch, 2010). The results provided evidence for the suitability and validity of TOSRA, and its use amongst Australian students and they support the cross-cultural validity of TOSRA in other settings and its use in other countries like the USA that is similar to the context of the UAE in its cultural diversity.

A panel of some experts provided their suggestions to improve and validate the survey. The panel included two science education professors, two science education advisers, “Academic Quality Improvement” and two experienced physics teachers. Modifications were done to some items of the survey (Appendix G). They provided some suggestions and some changes were conducted (Appendix H).

After reaching the final version of the survey, see appendix I. The survey was translated into the Arabic language to reduce any language barriers for the students and ensure they understand the different items found in the survey (Appendix J). The Arabic version was reviewed by two science education professors, two science education advisors, two experienced physics teachers, and translators who provided some comments regarding modifying some phrases to make it readable correctly by students. They suggested simplifying some items to ensure a full understanding of all the items.

3.5.6 Reliability of Survey of Physics Related Scientific Attitudes

The reliability of test of the Attitudes toward Scientific Inquiry, Enjoyment of Lessons and Career Interest (SEC) was collected by measuring split-half reliability coefficient. Cronbach's Alpha coefficient for “Scientific Inquiry” was 0.91 which indicted that this domain has excellent reliability, for “Enjoyment of Lessons” Cronbach's Alpha coefficient was 0.79, which indicted that this domain has a good reliability. In addition, Cronbach's Alpha coefficient for “Career Interest” was 0.83, which indicated that this domain has a very good reliability (George & Mallery, 2016). The internal consistency coefficient (Cronbach's Alpha) of the entire scale of Students' Attitudes toward Scientific Inquiry, Enjoyment of Lessons and Career Interest (SEC) was 0.88, which is considered a high internal consistency (Table 6).

Table 6: Reliability Coefficients for Survey of Students' Attitudes toward Scientific Inquiry, Enjoyment of Lessons and Career Interest (SEC)

Variable	Cronbach's Alpha	Items No.
Scientific Inquiry	0.91	10
Enjoyment of Lessons	0.79	10
Career Interest	0.83	10
Whole Survey	0.88	30

3.6 Procedures

3.6.1 Instructional Methodology & Procedures for POGIL Implementation

As part of this research, teachers provided activities and challenges that actively engaged students in inquiries that honor the ideas and skills students bring with them, while further deepening their conceptual understandings and essential skills. Here, understanding of big ideas for the teachers had enabled and encouraged students to use scientific thinking throughout their lives. As well, contextualized teaching and learning provided teachers with useful insights into their students' thinking, their understanding of concepts, and their ability to reflect on what they have done. This insight allowed teachers to provide supports to help enhance students' learning. In sum, as I detail everything in the following section, a wide variety of instructional strategies were used to provide learning opportunities to accommodate a variety of learning styles, interests and ability levels (Ministry of Education, 2019a).

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 for the treatment group. The unit was taught in 16 periods four physics periods a week for four weeks. Each period was 45 minutes. For samples of lesson plans (Appendices L and M).

The researcher and the other female 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).

The unit included the following topics: acceleration and net force; centripetal force and inertia; the centripetal force requirement; mathematical analysis of circular motion; newton's law of universal gravitation; the acceleration of gravity; satellite motion, weightlessness, and Kepler's laws of planetary motion.

3.6.2 Instructional Methods of Both Groups and Implementation

After developing the research instruments: (1) the pre and the post: (2) the survey of self-efficacy and (3) the survey of scientific attitudes, a consent form was sent to parents of the students in the two schools, see Appendix K. After receiving the approval, students were assigned to the experimental and the control groups in their intact classes. Teachers started teaching through the following procedures:

3.6.2.1 Procedure Followed with Experimental Groups

The following procedure was pursued with the experimental group:

1- Divide the student into (6) groups, each group includes (5) students.

2 - The two researchers explained the lesson using the periodic investigation form.

3- The researcher begins by raising the student's attention to the topic of the lesson circular motion by exposing them to a problem or event, and then begins with presenting a comprehensive explanation of the main concepts and ideas included in the topic of the lesson and ask the student to think about the concepts and ask as many questions as possible.

4- Then, the teachers write a list that includes all the questions that the students ask and write them on the board in front of the student to be answered and start asking questions.

5- After that, each group writes a report briefly about what it understood from the lesson and present it to the other groups for discussion among themselves

6- Through discussion, the wrongly- written questions are revealed to each group and corrected through discussion.

7- Upon completion of the lesson explanation, the teacher gave the student an opportunity to reflect on what has been achieved in the previous stages and whether they have new questions related to the topic of the lesson to answer them

8 - The researcher determined the homework required of the student to prepare for the next lesson.

3.6.2.2 Procedure Followed with the Control Groups

The use of a control group was vital as it enhanced the ability of the researcher to compare between the two groups. The control group was taught using lecture-based instruction in which the teacher did most of the work as follows. For lecture-based instruction class, the teachers in the control groups in both schools did the following: The teachers started with a warm-up activity and revised the previous materials and topics taken to find out what your students already know by asking questions about circular motions topics.

The teachers presented new topics, and introduced the main concepts of circular motions.

- The teachers gave examples relevant to students' knowledge and experiences.
- The teachers used meaningful sequencing, smooth transitions, examples, demonstrations, and illustrations to clarify their explanations to students.
- They also could use Microsoft Power Point slides or the board for key points.
- They made summary to sum up the main ideas and information together (Svinicki & McKeachie, 2012).

3.6.3 The Test (KAR) was Given Twice to Participant as Pre-test and Post-test

The two researchers conducted the post-achievement test and the students were informed of the date of the post-achievement test a week before taking it in order 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.

An example of teaching a lesson in the unit of circular motion is highlighted as follows:

- The topic was "Dynamics of Circular Motion- Centripetal Force"

- Three learning outcomes were set for this topic:

  I. To identify centripetal force, and mention examples about it.

  II. To discuss the formula of Fc and then solve problems.

  II. To analyze a conical pendulum and derive equations for its angle and height.

On the other hand, the control group students were taught using lecture-based instructional method.

3.7 Materials and Unit of Circular Motion

The curriculum of Physics subject in grade 12 enables students to deepen their understanding of physics concepts and theories. The curriculum taught in grade 12 includes the exploration of accelerated motion and the forces that affect motion in one and two dimensions and investigated gravitation and rotational motion. Students also explored the work, energy and machines. Also, they learn about momentum, energy and conservation. They further develop their scientific investigation skills and learning—the ability to analyze qualitative and quantitative data, concerning a variety of physics concepts and principles. Students also consider the impact of technological applications of circular motion on society and the environment. The rotational motion will be given from grade 9 as an introduction and given in details in grade 12. The main objectives in rotational motion chapter are to define uniform circular motion, explain centripetal and centrifugal forces and identify the real-world application of circular motion (Ministry of Education, 2019b). The major topics of the unit are acceleration and net force, centripetal force and inertia; the centripetal force requirement; mathematical analysis of circular motion, Newton's law of universal gravitation, the acceleration of gravity, satellite motion, weightlessness, and Kepler's laws of planetary motion.

The over-riding aim of this unit is to help students learn circular motion and apply their knowledge and skills. Students will be engaged when they can see the connection between the scientific concepts they are learning and their application in the world around them and real-life situations.

The concept of circular motion dominates many phenomena in our life. Circular motion is defined as a movement of an object along the circumference of a circle or rotation along a circular path. It can be uniform, with a constant angular rate of rotation and constant speed, or non-uniform with a changing rate of rotation. The rotation around a fixed axis of a three-dimensional body involves circular motion of its parts. The equations of motion describe the movement of the center of mass of a body. When an object is forced to move in a circle, there must exist a force F r acting on the object-directed towards the center. For example, the moon is falling towards the center of the earth. There are also other examples like the motion of the sun, stars and planets (Ministry of Education, 2019a). 3.7 Research Instruments

3.8 Normality Tests

In statistics, normality tests are used to determine if a data set is well-modeled by a normal distribution and to compute how likely it is for a random variable underlying the data set to be normally distributed. Normality tests or the tests that detect normality of scores distribution are considered as important statistical measurements that lead the researcher to choose the suitable deductive statistical tests for data analysis. If the distribution is normal, then parametric statistical tests should be used, otherwise non-parametric statistical tests should be used (Field & Golubitsky, 2009, Elliott & Woodward, 2007).

After data entered to SPSS program, the researcher made all the process needed to clean the data and check its normality using graphical methods namely histograms. The researcher applied a transformation on the data since it is a possible way to fix non-normality.

Transforming data is a method of changing the distribution by applying a mathematical function to each participant's data value. In this research, the researcher applied log-normal transformation on the data obtained from the students. Figures 4-6 below represent the histograms corresponded to the distribution of the scores for overall KAR test scores, overall Self-efficacy test scores, and overall scientific' attitudes test scores.

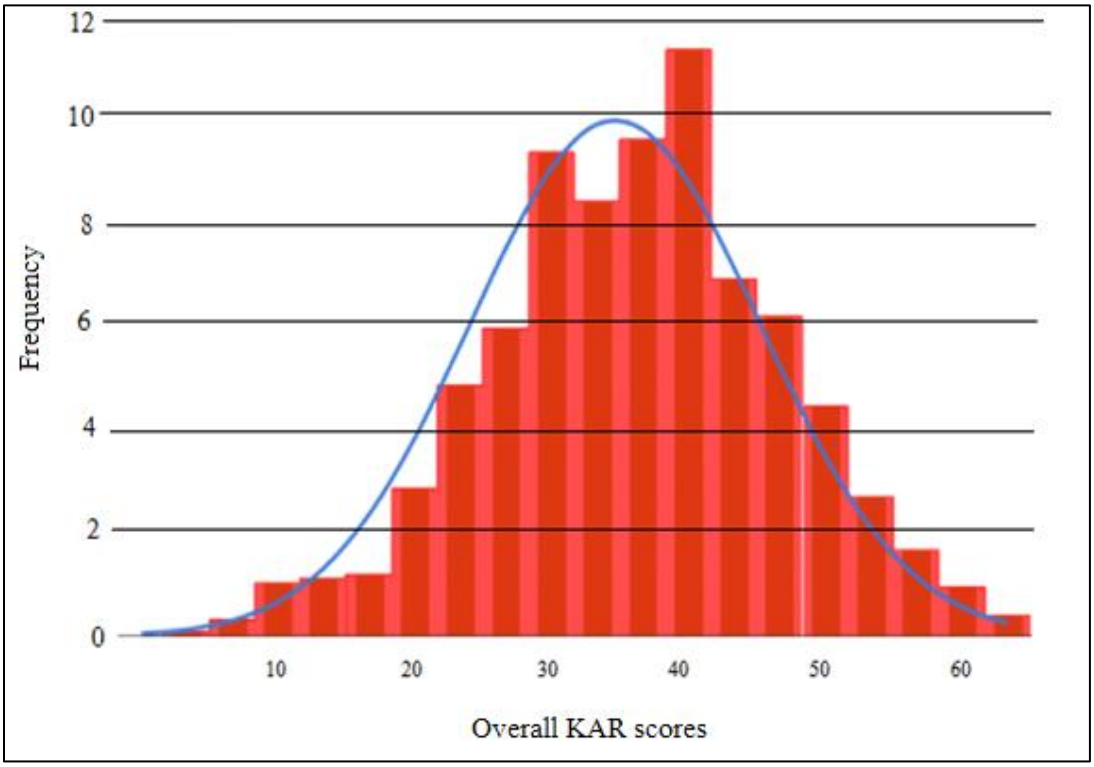

Figure 5: Distribution of Overall KAR Test Scores Using Log-Normal Transformation. Mean = 35, Std. Dev.= 9.69, N=110

As indicated by the above Figure 5, the distribution of overall KAR test scores using log-normal transformation for all students participated in the survey (N=110) is closer to a normal distribution, with mean of overall scores of 35 and standard deviation of 9.69.

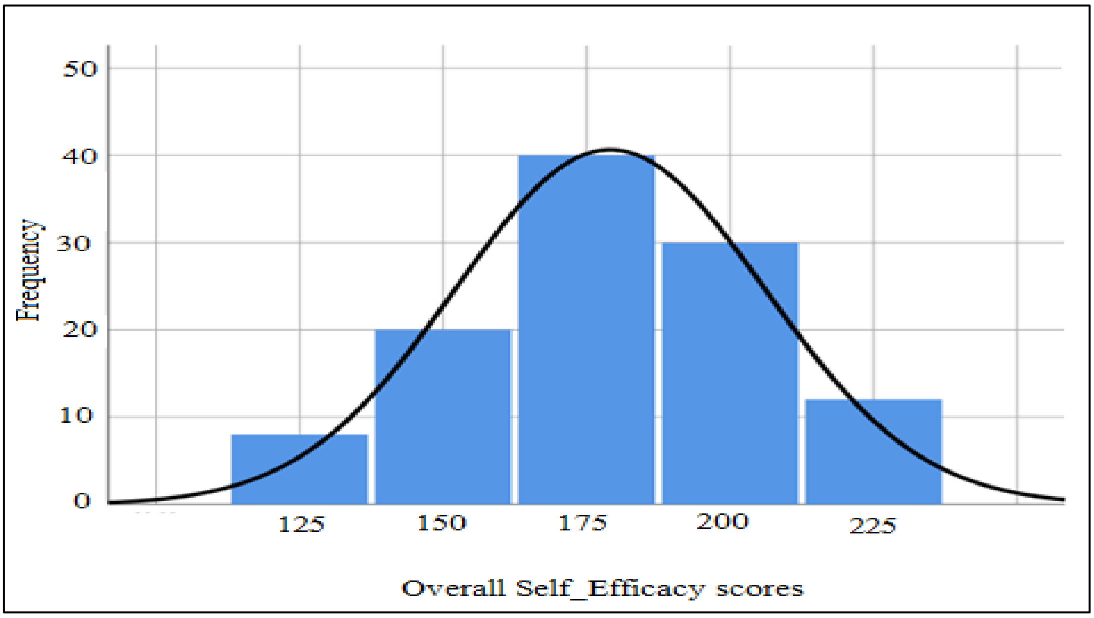

Figure 6: Distribution of Overall Self-efficacy Test Scores Using Log-Normal Transformation

As indicated by the above Figure 6, the distribution of overall Self-efficacy test scores using log-normal transformation for all students participated in the survey (N=110) is closer to a normal distribution, with mean of overall scores of 177.71 and standard deviation of 26.21.

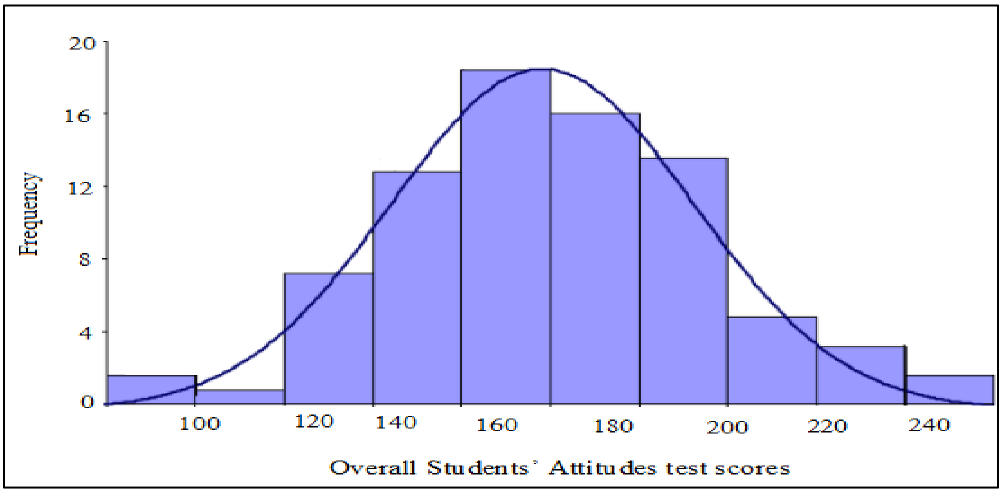

Figure 7: Distribution of Overall Students' Attitudes Test Scores Using Log-normal Transformation

As indicated by the Figure 7, the distribution of overall Students' Attitudes test scores using log-normal transformation for all students participated in the survey (N=110) is closer to a normal distribution, with mean of overall scores of 179.73 and standard deviation of 28.78.

The Description of the sample presented, in order to give a general idea about the composition of the sample's participants. Below is the description of the sample according to groups and gender.

Table 7: Sample Description- Group

Group	Frequency	Percent (%)
Control	56	50.9
Experimental	54	49.1
Total	**110**	**100**

As Table 7 shows, group ratio distributed equally (p-value > 0.05); since the control group consisted of 56 students (50.9%), while the experimental group consisted of 54 students (49.1%) (Figure 8).

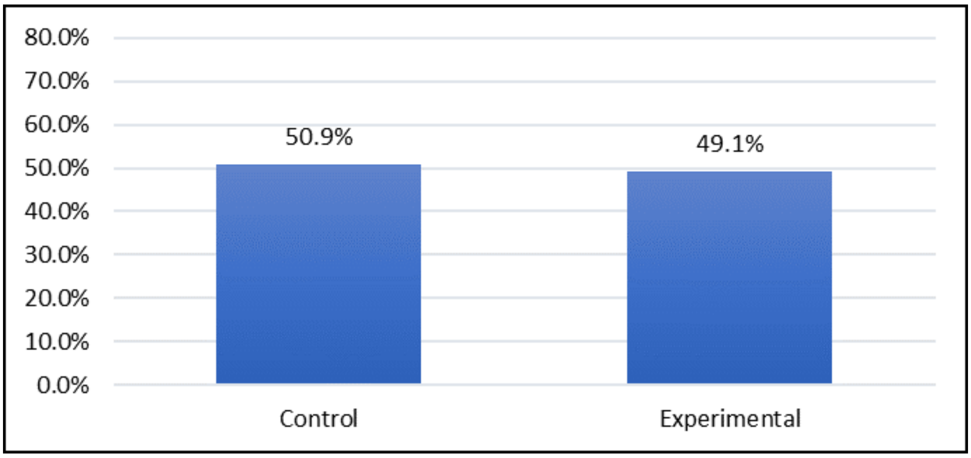

Figure 8: Sample Description- Group

3.9 General Analysis Plan

For the first, second, and the third research question, descriptive statistics was done by finding the mean and standard deviation for all the scales for the two groups. The data analysis employed an independent sample t-test to find out the mean scores of the pretest for the control and experimental groups. Another t-test was also conducted to make comparisons for the mean scores for the post-test between the control and the experimental group. Paired sample t-test was conducted to compare between the scores of the pretest and post-test for each group before and after the intervention. This procedure was done to compare between the scores obtained by the participants in all surveys: KAR test, students' Self-Efficacy Test, and students' attitudes towards scientific inquires.

For the fourth research question, a Pearson product-moment correlation coefficient was calculated to assess the relationship between grade 12 physics students' levels of achievement, self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers and three dimensions of attitudes; scientific inquiry, enjoyment of lessons and care interest.

In addition, the Effect size used. Effect sizes are essential for the outcomes in this study as they highlight their importance to communicate the practical significance of results (Figure 9).

Figure 9: Summary of the Analysis the Data for the Four Questions

3.9.1 Effect Size

Effect sizes are essential for the outcome of this experimental study as they highlight their importance to communicate the practical significance of results. They were measured by Effect Size Calculator by adding the mean scores and standard deviations of the variables and has symbol (d) (Lakens, 2013). Typically, this measure reported as Cohen's d, or simply referred to as "d." One type of effect size, the standardized mean effect, expresses the mean difference between two groups in standard deviation units. Though the values calculated for effect size are generally low, they share the same range as standard deviation (-3.0 to 3.0), so can be quite large.

Effect size is a standard measure that can be calculated from any number of statistical outputs. The meaning of effect size varies by context, but the standard interpretation is Cohen (1988):

0.8 = large (8/10 of a standard deviation unit)

0.5 = moderate (1/2 of a standard deviation)

0.2 = small (1/5 of a standard deviation).

3.9.2 Correlation Analysis

Correlation analysis is another tool critical for quantitative research (Pallant, 2020; Saunders, Lewis, & Thornhill, 2007). Correlation analysis is used to measure the strength and direction of relationship between two variables (Pallant, 2020). The correlation value is denoted by ‘r’ and usually takes any value from ‘0’ to ‘1’. As the value gets closer to ‘1’, it becomes stronger and as it moves away from ‘1’ and closer to ‘0’, it becomes weaker (Pallant, 2010). As indicated by Pallent (2010), ‘r’ value that is between 0 to ‘0.29’ is considered to be weak correlation, ‘r’ value between ‘0.3’ and ‘0.5’ is considered to be medium strength, while ‘r’ value that is above ‘0.5’ is considered to be strong.

3.9.3 Regression Analysis

The most commonly known and used dependence analysis in multivariate method is the multiple regression. The technique deals with the study of dependence of one variable on a set of predictor variables. The predictor set, also known as independent variables, influences the dependent variable or the response variable. The regression line for k explanatory variables $X_1, X_1, X_1, \dots, X_k$ is defined as

$$Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + e_i \quad \text{for i = 1, . . . , n,}$$

where β_0 =intercept of y = constant term. $\beta_1, \ldots, \beta_k$ are coefficients relating to k explanatory variables to the variables of interest. In order to estimate the β's we follow the least square approach. The variance σ^2 may be estimated by $s^2 = \frac{\sum e_i^2}{n-k-1}$, also known as the mean-squared error (or MSE). The estimate of the standard error s is the square root of the MSE. Across behavioral science disciplines, multiple linear regression (MR) is a standard statistical technique in a researchers toolbox. An extension of simple linear regression, multiple regression allows researchers to answer questions that consider the role(s) that multiple independent variables play in accounting for variance in a single dependent variable. Researchers tend to rely heavily on beta weights when interpreting MR results (Nimon, Henson, & Gates 2010; Zientek, 2008).

3.10 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.

The following are the main procedures that were followed when conducting the study; the researcher paid visits to the identified schools and selected the two classes that are used for the study and the classes assigned for the control group. The researcher then engaged the administration of the school regarding the timelines that are required to conduct the research. The administration of the school were informed of the timetable for the other research activities that include pre-test and post-test, a survey of science-related attitudes and a survey of levels of self-efficacy of the student towards learning physics. The researcher also ensured that the consent forms were sent to the parents of the students for their acknowledgement.

The students would then be subjected to the pre-tests. The POGIL-based instruction which is the experiment is implemented for four weeks. The same teacher was also instructing the control group using the traditional teaching method.

Data collection procedures took place in two phases: Pre-intervention and post-intervention. In the pre-intervention, the three instruments (KAR, Self-efficacy and attitudes) were administered before the intervention. In phase two, the same instruments were 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.

Then, an Arabic version of Survey of Self Efficacy was also given to the treatment group and the control groups before the administration of the intervention. It took 20 minutes to be completed. Next, an Arabic version of the Survey of Science Related Attitudes was given to the treatment group and the control groups before the administration of the treatment. It also took 20 minutes.

In phase two, 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. Then the Survey of Science Related Attitudes and Survey of Self Efficacy was given to the control and treatment group. The data collected were coded and given numbers to be ready for analysis (Figure 10).

Figure 10: Steps of Data Collection

3.11 Analysis

Data were coded and entered into a computer using of statistical analysis namely Statistical Package for Social Sciences (SPSS) version 26.0. This program used in different stages of data processing to process the raw data obtained from the questionnaires: for the two groups (Control and Experimental) and for all the three versions of the questionnaires.

3.12 Ethical Considerations

The researcher obtained formal permission and approval from ADEK to carry out the study. Another request for approval was submitted to Social Sciences Research Ethics Committee REC at the United Arab Emirates University, and it was granted. These ethical approvals were necessary to ensure that the study had met the essential ethical requirements. The consent form was sent to parents informing them of the research's aim and the nature of the information that sought from the students. The consent of the parents was also necessary to ensure the study was not carried out under duress or any other forms of coercion. Also, the students were informed that the information gathered during the study was for research purposes only and was not available to unauthorized parties. The students were informed that their participation was voluntary, and they had the right to withdraw at any time had they felt that the study was causing any harms to them.

3.13 Conclusion

This methodology chapter has outlined the design that was adopted for the study and the main approaches in areas such as sampling and the various measures that were used in the study when trying to answer the research questions. Also, the chapter has provided insights into the reliability and validity of the three instruments that were considered crucial in enhancing the quality of the results. For instance, aspects like construct validity have been highlighted to ensure the study was replicable in other settings without significant differences in the results obtained. All the materials and methods of carrying out the intervention in both groups were explained in detail. Such efforts are crucial in ensuring the relevance and purpose of the study are protected, as the findings are credible and authentic. This chapter provides insights for the discussion of the study findings in the next chapter.

Chapter 4: Results

4.1 Introduction

This chapter presents the results of the research study. The chapter will discuss the answers of the research questions and the findings related to question 1 to 4. For the benefit of the reader, the five research questions are:

- **Question 1:** "How do grade 12 students perform in POGIL based instruction versus lecturing based instruction in circular motion unit in physics curriculum of grade as measured by cognitive outcomes of Test of the variables of knowing, applying and reasoning (KAR)?".
- **Question 2:** "How does POGIL based instruction versus lecturing based instruction affect grade 12 students' self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers?".
- **Question 3:** "How does POGIL based instruction versus lecturing based instruction affect the students' attitudes toward scientific inquiry, enjoyment of lessons and career interest (SEC) in physics?".
- **Question 4:** "Are there any correlation between Grade 12 students' performance, self-efficacy and attitudes when they learn by POGIL based instruction and lecturing based instruction?".
- **Question 5:** "What is the effect of interaction, if any, between students' gender and the type of instruction (POGIL-based instruction and lecture-based instruction) on physics performance, their self-efficacy and scientific attitudes?".

In order to answer question 1, 2, 3 & 5 normality tests were conducted first to determine which statistically appropriate test would be used. Descriptive statistics such as mean and standard deviation used to compare between the students' performance in the two groups (control and experimental). To test for statistics significant, p-value less than 0.05 considered to be significant, while p-value less than 0.05 considered to be highly significant.

Finally, MANOVA test was employed to investigate if there are any statistically significant effects in students' performance in physics, their self-efficacy and scientific attitudes that can be attributed to gender. The chapter ends by summarizing the main result.

4.2 Results of Research Question 1

The results presented in Table 8 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 8: 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 8 (above) and Figure 11 showed that participants' Applying abilities was 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 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 of (KAR), participants scored higher in the experimental group (M= 13.91, SD =2.33) than the control group (M= 13.23, SD = 2.00).

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 pre-test measured in this study in circular motion unit in physics curriculum of grade 12, in both control and experimental groups before the intervention.

The results of 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 pre-test 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 pre-test 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) about students' reasoning abilities ($t = 1.067, DF = 108, p - value > 0.05$), which indicated that the performance of the students in the pre-test 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) 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.

The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted. As Huck (2011) showed that Bonferroni adjusted 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 is going to be used" p. 177.

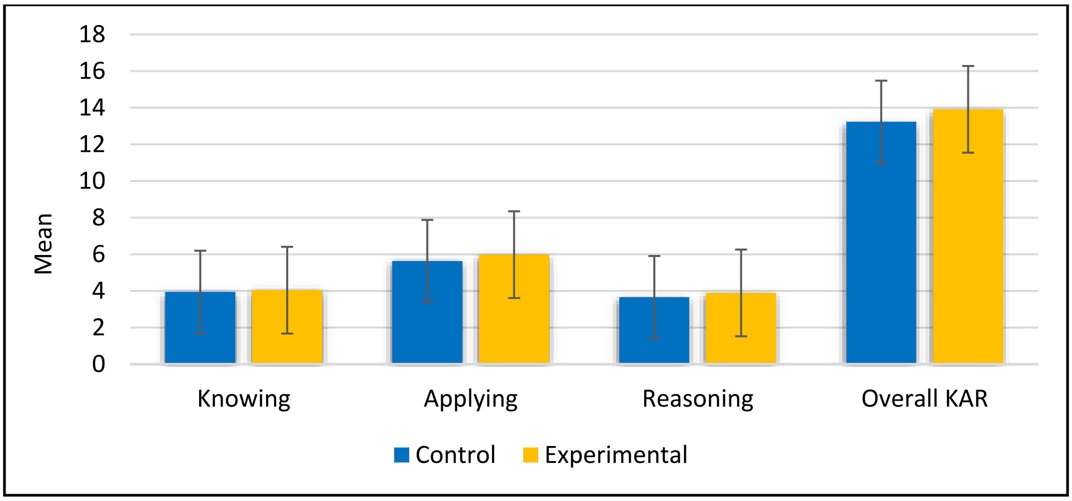

Figure 11: Profile of the Cognitive Outcomes of (KAR) Test –Pretest

Table 9: Results of Paired sample T- Test for the Cognitive Outcomes of the (KAR) Test in the Pre-Test 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

As presented in the Table 9, 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 the lowest (M= 3.64, SD = 1.10). In the total score of the cognitive outcomes of (KAR) test, participants scored mean of 13.45 (SD = 2.00).

In order 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 pre-test and post-test for the control group, the researcher ran Paired sample T- test for related samples.

Results of Paired sample T- test indicated that there was no significant difference in means of the students' knowing scores in the pre-test and post-test for control group ($t = 1.29, DF = 55, p - value > 0.05$). No significant difference shown in means of the students' applying scores ($t = 0.97, DF = 55, p - value > 0.05$), and no significant difference 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 pre-test and post-test for control group ($t = 0.641, DF = 55, p - value > 0.05$). We can conclude that the performance of the students in the cognitive outcomes of the (KAR) in pre-test and post-test for the control group was the same. The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted.

Table 10: 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.

Table 10 above and Figure 12 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). With regard to 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).

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 circular motion unit in physics curriculum of grade 12, in both control and experimental groups after the intervention.

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.

The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted.

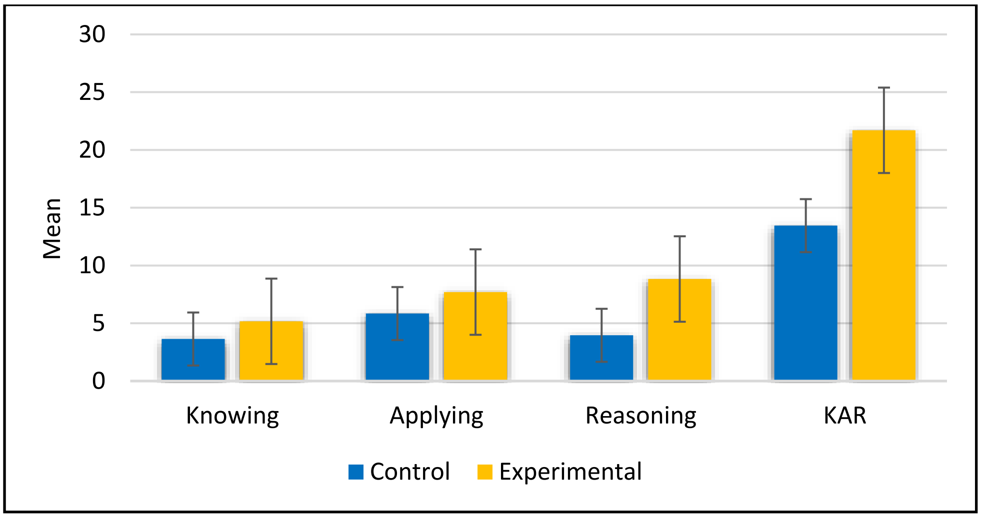

Figure 12: Profile of the Students in the Cognitive Outcomes of (KAR)-Post-Test

Table 11: Results of Paired sample T- Test for the Cognitive Outcomes of the (KAR) Test in the Pre-Test and Post-Test for the Experimental Group

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

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

The results presented in Table 11 displays the results of Paired sample T- test for related samples of the scores of three subscales of (KAR) test in pretest and post-test for experimental group taught by POGIL-based instruction.

The results indicated that there was a high significant difference in means of the scores of knowing in favor of post-test ($t = 5.30, DF = 53, p - value$ (0.00) $<$ 0.05). The mean of scores of knowing for students in the post-test was higher than that observed in the pretest. Students in the experimental group were more likely to had high performance in knowing after the intervention, comparing with their scores in the pretest.

In addition, there was a high significant difference in means of the scores of applying in favor of post-test ($t = 3.72, DF = 53, p - value$ $(0.00) < 0.05)$. The mean of scores of applying for students in the post-test was higher than that observed in the pretest. Students in the experimental group were more likely to had high performance in applying after the intervention, comparing with their scores in the pretest.

Moreover, there was a high significant difference in means of the scores of reasoning in favor of post-test ($t = 21.83, DF = 53, p - value$ $(0.00) < 0.05$). The mean of scores of reasoning for students in the post-test was higher than that observed in the pretest. Students in the experimental group were more likely to had high performance in reasoning after the intervention, comparing with their scores in the pretest.

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

The same results were obtained after using Bonferroni adjusted significance criterion of the p- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 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 KAR test.

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

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

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:

$$d = \frac{Mean\ diffrence}{\text{SDdiff}} \times 100 = \frac{1.13}{1.57} \times 100 = 0.75 \times 100 = 75\%$$

Through effect size of calculated above, it could be figured out 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:

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

Through effect size of calculated above, it could be figured out 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:

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

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for reasoning scores for the experimental group is 298%. This percentage indicates that this tool is effective in elevating 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:

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

Through effect size of calculated above, it could be figured out 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 13).

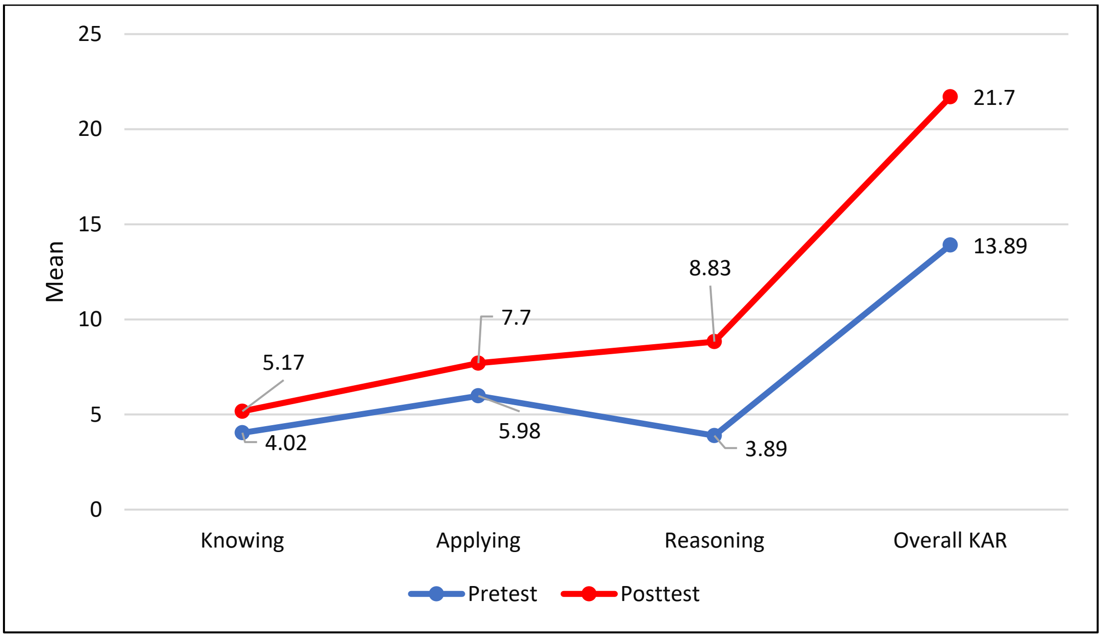

Figure 13: Profile of the cognitive outcomes Test of (KAR)-Pretest vs Post-test

4.3 Results of Research Question 2

"How does POGIL based instruction versus lecturing based instruction affect grade 12 students' self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers?"

In order to answer this question, the scores of the students in the pretest of self-efficacy survey were obtained. Then, descriptive statistics such as mean, and standard deviation used to compare between the students' performance in the two groups (control and experimental) regarding physics learning, understanding of physics, Willingness to learn physics, and the total scores of Self-Efficacy.

The data analysis employed T-test for independent sample to find out if there are statistically significant differences between the mean scores of the two groups, while T- test for related samples used find out if there are statistically significant differences between the mean scores of the pre- and post-measured in this study in each domain.

The results presented in Table 12 display the test scores of Self-efficacy subscales in pre-test in the control group taught by lecturing based instruction method and experimental group taught by POGIL-based instruction.

Table 12: Results of Independent Samples T- Test for Physics Learning, Understanding of Physics, Willingness to Learn Physics, and Overall Self-Efficacy: Pre-Test

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 12 and Figure 14 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 Self-efficacy test, participants scored higher in the experimental group (M= 8.13, SD =0.99) than 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 pre-test measured in this study for the subscales of 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) about 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 pre-test was the same.

Statistically, there is no significant difference was found between the control group (M =2.57, SD = 0.68) and experimental group (M =2.70, SD =0.60) about 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) about 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 was found between the control group (M = 7.89, SD = 1.02) and experimental group (M = 8.13, SD =0.99) about 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 Bonferroni adjusted significance criterion of the p- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted.

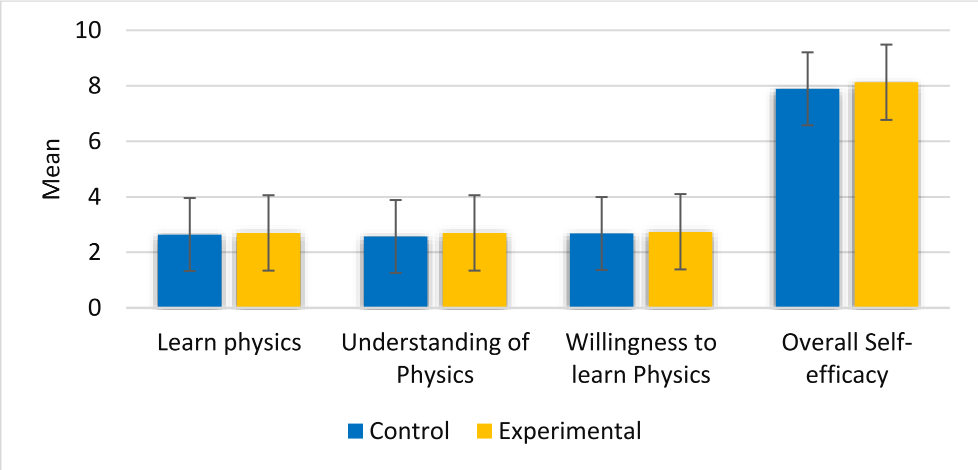

Figure 14: Profile of the Students in the Pre-Test for the Subscales and Whole Test of Self-Efficacy

Table 13: Results of T- Test for Related Samples in the Pre-Test 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 Efficacy1	Pretest	7.89	1.02	0.09	0.44	55	0.66
	Post-test	7.80	1.07				

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

As presented in the Table 13, for the control group the participants' understanding of Physics was the highest (M = 2.70, SD = 0.63), followed by willingness to learn Physics (M = 2.66, SD =0.61), while participants' Physics learning reported the lowest (M= 2.45, SD = 0.63). In the total scores of Self-efficacy test, participants scored mean of 7.80 (SD = 1.07).

Results of T-test for related samples indicated that no significant differences in means of the students' performance in the control group in learn physics in pre-test and post-test ($t = 1.56, DF = 55,\ p - value\ (0.12) > 0.05$), which indicated that the performance of the students in the pre-test and post-test of learn physics was the same.

With regard to students' understanding of physic, there was no significant difference in means of the in the control group in the pre-test and post-test ($t = 0.98, DF = 55,\ p - value\ (0.33) > 0.05$), which indicated that the performance of the students in the pre-test and post-test of understanding of physic was the same.

Likewise, statistically, no significant difference shown in means of the students' 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 pre-test and post-test of willingness to learn physics was the same. Overall, no significant difference in means of total scores of Self-efficacy in pre-test and post-test for control group ($t = 0.44, DF = 55,\ p - value\ (0.66) > 0.05$). We can conclude that the students' performance in Self-efficacy survey in for the control group was the same before and after the intervention.

The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted.

Table 14: Results of Independent Samples T- Test for 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

Table 14 shows that participants' willingness to learn Physics was the highest in experimental group (M = 4.17 and SD = 0.75), then Physics learning came with mean of 3.78 (SD = 0.60), while participants' understanding of Physics came last with mean scores of 3.74 (SD = 0.76). With regard to control group, participants' understanding of Physics was the highest (M = 2.70, SD = 0.63), then willingness to learn Physics came with 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 Self-efficacy test, participants scored higher in the experimental group (M= 11.69, SD = 1.24) than the control group (M = 7.80, SD = 1.07).

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 high significant difference between the control group and experimental group about students' Physics learning in favor of experimental group $(t = 11.31, DF = 108, p - value\ (0.00) < 0.05)$. Students in experimental group were more likely to had good performance in Physics learning in the post-test comparing to control group. In addition, statistically there was a high significant difference found between the control group and experimental group about students' understanding of Physics in favor of experimental group $(t = 7.88, DF = 108, p - value\ (0.00) < 0.05)$. Students in experimental group were more likely to had good performance in understanding Physics in the post-test comparing to control group.

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' willingness to learn Physics in favor of experimental group $(t = 11.60, DF = 108, p - value\ (0.00) < 0.05)$. Students in experimental group were more likely to had good performance in willingness to learn Physics in the post-test comparing to control group.

Statistically there was a high significant difference found between the control group and experimental group about students' Self- efficacy as whole in favor of experimental group $(t = 17.60, DF = 108, p - value\ (0.00) < 0.05)$. Students in experimental group were more likely to had good Self- efficacy in the post-test comparing to control group. The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (0.05/4) since 4 tests were conducted.

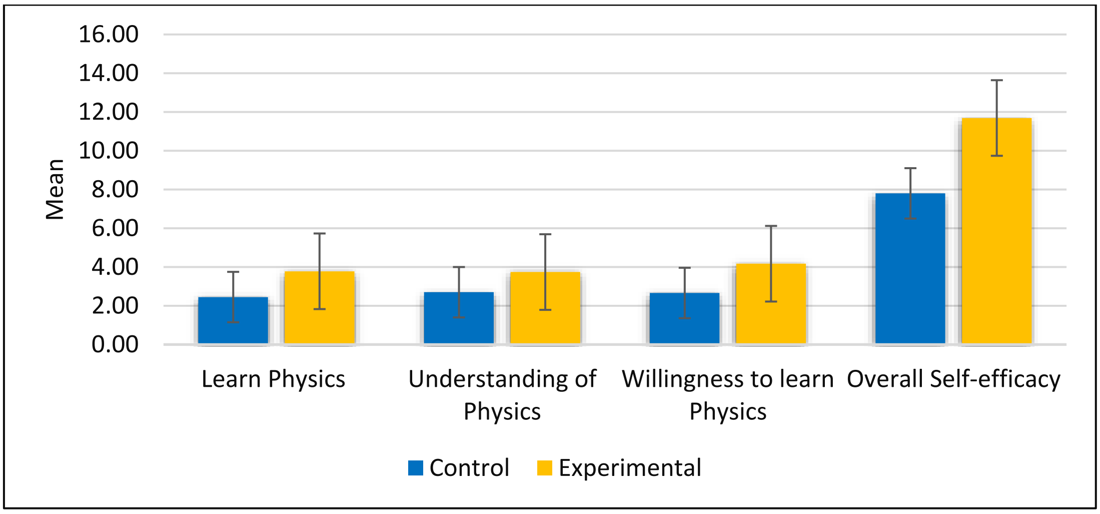

Figure 15: Profile of the Students in the Post-Test for the Subscales and Whole Test of Self-Efficacy

Table 15: Results of T-Test for Related Sample in the Pre-Test and Post-Test for the Experimental Group for the Subscales of Self-Efficacy Survey

Scale	Test	**Mean**	**Std. Dev.**	**Mean diff.**	**SD diff.**	**T**	**df**	**Sig.**	**d**
Physics Learning	Pre	2.69	0.54	1.09	0.78	10.25	53	0.000	1.40
	Post	3.78	0.60						
Applying Understanding of Physics	Pre	2.70	0.60	1.04	0.73	10.50	53	0.000	1.42
	Post	3.74	0.76						
Reasoning	Pre	2.74	0.59	1.43	0.98	10.66	53	0.000	1.46
	Post	4.17	0.75						
Willingness to learn Physics	Pre	8.13	0.99	3.56	1.40	18.71	53	0.000	2.54
	Post	11.7	1.24						

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

The results presented in Table 15 and Figure 15 display the results T-test for related samples of the scores of the domains of Self- efficacy in pretest and post-test for experimental group taught by POGIL-based instruction.

The results indicated that there was a high significant difference in means of the scores of learn Physics in favor of post-test $(t = 10.25, DF = 53, p - value\ (0.00) < 0.05)$. The mean of scores of students' Physics learning was higher than that observed in the pretest. Students in the experimental group were more likely to had good performance Physics learning after the intervention.

In addition, there was a high significant difference in means of the scores of understanding of Physics in favor of post-test ($t = 10.50, DF = 53, p-value$ $(0.00) < 0.05$). The mean of scores of students' understanding of Physics was higher than that observed in the pretest. Students in the experimental group were more likely to had had good performance in understanding of Physics after the intervention.

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

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

Thus, students in the experimental group were more likely to had good Self-efficacy after the intervention (Figure 15 below). Using the data presented in Table 15, the effect size of the POGIL approach for Physics learning scores for the experimental group will be:

$$D = \frac{Mean\ diffrence}{\text{SDdiff}} \times 100 = \frac{1.09}{0.78} \times 100 = 1.40 \times 100 = 140\%$$

Through effect size of calculated above, it could be figured out 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 understanding of Physics scores for the experimental group will be:

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

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for understanding of Physics scores for the experimental group is 142%. This percentage indicates that this tool is effective in elevating 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:

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

Through effect size of calculated above, it could be figured out 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 is effective in elevating 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. With regard to overall students' self- efficacy, the effect size of the POGIL approach for Self- efficacy scores for the experimental group will be:

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

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for Self- efficacy scores for the experimental group is 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 16).

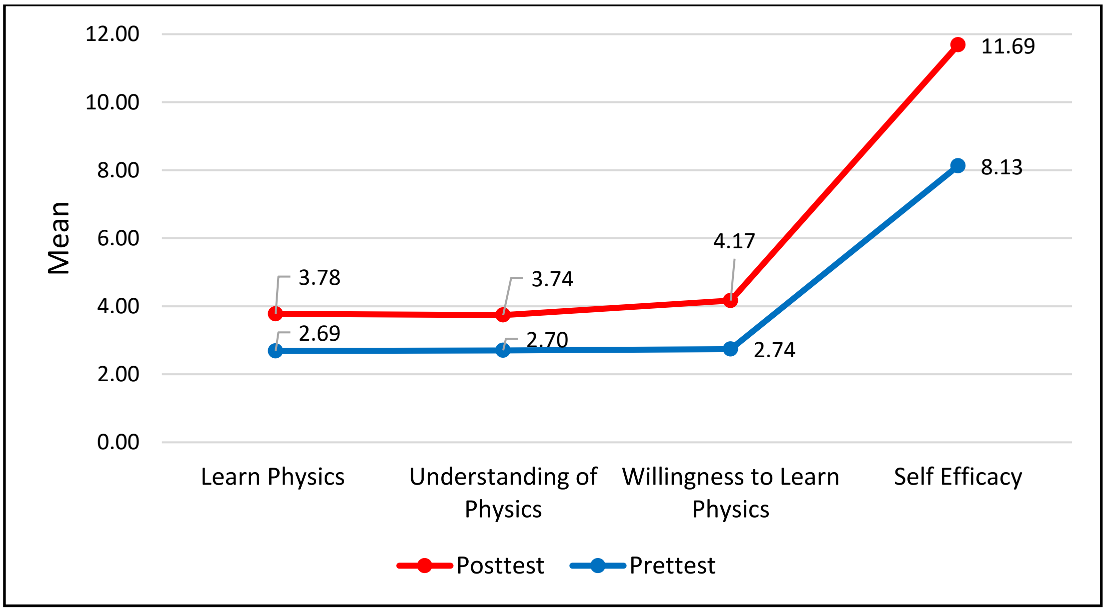

Figure 16: Profile of the Experimental Group in the Subscales of Self- Efficacy Survey: Pretest vs Post-Test

4.4 Results of Research Question 3

"How do POGIL based instructions versus lecturing based instruction affect Grade 12 students' attitudes toward scientific inquiry, enjoyment of lessons and career interest (SEC) in physics?”

To answer this question, the scores of the students in the pretest of students' attitudes toward scientific inquiry were obtained. Descriptive statistics such as mean, and standard deviation used to compare between the students' attitudes in the two groups (control and experimental) regarding Scientific inquiry, Enjoyment of Science lessons, Career interest in Science, and the total scores of attitudes towards scientific inquiry.

The data analysis employed T-test for independent sample to find out if there are statistically significant differences between the mean scores of the two groups, while T-test for related samples used find out if there are statistically significant differences between the mean scores of the pre- and post-measured in this study in each domain of students' attitudes towards scientific inquiry.

Table 16: T-test for Independent Samples for the Subscales of Students' Attitudes Towards Scientific Inquiry Survey: Pre-Test

Scale	Group	N	Mean	Std. Dev.	t	df	Sig.
Scientific inquiry	Control	56	2.54	0.71	0.61	108	0.540
	Experimental	54	2.61	0.56			
	Total	110	2.57	0.64			
Enjoyment of Science lessons	Control	56	2.50	0.54	0.83	108	0.409
	Experimental	54	2.59	0.63			
	Total	110	2.55	0.58			
Career interest in Science	Control	56	2.64	0.52	1.06	108	0.291
	Experimental	54	2.74	0.44			
	Total	110	2.69	0.48			
Overall attitudes towards scientific inquiry	Control	56	7.79	1.12	0.80	108	0.428
	Experimental	54	7.94	0.96			
	Total	110	7.86	1.05			

Std. Dev.=Standard Deviation

The results presented in Table 16 describe the T-test results for independent samples for the subscales and the whole scale before and after the intervention in the control group taught by lecturing based instruction method and experimental group taught by POGIL-based instruction. As showed from the table, participants' attitudes in Career interest in Science was the highest in both groups (Control Group M = 2.64, SD = 0.52) and (Experimental Group M =2.74, SD = 0.44) followed by their attitudes in Scientific inquiry (Control Group M = 2.54, SD = 0.71) and (Experimental Group M = 2.61, SD = 0.56).

However, participants' Enjoyment of Science lessons reported the lowest in both groups (Control Group M = 2.50, SD = 0.54) and (Experimental Group M = 2.59, SD = 0.63). In the total score of the students' attitudes towards scientific inquiry, participants scored higher in the experimental group (M = 7.94, SD = 0.96) than the control group (M = 7.79, SD = 1.12).

The results of T-test for independent samples showed that statistically there were no significant differences between the control group (M =2.54, SD = 0.71) and experimental group (M = 2.61, SD = 0.55) about students' perceptions towards Scientific inquiry ($t = 0.61, DF = 108, p - value$ (0.54) > 0.05), which indicated that students' perceptions towards Scientific inquiry in the pre-test was the same.

In addition, statistically there is no significant difference was found between the control group (M = 2.50, SD = 0.54) and experimental group (M = 2.59, SD = 0.63) about students' perceptions towards Enjoyment of Science lessons ($t = 0.83, DF = 108, p - value$ (0.40) > 0.05, which indicated that students' perceptions towards Enjoyment of Science lessons before the intervention was the same. Moreover, no statistically significant difference was shown between the control group (M = 2.64, SD = 0.52) and experimental group (M = 2.74, SD = 0.44) about students' perceptions towards Career interest in science, which indicated that students' perceptions towards Career interest in science before the intervention was the same

$(t = 1.06, DF = 108, p - value\ (0.29) > 0.05)$.

Overall, statistically there is no significant difference was found between the control group (M = 7.79, SD = 1.12) and experimental group (M = 7.94, SD = 0.96) in overall attitudes towards scientific inquiry $(t = 0.80, DF = 108, p - value\ (0.42) > 0.05$, which indicated that the overall students' perceptions towards scientific inquiry to before the intervention was the same.

The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted (Figure 17).

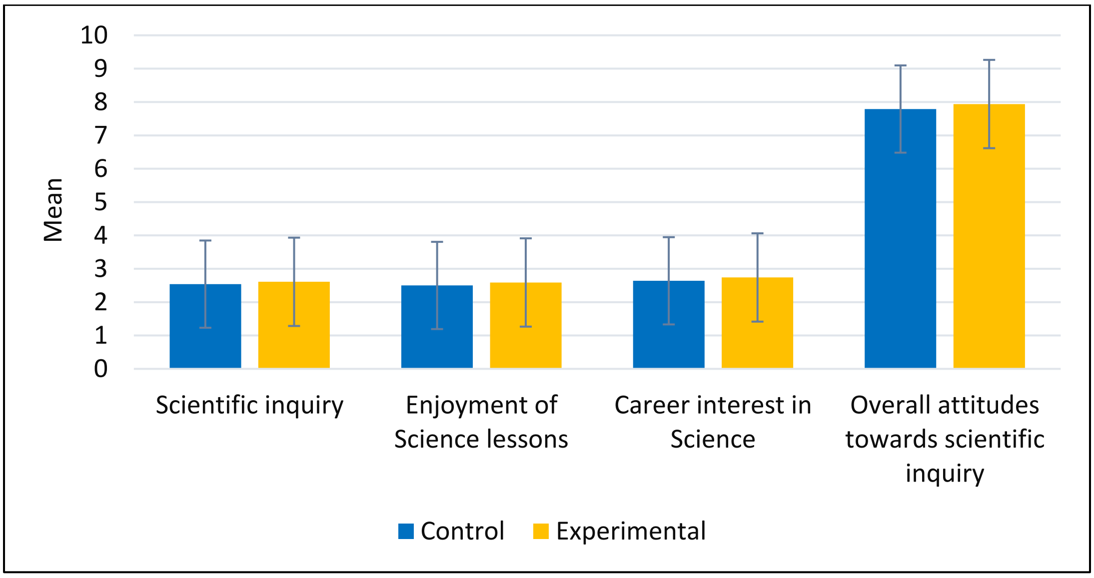

Figure 17: Profile of the Students in the Subscales of Students' Attitudes towards Scientific Inquiry: Pretest

Table 17: Results of T-test Test for Related Samples for the Students' Attitudes towards Scientific Inquiry Survey in the Pre-Test and Post-Test for the Control Group

Scale	Test	Mean	Std. Dev.	Mean Diff.	t	Df	Sig.
Scientific inquiry	Pretest	2.54	0.71	0.14	1.21	55	0.231
	Post-test	2.68	0.47				
Enjoyment of Science lessons	Pretest	2.50	0.54	0.07	0.63	55	0.532
	Post-test	2.43	0.60				
Career interest in Science	Pretest	2.64	0.52	0.09	0.96	55	0.340
	Post-test	2.73	0.49				
Overall attitudes towards scientific inquiry	Pretest	7.79	1.12	0.05	0.26	55	0.799
	Post-test	2.54	0.71				

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

As presented in Table 17 above, participants' perceptions towards career interest in science was the highest (M = 2.73, SD = 0.50), followed by students' Scientific inquiry (M = 2.68, SD = 0.47), while participants' perception towards Enjoyment of Science lessons reported the lowest (M = 2.43, SD = 0.60). In the total score of the students' attitudes towards scientific inquiry participants scored mean of 7.84 (SD = 1.00).

In order to detect whether there were statistically significant differences between the means of the scores of the students' attitudes towards scientific inquiry in the pre-test and post-test for the control group, the researcher ran T-test test for related samples.

Results of T-test test for related samples indicated that, no significant differences in means of the students' perceptions in the control group towards scientific inquiry in pre-test and post-test ($t = 1.21, DF = 55, p - value$ (0.23) $>$ 0.05), which indicated that students' perceptions towards Scientific inquiry was the same.

In addition, no significant difference in means of the students' perceptions in the control group towards Enjoyment of Science lessons before and after the intervention ($t = 0.63, DF = 55, p - value$ (0.53) > 0.05), which indicated that students' perceptions towards Enjoyment of Science lessons was the same.

Likewise, no significant difference in means of the students' perceptions in the control group towards Career interest in Science the in pre-test and post-test ($t = 0.96, DF = 55, p - value$ (0.34) > 0.05), which indicated that students' perceptions towards Career interest in Science was the same.

Overall, no significant difference in means of total scores of the students' attitudes towards scientific inquiry before and after the intervention for control group ($t = 0.26, DF = 55. p - value$ (0.79) > 0.05). We can conclude that the perceived perceptions of the students' attitudes towards scientific inquiry survey in for the control group was the same before and after the intervention.

The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted.

Table 18: Descriptive Statistics of the Perceived Perceptions of Students' Attitudes towards Scientific Inquiry for the Students in the Two Groups -Post-Test

Scale	Group	N	Mean	Std. Dev.	t	df	Sig.
Scientific inquiry	Control	56	2.68	0.47	13.91	108	0.000
	Experimental	54	4.13	0.62			
	Total	100	3.39	0.91			
Enjoyment of Science lessons	Control	56	2.43	0.60	16.47	108	0.000
	Experimental	54	4.20	0.53			
	Total	100	3.30	1.05			
Career interest in Science	Control	56	2.73	0.49	15.86	108	0.000
	Experimental	54	4.24	0.51			
	Total	100	3.47	0.91			
Overall attitudes towards scientific inquiry	Control	56	7.84	1.00	23.29	108	0.000
	Experimental	54	12.57	1.14			
	Total	100	10.16	2.60			

Std. Dev.= Standard Deviation.

Table 18 shows that participants' perceived perceptions for Career interest in science was the highest in experimental group (M = 4.24, SD = 0.51), then perceived perceptions for Enjoyment of Science lessons came with mean of 4.20 (SD = 0.53), while perceived perceptions for Scientific inquiry came last with mean scores of 4.13 (SD = 0.62). With regard to control group, participants' perceived perceptions for Career interest in science was the highest (M = 2.73, SD = 0.49), then perceived perceptions for Scientific inquiry came with mean of 2.68 (SD = 0.47), while perceived perceptions for Enjoyment of Science lessons came last with mean scores of 2.43 (SD = 0.60). In the total score of the students' attitudes towards scientific inquiry, participants scored higher in the experimental group (M = 12.57, SD = 1.14) than the control group (M = 7.84, SD = 1.00).

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' perceived perceptions of Scientific inquiry in favor of experimental group ($t = 13.91, DF = 108, p - value\ (0.00) < 0.05$). Students in experimental group were more likely to had positive perceptions in scientific inquiry 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' perceived perceptions of Enjoyment of Science lessons in favor of experimental group ($t = 16.47, DF = 108, p - value$ (0.00) < 0.05). Students in experimental group were more likely to have positive perceptions in Enjoyment of Science lessons after the intervention comparing to control group.

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' Career interest in Science in favor of experimental group ($t = 15.86, DF = 108, p - value$ (0.00) < 0.05). Students in experimental group were more likely to had positive perceptions in Career interest in science in after the intervention comparing to control group.

Overall, statistically there was a high significant difference found between the control group and experimental group about students' attitudes towards scientific inquiry as whole in favor of experimental group ($t = 23.29, DF = 108, p - value$ (0.00) < 0.05). Students in experimental group were more likely to had positive perceptions towards scientific inquiry after the intervention comparing to control group.

The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted (Figure 18).

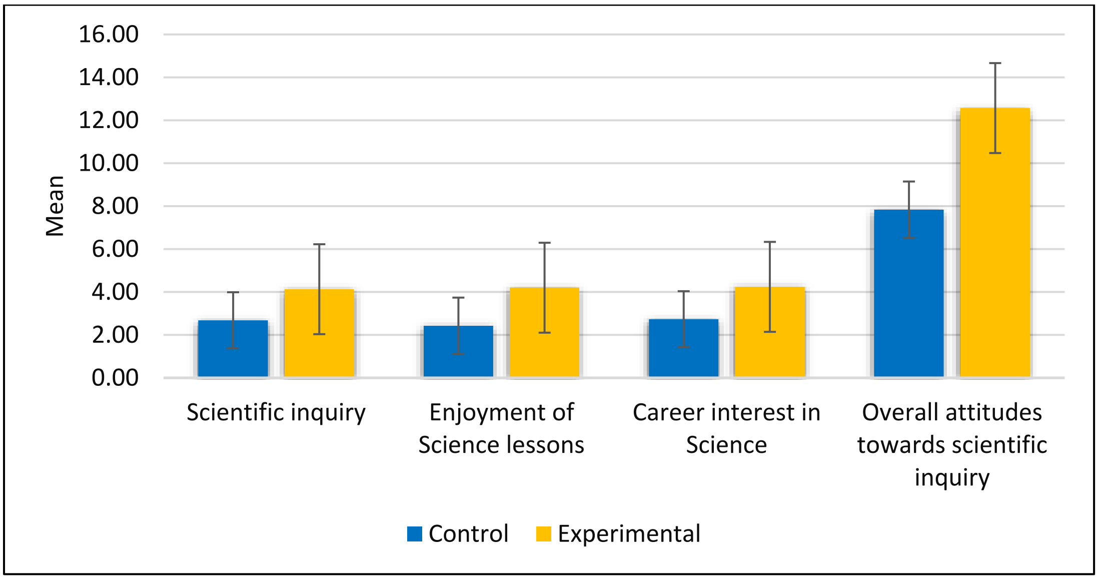

Figure 18: Profile of the Student's Perceptions towards Scientific Inquiry after the Intervention

Table 19: Results of T-test for Related Samples for the Student's Perceptions Towards Scientific Inquiry in the Pre-Test and Post-Test for the Experimental Group

Scale	Test	Mean	Std. Dev.	Mean diff.	SD diff.	t	df	Sig.	d
Scientific inquiry	Pretest	2.61	0.56	1.52	0.84	13.27	53	0.000	1.81
	Post-test	4.13	0.62						
Enjoyment of Science lessons	Pretest	2.59	0.63	1.61	0.88	13.49	53	0.000	1.83
	Post-test	4.20	0.53						
Career interest in Science	Pretest	2.74	0.44	1.50	0.64	17.31	53	0.000	2.43
	Post-test	4.24	0.51						
Overall attitudes	Pretest	7.94	0.96	4.63	1.59	21.35	53	0.000	2.91
	Post-test	12.57	1.14						

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

The results presented in Table 19 displays the results of T-test for related samples of the scores of the student's perceptions towards scientific inquiry in pretest and post-test for experimental group taught by POGIL-based instruction.

The results indicated that there was a high significant difference in means of the scores of scientific inquiries in favor of post-test $(t = 13.27, DF = 53, p - value\ (0.00) < 0.05)$. The mean of scores of students' perceived perceptions of scientific inquiry was higher than that observed in the pretest. Students in the experimental group were more likely to had positive perceptions in scientific inquiry after the intervention. In addition, there was a high significant difference in means of the scores of Enjoyments of Science lessons in favor of post-test ($t = 13.49, DF = 53, p - value$ (0.00) < 0.05. The mean of scores of students' perceived perceptions of Enjoyment of Science lessons was higher than that observed in the pretest. Students in the experimental group were more likely to had positive perceptions in Enjoyment of Science lessons after the intervention.

Moreover, there was a high significant difference in means of the scores of Career interest in science in favor of post-test ($t = 17.31, DF = 53, p - value$ (0.00) < 0.05). The mean of scores of students' perceived perceptions of Career interest in science was higher than that observed in the pretest. Students in the experimental group were more likely to had positive perceptions in Career interest in science after the intervention.

Overall, there was a high significant difference in means of the scores of the total scores of the students' attitudes towards scientific inquiry in favor of post-test ($t = 21.35, DF = 53, p - value$ (0.00) < 0.05). The mean of scores of students' perceived perceptions of overall attitudes towards scientific inquiry was higher than that observed in the pretest. The same results were obtained after using Bonferroni adjusted significance criterion of the *p*- value 0.05. The adjusted p-value was = 0.0125 (.05/4) since 4 tests were conducted.

Thus, students in the experimental group were more likely to have positive perceptions in attitudes towards scientific inquiry after the intervention (Figure 19). Using the data presented in Table 19, the effect size of the POGIL approach for scientific inquiry scores for the experimental group will be:

$$D = \frac{Mean\ diffrence}{\text{SDdiff}} \times 100 = \frac{1.52}{0.84} \times 100 = 1.81 \times 100 = 181\%$$

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for scientific inquiry scores for the experimental group is 181%. This percentage indicates that this tool is effective in elevating scientific inquiry ability among the students in the experimental group by approximately 1.81 level of standard deviation. Further, Cohen's effect size value (*d* =1.81) suggested a high practical significance. In addition, the effect size of the POGIL approach for Enjoyment of Science lessons scores for the experimental group will be:

$$D = \frac{Mean\ diffrence}{\text{SDdiff}} \times 100 = \frac{1.61}{0.88} \times 100 = 1.83 \times 100 = 183\%$$

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for Enjoyment of Science lessons scores for the experimental group is 183%. This percentage indicates that this tool is effective in elevating Enjoyment of Science lesson's ability among the students in the experimental group by approximately 1.83 level of standard deviation. Further, Cohen's effect size value (*d* = 1.83) suggested a high practical significance. Likewise, the effect size of the POGIL approach for Career interest in science scores for the experimental group will be:

$$D = \frac{Mean\ diffrence}{\text{SDdiff}} \times 100 = \frac{1.50}{0.64} \times 100 = 2.34 \times 100 = 243\%$$

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for Career interest in Science scores for the experimental group is 243%. This percentage indicates that this tool is effective in elevating Career interest in Science among the students in the experimental group by approximately 2.43 level of standard deviation. Further, Cohen's effect size value (*d* = 2.43) suggested a very high practical significance. The effect size of the POGIL approach for students' attitudes towards scientific inquiry scores for the experimental group will be:

$$D = \frac{Mean\ diffrence}{\text{SDdiff}} \times 100 = \frac{4.63}{1.59} \times 100 = 2.91 \times 100 = 291\%$$

Through effect size of calculated above, it could be figured out that the percentage of the POGIL approach for students' attitudes towards scientific inquiry scores for the experimental group is 291%. This percentage indicates that this tool is effective in elevating students' attitudes towards scientific inquiry among the students in the experimental group by approximately 2.91 level of standard deviation. Further, Cohen's effect size value (*d* = 2.91) suggested a high practical significance.

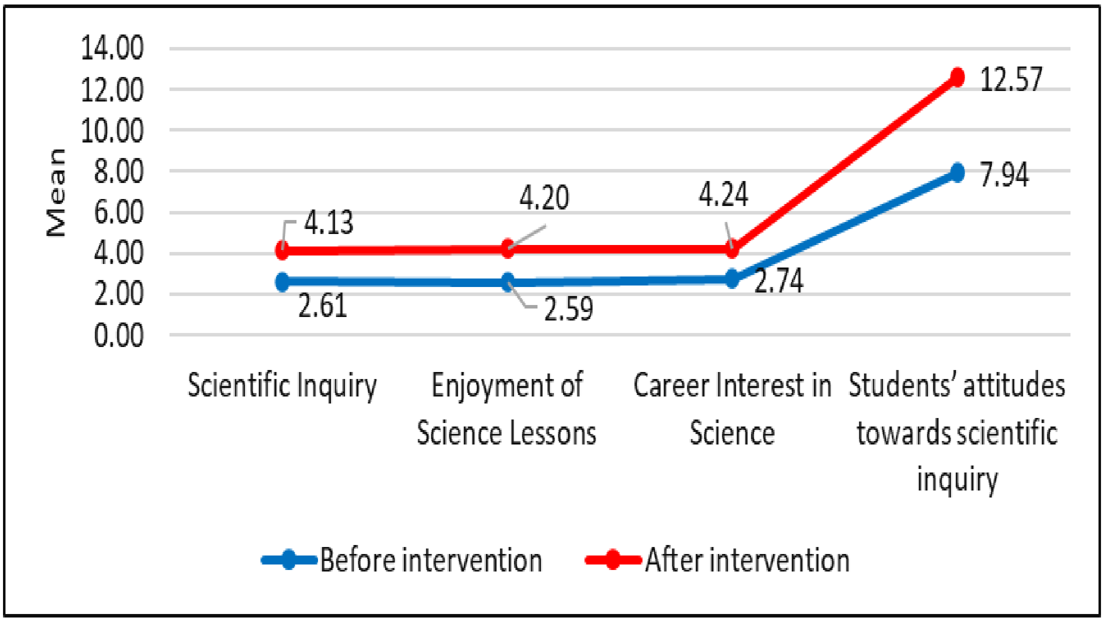

Figure 19: Profile of the Experimental Group in the Attitudes towards Scientific Inquiry -Pretest vs Post-Test

4.5 Results of Research Question 4

> "Is there any correlation between Grade 12 students' performance, self-efficacy and attitudes when they learn by POGIL based instruction and lecturing based instruction?"

This research question aims to make correlation and relationships between all the themes of the research, including Grade 12 students' academic performance, self-efficacy and attitudes when learning via POGIL based instruction and lecturing based instruction. This question is an attempt to connect all the variables and themes to draw the whole portrait of the study.

4.5.1 Correlation Analysis

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

Table 20: 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 21: 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 conducted to determine the correlation between students' performance in KAR, Self-Efficacy, and views towards science inquiry amongst 54 participants in experimental group. Statistically, there was a very strong, positive and significant correlation between students' performance in KAR and their Self-Efficacy $(r = 0.704, p - value\ (0.00) < 0.05)$ which indicated that as students' performance in KAR increase, their Self-Efficacy increase.

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

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

4.5.2 Regression Analysis

Multiple Liner Regression was conducted in order to find the relationship between Grade 12 students' performance as dependent variable, 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 in order to examine all the paths of the relations through the resultant path coefficients.

Table 22: Model Summary: Relationship between Students' Performance, Self-Efficacy and Attitudes when They Learn by POGIL Based Instruction

R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
0.732	0.536	0.513	2.053

Table 23: ANOVA for 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**			

The prediction model contained two predictors namely Self-Efficacy and students' attitudes towards science inquiry used to predict Students' performance in KAR. As Tables 22-23 showed, the multiple correlation R indicated that there was positive correlation between the independent variables and the dependent variable (r = 0.732).

The model was statistically significant, F (2, 51) = 29.45, p-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 24: 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 24. The Coefficients table provides us with the necessary information to predict the dependent variable from the predictors, as well as determine whether the predictors contribute statistically significantly to the model.

Self-Efficacy received the strongest weight in the model. Therefore, Self-Efficacy statistically has a positive effect on students' performance since the results indicated that ($\beta = 0.57, t = 4.88, p - value\ (0.00) < 0.05$). In addition, students' attitudes towards science inquiry statistically has a positive effect on students' performance since ($\beta = 0.24, t = 2.10, p - value\ (0.04) < 0.05$).

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 a 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 students' attitudes towards science inquiry has positive effect on students' performance.

4.6 Results of Research Question 5

> "What is the effect of interaction, if any, between students' gender and the type of instruction (POGIL-based instruction and lecture-based instruction) on physics performance, their self-efficacy and scientific attitudes?".

This research question aims to investigate whether gender may have interacted with the type of treatment (when learning via POGIL based instruction and lecturing based instruction) for Grade 12 students' academic performance in physics, self-efficacy and attitudes.

To statistically analyze this question, it is more convenient to rephrase it as follows;

This question can be divided into three parts to be analyzed and three Multivariate analyses were conducted:

1- Is there a statistically significant interaction between students' gender and types of instruction with regard to academic performance in physics?

2- Is there a statistically significant interaction between students' gender and types of instruction with regard to their self-efficacy?
3- Is there a statistically significant interaction between students' gender and types of instruction with regard to scientific attitudes?

4.6.1 Academic Performance &Interaction between Gender and Treatment

The descriptive statistics listed in Table 25 show that there are differences in means between male and female students in (KAR). To ensure whether these differences are statistically significant, a multivariate analysis of variance was conducted.

Table 25: Descriptive Statistics, Gender & Physics Achievement

Treatment			Mean	Std. Deviation	N
Sum_Knowing_Post	Control	female	3.67	1.109	27
		male	3.62	1.115	29
		Total	3.64	1.103	56
	Experimental	female	5.04	1.060	25
		male	5.28	0.702	29
		Total	5.17	0.885	54
	Total	female	4.33	1.279	52
		male	4.45	1.245	58
		Total	4.39	1.257	110
Sum_Applying_Post	Control	female	6.04	1.454	27
		male	5.66	1.233	29
		Total	5.84	1.345	56
	Experimental	female	7.84	1.599	25
		male	7.59	2.529	29
		Total	7.70	2.134	54
	Total	female	6.90	1.763	52
		male	6.62	2.199	58
		Total	6.75	2.001	110
Sum_Reasoning_Post	Control	female	4.26	1.534	27
		male	3.69	1.198	29
		Total	3.96	1.388	56
	Experimental	female	8.88	1.301	25
		male	8.79	1.521	29
		Total	8.83	1.411	54
	Total	female	6.48	2.726	52
		male	6.24	2.910	58
		Total	6.35	2.814	110

Table 26: Multivariate Tests, Gender Interaction with Treatment in Physics Achievement

Effect		Value	F	Hypothesis df	Error df	Sig.
	Pillai's Trace	0.982	1942.731^b	3.000	104.000	0.000
	Wilks' Lambda	0.018	1942.731^b	3.000	104.000	0.000
	Hotelling's Trace	56.040	1942.731^b	3.000	104.000	0.000
	Roy's Largest Root	56.040	1942.731^b	3.000	104.000	0.000
Treatment	Pillai's Trace	0.791	130.811^b	3.000	104.000	0.000
	Wilks' Lambda	0.209	130.811^b	3.000	104.000	0.000
	Hotelling's Trace	3.773	130.811^b	3.000	104.000	0.000
	Roy's Largest Root	3.773	130.811^b	3.000	104.000	0.000
Gender	Pillai's Trace	0.022	$.767^b$	3.000	104.000	0.515
	Wilks' Lambda	0.978	$.767^b$	3.000	104.000	0.515
	Hotelling's Trace	0.022	$.767^b$	3.000	104.000	0.515
	Roy's Largest Root	0.022	$.767^b$	3.000	104.000	0.515
Treatment * Gender	Pillai's Trace	0.012	$.432^b$	3.000	104.000	0.730
	Wilks' Lambda	0.988	$.432^b$	3.000	104.000	0.730
	Hotelling's Trace	0.012	$.432^b$	3.000	104.000	0.730
	Roy's Largest Root	0.012	$.432^b$	3.000	104.000	0.730

a. Design: + Treatment + Gender + Treatment * Gender
b. Exact statistic

Table 26 shows that there was no statistically significant interaction effect between gender and type of intervention with regard to the academic performance in physics on the combined dependent variables, $F (3, 104) = 0.432$, $p = .730$; Wilks' $\Lambda = .988$.

4.6.2 Self Efficacy &Interaction between Gender and Treatment

The descriptive statistics listed in Table 27 show that there are differences in means between male and female students in with regard to self-efficacy. To ensure whether these differences are statistically significant, a multivariate analysis was conducted.

Table 27: Descriptive Statistics, Gender & Self-Efficacy

Treatment			Mean	Std. Deviation	N
Sum_Knowing_Post	Control	female	3.67	1.109	27
		male	3.62	1.115	29
		Total	3.64	1.103	56
	Experimental	female	5.04	1.060	25
		male	5.28	0.702	29
		Total	5.17	0.885	54
	Total	female	4.33	1.279	52
		male	4.45	1.245	58
		Total	4.39	1.257	110
Sum_Applying_Post	Control	female	6.04	1.454	27
		male	5.66	1.233	29
		Total	5.84	1.345	56
	Experimental	female	7.84	1.599	25
		male	7.59	2.529	29
		Total	7.70	2.134	54
	Total	female	6.90	1.763	52
		male	6.62	2.199	58
		Total	6.75	2.001	110
Sum_Reasoning_Post	Control	female	4.26	1.534	27
		male	3.69	1.198	29
		Total	3.96	1.388	56
	Experimental	female	8.88	1.301	25
		male	8.79	1.521	29
		Total	8.83	1.411	54
	Total	female	6.48	2.726	52
		male	6.24	2.910	58
		Total	6.35	2.814	110

Table 28: Multivariate Tests, Gender Interaction with Treatment in Self-Efficacy

Effect		Value	F	Hypothesis df	Error df	Sig.
	Pillai's Trace	0.987	2643.012[b]	3.000	104.000	0.000
	Wilks' Lambda	0.013	2643.012[b]	3.000	104.000	0.000
	Hotelling's Trace	76.241	2643.012[b]	3.000	104.000	0.000
	Roy's Largest Root	76.241	2643.012[b]	3.000	104.000	0.000
Treatment	Pillai's Trace	0.750	104.219[b]	3.000	104.000	0.000
	Wilks' Lambda	0.250	104.219[b]	3.000	104.000	0.000
	Hotelling's Trace	3.006	104.219[b]	3.000	104.000	0.000
	Roy's Largest Root	3.006	104.219[b]	3.000	104.000	0.000
Gender	Pillai's Trace	0.048	1.750[b]	3.000	104.000	0.161
	Wilks' Lambda	0.952	1.750[b]	3.000	104.000	0.161
	Hotelling's Trace	0.050	1.750[b]	3.000	104.000	0.161
	Roy's Largest Root	0.050	1.750[b]	3.000	104.000	0.161
Treatment * Gender	Pillai's Trace	0.059	2.165[b]	3.000	104.000	0.097
	Wilks' Lambda	0.941	2.165[b]	3.000	104.000	0.097
	Hotelling's Trace	0.062	2.165[b]	3.000	104.000	0.097
	Roy's Largest Root	0.062	2.165[b]	3.000	104.000	0.097

a. Design: + Treatment + Gender + Treatment * Gender
b. Exact statistic

Table 28 shows that there was no statistically significant interaction effect between gender and type of intervention with regard to self-efficacy on the combined dependent variables, F (3, 104) = 2.165, p = .097; Wilks' Λ = 0.941.

4.6.3 Scientific Attitudes &Interaction between Gender and Treatment

The descriptive statistics listed in Table 29 show that there are differences in means between male and female students in attitudes. To ensure whether these differences are statistically significant, a multivariate analysis was conducted.

Table 29: Descriptive Statistics, Gender & Attitudes

Treatment			Mean	Std. Deviation	N
Scientific_Inquire_Post	Control	female	27.41	4.466	27
		male	26.21	4.938	29
		Total	26.79	4.713	56
	Experimental	female	40.00	5.774	25
		male	42.41	6.356	29
		Total	41.30	6.157	54
	Total	female	33.46	8.137	52
		male	34.31	9.932	58
		Total	33.91	9.096	110
Enjoyment_Post	Control	female	24.81	5.092	27
		male	23.79	6.769	29
		Total	24.29	5.987	56
	Experimental	female	42.00	5.000	25
		male	42.07	5.593	29
		Total	42.04	5.277	54
	Total	female	33.08	10.008	52
		male	32.93	11.083	58
		Total	33.00	10.540	110
Career_Post	Control	female	25.93	5.007	27
		male	28.62	4.411	29
		Total	27.32	4.858	56
	Experimental	female	42.00	5.774	25
		male	42.76	4.549	29
		Total	42.41	5.116	54
	Total	female	33.65	9.707	52
		male	35.69	8.401	58
		Total	34.73	9.057	110

Table 30: Multivariate Tests, Gender Interaction with Treatment in Attitudes

Effect		Value	F	Hypothesis df	Error df	Sig.
	Pillai's Trace	0.990	3326.037[b]	3.000	104.000	0.000
	Wilks' Lambda	0.010	3326.037[b]	3.000	104.000	0.000
	Hotelling's Trace	95.943	3326.037[b]	3.000	104.000	0.000
	Roy's Largest Root	95.943	3326.037[b]	3.000	104.000	0.000
Treatment	Pillai's Trace	0.836	176.338[b]	3.000	104.000	0.000
	Wilks' Lambda	0.164	176.338[b]	3.000	104.000	0.000
	Hotelling's Trace	5.087	176.338[b]	3.000	104.000	0.000
	Roy's Largest Root	5.087	176.338[b]	3.000	104.000	0.000
Gender	Pillai's Trace	0.037	1.341[b]	3.000	104.000	0.265
	Wilks' Lambda	0.963	1.341[b]	3.000	104.000	0.265
	Hotelling's Trace	0.039	1.341[b]	3.000	104.000	0.265
	Roy's Largest Root	0.039	1.341[b]	3.000	104.000	0.265
Treatment * Gender	Pillai's Trace	0.045	1.636[b]	3.000	104.000	0.186
	Wilks' Lambda	0.955	1.636[b]	3.000	104.000	0.186
	Hotelling's Trace	0.047	1.636[b]	3.000	104.000	0.186
	Roy's Largest Root	0.047	1.636[b]	3.000	104.000	0.186

a. Design: + Treatment + Gender + Treatment * Gender
b. Exact statistic

Table 30 shows that there was no statistically significant interaction effect between gender and type of intervention with regard to the attitudes towards science on the combined dependent variables, F (3, 104) = 1.636, p = 0.186; Wilks' Λ = .955.

Chapter 5: Discussion, Conclusion and Recommendations

5.1 Overview

This chapter discusses the major results of the four research questions in light of the literature review and theoretical backgrounds. The results of the research questions are discussed and compared with the results of relevant studies in other contexts. Then, the conclusion is made, recommendations are suggested and the study limitations are acknowledged and future research opportunities are offered to fill the research gap.

5.2 Discussion of Question 1

The first research question explored how POGIL-based instruction versus lecturing based instruction affected student performance as measured by cognitive outcomes of Knowing, Applying and Reasoning (KAR) in circular motion unit in physics curriculum of Grade 12.

Statistically, results of T-test for related samples indicated that there were no significant differences in means of students' abilities of Knowing, Applying and Reasoning and the total mean scores in the control group that used lecture-based instruction as reported previously in Table 9 (p - $value$ >0.05). In contrast, results of T-test for related samples in the pre-test and post-test for the experimental group (i.e., the group that used POGIL-based instruction) indicated that there were high significant differences in means of students' abilities of Knowing, Applying and Reasoning in favor of post-test (p - $value$ <0.05) as presented before in Table 11. The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125. Students in the experimental group were more likely to have a high performance in

KAR test after the intervention, compared to their scores in the pretest.

In other words, POGIL-based instruction influenced positively students' abilities of Knowing, Applying and Reasoning. Additionally, the mean scores of the students' Reasoning abilities were reported the highest (M = 8.83, SD = 1.41), followed by the students' Applying abilities (M = 7.70, SD = 2.13), and the students' Knowing abilities (M = 5.17, SD = 0.88) in the experimental group as presented in Table 16.

The effect size in the experimental group is between (0.75 -2.98); suggesting either a medium or a very high practical significance. The results the effect size can be referred to as the impact of POGIL-based instruction on higher thinking skills or cognitive levels. POGIL-based instruction 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 learn through lecture-based instruction. This finding joins the conclusion that Barthlow and Watson (2014) had reached in their research. Thus, while the results showed that the students' reasoning abilities were the highest while learning by POGIL-based instruction, they also showed that students' reasoning abilities were the lowest when learning by lecture-based instruction.

In answering the first question of this dissertation, it is clear that POGIL-Based instruction has not only proved to be useful but it comes out as the highly recommended pedagogical approach. However, in the Emirati context, according to Tairab and Al-Naqbi (2018), inquiry-based instruction challenges science education students. It is worth reiterating that POGIL is an inquiry-based approach. 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. These are some of reasons that make reasoning a challenge in a lecture-based instruction. 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).

The use of inquiry-based instruction in general and POGIL in particular, one may conclude, has many merits for teaching and learning and enhances students’ abilities of knowing, applying and reasoning (Cavallo et al., 2004; Shaw, 2003). For example, knowledge is usually transmitted from teachers to students in both lecture and POGIL methods. However, students-students interaction as done on POGIL was observed to be more facilitative for active meaning-construction than teacher–students’ interaction (Nihalani et al., 2010). Additionally, POGIL method of instruction is implemented through cooperative working and practicing that enable students to apply content knowledge while dealing with real-world problems. This contributes in developing their higher cognitive skills and increasing their performance and achievement as well (Kuhn et al., 2000). However, building on my experience as physics teacher, the students learn better through project-based learning or doing as this type of instruction increases students’ abilities to construct knowledge and concepts (Alneyadi, 2019). Additionally, this also reinforces higher thinking skills like applying and reasoning through experimentation and demonstration. It is expected that students’ performance improves since POGIL-based instruction increases their understanding abilities and deepens their higher thinking skills while lecture-based instruction is usually concerned only with lower cognitive skills. Additionally, POGIL-based instruction enables students to be knowledge producers whereas lecture-based instruction makes students' knowledge consumers (Quitadamo, Faiola, Johnson, & Kurtz, 2008).

The results of the current study found that POGIL-based instruction affected Grade 12 students' performance positively. These findings are similar to the results of the study 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.

Similar to 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 concepts, apply and these 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 are not similar to the results and findings of some 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 just now 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), which I will explore further in the next 5.3

section. Indeed, according to this 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.

5.3 Discussion of Question 2

The second research question was an attempt to explore how POGIL based instruction affected Grade 12 students' self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers. This question was addressed by comparing the mean scores of the self-efficacy survey before and after the intervention in the control group taught by traditional method and treatment group taught by POGIL-based instruction.

Before the intervention, Table 12 shows 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 self-efficacy test, participants scored higher in the experimental group (M = 8.13, SD = 0.99) than the control group (M =

7.89, SD = 1.02). The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125.

After the intervention, Table 14 shows that participants' willingness to learn physics was the highest in experimental group (M = 4.17 and SD = 0.75), then physics learning came with mean of 3.78 (SD = 0.60), while participants' understanding of physics came last with mean scores of 3.74 (SD = 0.76). With regard to control group, participants' understanding of physics was the highest (M = 2.70, SD = 0.63), then willingness to learn physics came with mean of 2.66 (SD = 0.61), while participants' physics learning came last with mean scores of 2.45 (SD = 0.63). The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125.

In addition, the results presented in Table 15 indicated that there was a high significant difference in means of the scores of learn Physics ($p - value < 0.05$), Understanding of Physics ($p - value < 0.05$) in, willingness to learn Physics (p - $value < 0.05$), and overall Self-efficacy (p - $value < 0.05$) after the intervention for the experimental group. The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125.

The effect size in the experimental group differs between (1.4 -2.54); suggesting either a high or a very high practical significance. These results confirm the positive impact of POGIL-based instruction on students' self-efficacy. This positive impact, in part, is because POGIL is based on the process of learning by doing and practice. As shown from the results, POGIL improved the participants' physics learning, understanding, and willingness to learn and use it in their future careers (Wang, 2020).

POGIL also impacted students' academic confidence to study physics. Such confidence is subsumed in the concept of self-efficacy (Sander & Sanders, 2005).

Bandura (1986) defined self-efficacy “as people’s judgments of their capabilities to organize and execute courses of action required to obtain designated types of performance” (p. 391). POGIL can stimulate such self-efficacy since students are engaged primarily in concept invention that helps them to facilitate their understandings. Therefore, if students can discuss their performance on tasks associated with their self-efficacy whilst pursuing academic goals, then we can have a measure of their academic confidence.

These results are similar to the results of the study by Fencl and Scheel (2005) who found out that POGIL had the greatest a positive impact on students’ self-efficacy. Nihalani et al. (2010) stated that POGIL-based approach enhanced the psychomotor and cognitive skills of the learners that could lead to improved levels of self-efficacy. Additionally, self-efficacy is a belief about what a student can do whatever skills the person possesses in certain conditions. Since POGIL as shown in the previous discussion of the results can improve students’ performance, it can also enhance students’ self- efficacy, which in turn can impact their sense of their abilities to perform well in physics (Artino, 2012).

Similar to the results of the current study, Kuhn et al. (2000) showed that POGIL-based learning increased the levels of self-efficacy in the learners. POGIL-based learning promotes peer-to-peer interactions during the learning process that facilitates the ability of the student to make meaning with the concepts being learned. Also, POGIL enhanced the levels of self-efficacy as evident in stages such as the exploration phase when the learner becomes critical towards the presented data and concepts (Chase et al., 2013). Furthermore, according to Vacek (2011), POGIL-based approaches are filled with opportunities to improve students’ self-confidence and self-efficacy, especially when it comes to active learning.

Situated within the theory of social constructivism, active learning is a process that allows the learner to construct new knowledge through experiences that build upon prior knowledge and experience. In the current study as well as in other studies, POGIL has used this theoretical framework to explain the phenomena of active, inquiry-based learning. It also describes student and teacher roles in an active learning environment as moving from teacher owned to the student being motivated to learn independently. POGIL in this regard helps learners to build their confidence and increase motivation.

5.4 Discussion of Question 3

The third research question attempted to explore how POGIL-based instruction affected Grade 12 students' attitudes toward scientific inquiry, enjoyment of lessons and career interest in physics as described in the Test of Science Related Attitudes (TOSRA) (Fraser, l98l). This question was addressed by comparing the mean scores of the survey of Science Related Attitude toward scientific inquiry, enjoyment of lessons and career interest in physics before and after the intervention in the control group taught by traditional Based instruction and experimental group taught by POGIL-based instruction.

Before the intervention, the results indicated that (as in Table 16) participants' attitudes in Career interest in Science was the highest in both groups (Control Group M = 2.64, SD = 0.52) and (Experimental Group M = 2.74, SD = 0.44) followed by their attitudes in Scientific inquiry (Control Group M = 2.54, SD = 0.71) and (Experimental Group M = 2.61, SD = 0.56). However, participants' Enjoyment of Science lessons reported the lowest in both groups (Control Group M = 2.50, SD = 0.54) and (Experimental Group M = 2.59, SD = 0.63). In the total score of the students' attitudes towards scientific inquiry, participants scored higher in the experimental group (M = 7.94, SD = 0.96) than the control group (M = 7.79, SD = 1.12). No statistical differences shown in the pretest between the two groups (*p - value* > 0.05). The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125.

After the intervention, the results indicated that (as in Table 18) participants' perceived perceptions for Career interest in Science was the highest in experimental group (M = 4.24, SD = 0.51), then perceived perceptions for Enjoyment of Science lessons came with mean of 4.20 (SD = 0.53), while perceived perceptions for Scientific inquiry came last with mean scores of 4.13 (SD = 0.62). With regard to control group, participants' perceived perceptions for Career interest in Science was the highest (M = 2.73, SD = 0.49), then perceived perceptions for Scientific inquiry came with mean of 2.68 (SD = 0.47), while perceived perceptions for Enjoyment of Science lessons came last with mean scores of 2.43 (SD = 0.60). In the total score of the students' attitudes towards scientific inquiry, participants scored higher in the experimental group (M = 12.57, SD = 1.14) than the control group (M = 7.84, SD = 1.00).

The results of T-test test for independent samples (as in Table 19) showed that statistically there was a high significant difference between the control group and experimental group in means of scales of students' attitudes towards scientific inquiry (p-value < 0.05) in favor of the experimental group. The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125.

In addition, the results presented in Table 17 indicated that there was a high significant difference in means of the scores of Scientific inquiry (*p - value* < 0.05), Enjoyment of Science lessons (*p - value* < 0.05) in, Career interest in Science (*p-value* < 0.05), and overall students' attitudes towards scientific inquiry (*p - value* < 0.05) after the intervention for the experimental group. The same results were obtained after adjusting the p-value using Bonferroni adjustment 0.0125.

As shown earlier, POGIL-based instruction has a high impact on the participants' abilities of Knowing, Applying and Reasoning from one side and the participants' self-efficacy from the other. Similarly, POGIL influenced positively the participants' attitudes towards physics learning. This can be inferred that the students' attitude toward the study of physics which has been used as predictor of their achievement in this subject or course (Kahveci, 2015). Additionally, positive changes in students' attitudes did occur in the current study because of collaborative learning, which is one of the basic aspects of POGIL-based instruction (Bartle et al., 2011).

In general, some students develop an attitude that physics is a difficult subject; this attitude can be changed if we could present this subject in a practical method of instruction as POGIL that enable students to explore and learn by doing, hence being able to produce and construct knowledge. Additionally, the students' success and achievement will change their self-efficacy and attitude positively toward physics in particular and science in general (Hofstein & Mamlok-Naaman, 2011).

The active learning and group work experienced by students in POGIL-based instruction was beneficial to develop students' positive attitudes toward physics. The improvement in students' feeling and thinking of physics or science as a result of their active participation in POGIL classes reflect their understanding of the application of conceptual science and supports the view that the traditional lecturing methods are less favorable to students' academic needs of science (Fowler, 2012; Fan, Chai, Deng, & Dong, 2015).

Though the previous studies have not tackled POGIL directly, they shed some 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 that favor student center and active learning. Similar to the current study results, Oh and Yager (2004) correlated students' negative attitudes toward science with a traditional approach in science instruction whereas their positive attitudes were connected with constructivist science classrooms like POGIL. Oh and Yager (2004) also recommended enhancing the learning environment to allow students to attain scientific knowledge and gain a more positive attitude toward science.

Other studies state that the classroom learning environment that is based on process and inquiry is a strong factor in determining and predicting students' attitudes toward science (Simpson & Oliver, 1990; Goh & Fraser, 1997; Fraser et al., 2010). Walker and Warfa (2017) reached the same results as the current study, where students who were taught using POGIL-based instructional strategy developed positive attitudes towards science and physics; their level of course satisfaction was higher; and their grades were higher than the students who did not experience POGIL (Roller & Zori, 2017).

5.5 Discussion of Question 4

The fourth research question explored the relationship between students' academic performance, self-efficacy and attitudes when learning via POGIL-based instruction and lecture-based instruction.

A Pearson's correlation was run to determine the correlation between students' performance in KAR, Self-Efficacy, and their views towards science inquiry amongst the 56 participants in the control group (Table 20). Statistically, there was no significant correlation between students' performance in KAR and their Self-Efficacy ($r = 0.076, p - value > 0.05$), no significant correlation between students' performance in KAR and their views towards science inquiry ($r = 0.037, p - value > 0.05$), and no significant correlation between students' Self-Efficacy and their views towards science inquiry ($r = 0.194, p - value > 0.05$).

On the other hand, A Pearson's correlation was run to determine the correlation between students' performance in KAR, Self-Efficacy, and views towards science inquiry amongst the 54 participants in the experimental group (Table 21). Statistically, there was a very strong, positive and significant correlation between students' performance in KAR and their Self-Efficacy ($r = 0.704, p - value < 0.05$) which indicated that as students' performance in KAR increased, their Self-Efficacy increased. In addition, there was a strong, positive and significant correlation between students' performance in KAR and their views towards science inquiry ($r = 0.565, p - value < 0.05$), which indicated that as students' performance in KAR increased, their views towards science inquiry were more positive. Moreover, there was a strong, positive and significant correlation between students' Self-Efficacy and attitudes towards science inquiry ($r = 0.569, p - value < 0.05$), which indicated that as students' Self-Efficacy increased, their views towards science inquiry were more positive.

Furthermore, Self-Efficacy received the strongest weight in the model. Therefore, Self-Efficacy statistically has a positive effect on students' performance since the results indicated that ($\beta = 0.57, t = 4.88, p - value < 0.05$). In addition, students' attitudes towards science inquiry statistically has a positive effect on students' performance since ($\beta = 0.24, t = 2.10, p - value < 0.05$).

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 a 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 students' attitudes towards science inquiry has positive effect on students' performance.

Similar to the current study, Suprapto et al. (2017) carried out research that aimed at exploring the correlation between students' conception of learning physics and their physics' self-efficacy. The results showed a moderate correlation between students' conception of learning physics and their physics' self-efficacy. In their study, Fencl and Scheel (2005) found out that POGIL had the greatest positive impact on students' achievement and self-efficacy. Likewise, studies done by Devitri et al. (2019) and Zamista and Rahmi (2019) showed positive results of using POGIL in improving literacy ability of students' science. Moreover, for Nihalani et al. (2010), POGIL-based approach enhances the psychomotor and cognitive skills of the learners which could lead to improved levels of self-efficacy and attitudes.

Some researchers have similar results as the current study and found positive relationships between students' self-efficacy and grades or achievement in science (Soltis et al., 2015; Caprara et al., 2008; Britner, 2008; Lin et al., 2015; Chiou & Liang, 2012). Also, other studies found out positive or moderate relationships between attitudes and students' achievement in primary and secondary schools (Genç, 2001; Tepe, 1999; Turhan, 2003). Additionally, some of the studies found that students' attitude towards science learning increased as their grade increased (Alkan, 2006; Çakır et al., 2007; Ilgaz, 2006).

5.6 Discussion of Question 5

The fifth research question was an attempt to examine if there is any interaction between gender and the type of treatment (POGIL-based instruction or lecture- based instruction) which may have affected Grade 12 students' academic performance in physics, their self-efficacy for physics learning, or their scientific attitudes. This question was addressed by conducting three multivariate analysis of variance on the three dependent variables.

Descriptive statistics shown in Tables 25, 27 and 29 highlighted differences in mean scores for each construct of the dependent variable. However, the three multivariate analysis represented in Tables 26, 28 and 30 showed the following:

1- There was no statistically significant interaction effect between gender and type of intervention with regard to the academic performance in physics on the combined dependent variables, $F(3, 104) = 0.432$, $p = .730$; Wilks' $\Lambda = .988$.

2- There was no statistically significant interaction effect between gender and type of intervention with regard to self-efficacy on the combined dependent variables, $F(3, 104) = 2.165$, $p = .097$; Wilks' $\Lambda = 0.941$.

3- There was no statistically significant interaction effect between gender and type of intervention with regard to scientific attitudes on the combined dependent variables, $F(3, 104) = 1.636$, $p = 0.186$; Wilks' $\Lambda = .955$.

Overall, results of the fifth question showed that there was no interaction between gender and the type of instruction. This meant that gender as an independent did not interact with the grouping variable. Thus, it can be argued that the results of this study go in harmony with the results of similar studies that focused on gender differences in science education in general and physics education in particular.

The results of this research study conform with the results of David et al. (2020) and Alghamdi and Alanazi (2020) discussed earlier. These investigations yielded no significant gender differences when employing POGIL in science education or chemistry. In general, there were no statistically significant differences in science academic performance between male and female students within either the experimental or the control group after employing POGIL.

However, the results of this research study were not similar to the results of a detailed longitudinal study conducted by Marshman et al. (2018). This study which was discussed earlier found gender differences concerning academic performance in specific concepts such as “Force Concept Inventory” where female students underperform male students. This may be partly attributed to certain external factors such as the complexity of such concept which might have increased the stereotypical female students’ anxiety when faced with difficult concepts compared to males’ lower levels of anxiety in similar situations and not because of the interaction between gender and the method of teaching; POGIL vs traditional methods.

In addition, in a study conducted in other relevant subjects like teaching computer sciences by Hu et al. (2016) yielded contradictory results than the longitudinal study conducted by Marshman et al. (2018). In this study, pass rates increased for female students but not males. Similarly, in teaching Chemistry, Zgraggen (2018) found that there were statistically significant differences in performance between males and females where *females* performed better than males overall but there were no interaction effects between group and gender.

In short, the discrepancies of the results of the studies conducted on POGIL and the interaction with gender emphasize the conclusion that such differences in gender might be due to other extraneous factors. Consequently, the results of this research study which showed no significant differences between males and females in academic performance.

With regard to the interaction between gender differences and self-efficacy, the results of this research study did not go in harmony with Marshman et al. (2018). In this longitudinal study, there were gender differences in self-efficacy in middle school and throughout high school where female students scored low scores than male students in self-efficacy scales. However, such differences in gender as Marshman et al. (2018) argued may be associated with the societal stereotypes and biases.

As for scientific attitudes, the results of this research study did not conform with the study conducted by Akpinar et al. (2009). In that study, there was a significant difference between female and male students in terms of “interest in science”, “enjoyment of science, anxiety” and “enjoyment of science experiments in favor of female.

5.7 Conclusion

Five major points could be concluded from this research study. 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. This is especially true when it comes to their self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers. Third, in Science Related Attitude, Grade 12 students taught by POGIL-based instruction performed better than their counterpart students taught by traditional method. Fourth, correlations were found between the three variables; students' science performance, self-efficacy and scientific attitudes in both groups when they learn by POGIL-based instruction. Finally, there was interaction effect between gender and type of intervention with regard to students' performance in physics, self-efficacy and scientific attitudes.

Thus, the major conclusion of this dissertation is that: POGIL-based instruction positively improved Grade 12 students' scientific performing abilities of reasoning, applying and knowing, self-efficacy and their scientific attitudes. POGIL is the core factor that impacted positively students' science performance, self-efficacy and scientific attitudes.

5.8 Implications

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. The Hope mission to Mars is only the beginning.

POGIL-based instructional methods also build learners' confidence and provide the opportunity to solve real world problems (Lombardi, 2007). As well, there are implications of using POGIL on the cognitive, affective and psychomotor skills of students. This may be reflected in better performance in examinations assessing these aspects of student learning (Mitchell & Hiatt, 2010). POGIL, finally, helps students to develop competencies in decision making as they formulate hypotheses (Bauer, Cole, & Walter, 2005).

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.

5.9 Recommendations

Based on the major results of the four research questions, suggestions and recommendations are provided that may support scientific research as well as instruction and pedagogy.

- First, educational decision-makers and schools need to shift towards inquiry-based instruction as well as POGIL-based instruction that enhanced students' performance, scientific attitudes and self-efficacy.
- Second, 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, self-efficacy and scientific attitudes.
- Third, physics curriculum should be introduced and presented in a way that

improves the students' self-efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers. This can be done by simplifying the curriculum through learning by doing and relating physics to real-life contexts.

● Fourth, 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. This increases student's self-efficacy toward physics.

● Fifth, the lecturing method of instruction and rote learning should be completely eliminated from school at all levels.

● Sixth, science teachers should be provided with continuous professional development programs in POGIL-based instruction and group-learning instructional strategies to increase their instructional effectiveness.

● Seventh, school principals, advisors and heads of science department should encourage the implementation of POGIL-based instruction and make the student the center of pedagogy, teaching and learning.

● Eighth, schools are recommended to spread a culture that reinforces the power of physics and its importance in enhancing student' knowledge, applying and reasoning.

● Ninth, induction programs for students are needed for enhancing students' scientific attitudes.

● Tenth, employing POGIL in teaching and learning physics has positive impacts upon both male and female students.

5.10 Limitations and Future Research Opportunities

Though this study had addressed POGIL-based instruction and how it might have impacted Grade 12 students' performance, self-efficacy, and scientific attitudes, some limitations were acknowledged. For instance, the study only sampled 110 Grade 12 students, in two high government 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 like Grade 10 and Grade 11. Due to the constraints dictated by school structures, random distribution of students to either the control or the experimental group is not achieved in quasi-experimental design.

Further research studies are suggested to explore the impact of POGIL-based instruction on students' performance, self-efficacy, and scientific attitudes in other science subjects like chemistry, biology and geology.

Future research studies are also needed by expanding the sample to include other classes and other stages of education including the elementary and high stages in private and government schools.

Future research studies using a mixed-method approach is also recommended to conduct triangulation and ensuring the causal relationship between the independent variable (the use of POGIL) and the other dependent variables. Additionally, sampling needs to include teachers and advisors as well.

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Appendices

Appendix A: Jury of Referees for Validating Physics Test

Name	College	Department
Prof. Hassan Tairab	College of Education,	Curriculum & Instruction
Dr. Negmelden Alsheikh	College of Education, UAEU	Curriculum & Instruction UAEU
Dr. Sadiq Ismail	College of Education, UAEU	Curriculum & Instruction UAEU
Dr. Hala El Hwoeris	College of Education, UAEU	Curriculum & Instruction
Dr.Moh. Sadag Shaban	College of Education, UAEU	Curriculum & Instruction
Mr Sadiq Al Sareehi	ADEK	
Mrs Majddi Alwana	ADEK	

Appendix B: Pretest-Post-test Standardized Test about Circular Motion

Student No. **School No.** **Gender: F /M**
Recall/Recognize:

Knowing

1. What is the distance moved by an object at a specific angled termed as in circular motion?
   A. Linear displacement
   B. Linear distance
   C. Angular displacement
   D. Angular distance

2. If a car moves at a circular pattern and velocity is tripled what will happen to the centripetal force?
   A. Nothing as you don't know the radius of the arc.
   B. The centripetal force increases by a factor of three.
   C. The centripetal force increase by a factor of nine.
   D. The centripetal force decreases by a factor of three

Describe:

3. How will an object moving in a circular path be described?
   A. In equilibrium
   B. Not in equilibrium
   C. Not moving with constant speed
   D. In random motion

4. A ball suspended from the string is moving in a semicircular or pendulum motion. What will be true for the time when ball is at the bottom of the arc?
   A. It has no net force acting on it
   B. It has no net force acting in the vertical.
   C. The tension and gravity balance one another out.
   D. There is no centrifugal force

Provide example:

5. If an object is in a circular motion with the radius r and covers an arc distance of s how will the angular displacement be measured?
   A. s/r

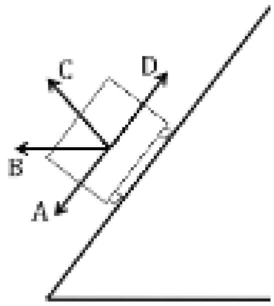
B. r ⁄ s

C. r*s

D. r^2s

6. A car makes a steep corner in a roundabout circular motion. The force diagram is given in the figure which of the following will be the direction of the centripetal force?

A. A
B. B
C. C
D. D



Applying

Compare:

7. Which of the following is a correct comparison between degrees and radian, value of π rad

A. 110^0

B. 90^0

C. 120^0

D. 180^0

8. Compared to linear motion what is the correct value for work done when an object moves in a uniform circular motion?

A. zero

B. positive

C. negative

D. infinite

Contrast:

9. What is the angular relation between the acceleration and centripetal force according to Newton's 2^{nd}

A. At right angles to each other

B. Anti-parallel to each other

C. Make acute angle with each other

D. In same direction

10. How will you explain the nature of motion for a stone whirling in a horizontal circle whilst tied to a string and is suspended from a point?

A. conical pendulum

B. cone

C. pendulum

D. eclipse

Classify:

11. What is the direction of the centripetal force when an object moves in circular motion?

A. Tangent to circle

B. Center

C. Normal to circle

D. Parallel to circle

12. What happens when the centripetal force is less than that of the centrifugal force?

A. The object continues to be in circular motion
B. The object goes into linear motion
C. The object comes to rest
D. None of the above

Relate:

13. What is the angular velocity for the minute hand of a clock?

A. 2 rad s^{-1}

B. 3 rad s^{-1}

C. 1 rad s^{-1}

D. 0.00175 rad s^{-1}

14. Relate the parameters on which the circular motion of an object depends?

A. angular velocity

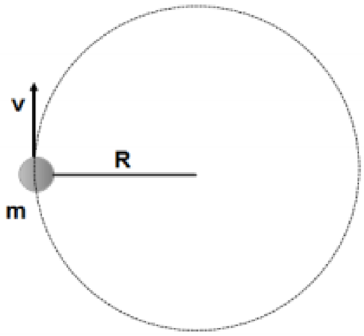
B. radius

C. circumference

D. both A and B

Use models:

15. What shall be the force for the model where an object of mass M moves in a circular motion with speed V along the radius R as given in the model?
    A. MVR
    B. MV^2 / R
    C. MV/ R
    D. V^2 / R
16. In the same model what will happen if the speed V is doubled?
    A. It doubles
    B. It quadruples
    C. Stays the same
    D. Is cut to one-half
    E. Is cut to one-quarter



Interpret Information:

17. What is the direction of centripetal force F when an object is in uniform circular motion?

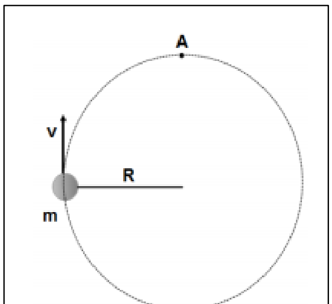
A. Tangent to circle
B. Center
C. Normal to circle
D. Parallel to circle

18. What will be the velocity of an object orbiting around the planet earth?
    A. 9 km s^{-1}
    B. 7 km s^{-1}
    C. 8 km s^{-1}
    D. 10 km s^{-1}

Reasoning

Analyze:

19. What will be the relation between magnitude of force at the points A and B for a ball of mass M in circular motion



with a radius R suspended from a string in a constant speed V?

A. The net force at point A is greater than at point B
B. The net force at point A is less than at point B
C. The net force is zero at all points around the circle
D. The net force at point A is equal to the net force at point B

20. For an object of mass M in circular motion with a radius R and speed V, what will happen to the acceleration when speed is constant and radius is doubled?

A. It doubles
B. It quadruples
C. It is cut to a half
D. It is cut to a quarter
E. Stays unchanged

Synthesize:

21. Which of the following statement is true for a body moving in a circular motion with a constant speed?

A. The acceleration is zero because it has a constant speed
B. The acceleration is not zero and causes the car to slow down
C. The acceleration is not zero and causes the car to speed up
D. The acceleration is not zero and causes the change in the direction of the car’s velocity
E. None from the above

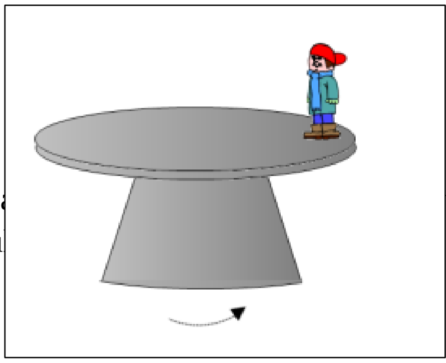
22. A bicycle moves in a circular motion with a radius R which of the following statement is true?

A. The bicycle’s velocity is constant
B. The bicycle’s acceleration is constant
C. The bicycle’s acceleration is zero
D. The bicycle’s velocity is directed toward the center
E. The bicycle’s acceleration is directed toward the center

Design investigations:

23. in the attached arrangement as the boy stands on a rotating platform which of the following keeps him from falling off the platform?

A. The force of gravity
B. The normal force
C. The static friction
D. The kinetic friction
E. None of these



24. While turning through an inclined road a c th a radius R what will be the banking angle formu

A. $\tan\theta = V^2 / R g$
B. $\tan\theta = VR / g$
C. $\tan\theta = Vg * R$
D. $\tan\theta = V^2 R^2 / g$
E. None of the above

Evaluate:

25. An object moves in a circular path with 5 revolutions in 20 seconds evaluate the rotation period for the object?

A. 5 seconds
B. 10 seconds
C. 4 seconds
D. 20 seconds
E. 15 seconds

26. Evaluate the frequency of a ball moving in a circular path making 10 revolutions in a span of five seconds?

A. 2 Hertz
B. 6 Hertz
C. 4 Hertz
D. 10 Hertz
E. 20 Hertz

Draw conclusions:

27. A pilot performs a loop in mid - air with a radius R select the true conclusions about the apparent weight of the pilot?

A. It increases when he moves from the lowest to the highest point of the circle
B. It decreases when he moves from the lowest to the highest point of the circle
C. It decreases when he moves from the highest to the lowest point of the circle
D. Remains constant at all points
E. More information is required

28. A string is wrapped around a pipe with a stone tied in the end in a circular motion with constant speed. As the string wraps itself the radius is constantly decreasing what will be the impact on the centripetal force?

A. It will stay the same.
B. It will diminish.
C. It will increase.
D. None of the above

Generalize:

29. The centripetal and centrifugal forces in uniform circular motion should be equal and opposite – Validate the statement

A. True
B. False
C. None of the above

30. If a pendulum rotates in a vertical loop which of the following statements will be true when the bob is at the vertical top?

A. The velocity at the top will be zero.
B. The tension in the string at the top will be zero.
C. The centripetal force at the top will be zero.
D. The acceleration at the top will be zero

Answers Key

1. C	16. B
2. C	17. B
3. B	18. C
4. D	19. D
5. A	20. C
6. B	21. D
7. D	22. E
8. A	23. C
9. D	24. A
10. A	25. C
11. B	26. A
12. B	27. B
13. D	28. C
14. A	29. A
15. B	30. B

Appendix C: Jury of Referees for Validating Survey of Self Efficacy

Name	Title	Department
Prof. Hassan Tairab	College of Education,	Curriculum & Instruction
Dr. Negmelden Alsheikh	College of Education, UAEU	Curriculum & Instruction UAEU
Dr. Sadiq Ismail	College of Education, UAEU	Curriculum & Instruction UAEU
Dr. Hala El Hwoeris	College of Education, UAEU	Curriculum & Instruction
Dr.Moh. Sadag Shaban	College of Education, UAEU	Curriculum & Instruction

Appendix D: Modifying Some Items in the Self Efficacy Survey

Before	After modification
Physics Learning	
1.I like learn physics.	1.I am continually finding better ways to learn physics.
Understanding of Physics,	
12.I acquire science concepts effectively	12.I know the steps necessary to acquire science concepts effectively
16.Physics class organizes my ideas.	16.Physics class helps me organize my ideas.
Willingness to Learn Physics for Future Careers	
20.I may do well in physics.	20.I will do well in physics next year.
27.I feel satisfied at difficult scientific texts.	27.I feel satisfied when I understand difficult scientific texts.
30.Understanding physics opens avenues in the future.	30.Understanding physics opens avenues for all good colleges in the future.

Appendix E: Survey of Physics Learning Self Efficacy (SPLSE)

Dear Students,

The purpose of this survey is to collect information about your self -efficacy for physics learning, understanding of physics, and the willingness to learn it in their future careers.

All of the items below refer to efficacy levels associated with science. Each statement is followed by five numbers (1, 2, 3, 4, 5). Each number means the following:

1-Strongly disagree (1)

2- Disagree (2)

3- Neutral (3)

4- Agree (4)

5- Strongly Agree (5)

After reading each statement, circle the number (1, 2, 3, 4, or 5) which reflects your opinion.

Participating in this survey is voluntarily and your data will be used for research purposes ONLY.

Note that there is no right or wrong answer to any of the items on this survey.

Thank you

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Physics Learning					
1. I am continually finding better ways to learn physics.	5	4	3	2	1
2. Even when I try very hard, I don't learn physics. as well as I do most subjects.	5	4	3	2	1
3. I am not very effective in carrying out science experiments.	5	4	3	2	1
4. I am continually finding better ways to learn physics. .	5	4	3	2	1
5. When I do better than usual in science, it is often because I exerted a little extra effort.	5	4	3	2	1
6. Even when I try very hard, I don't learn science as well as I do most subjects.	5	4	3	2	1
7. I generally learn science ineffectively.	5	4	3	2	1
8. I am not very effective in carrying out science experiments.	5	4	3	2	1
9. I am generally responsible for my achievement in science.	5	4	3	2	1
10. My achievement in science is directly related to my teacher's effectiveness in science teaching	5	4	3	2	1
Understanding of Physics					
11. Physics class helps improve my academic achievements in all subjects.	5	4	3	2	1
12. I know the steps necessary to acquire science concepts effectively	5	4	3	2	1
13. I find it difficult to understand why physics experiments work.	5	4	3	2	1
14. I am typically able to answer teachers' physics questions.	5	4	3	2	1
15. Physics class is important as it widens my view.	5	4	3	2	1
16. Physics class helps me organize my ideas.	5	4	3	2	1

17. Physics class increases my ability in taking decisions	5	4	3	2	1
18. Physics class increases my higher thinking skills	5	4	3	2	1
Willingness to Learn Physics for Future Careers					
19. When my physics grades improve, it is most often due to their desire of learning.	5	4	3	2	1
20. I will do well in physics next year.	5	4	3	2	1
21. The inadequacy of my physics background can be overcome by intensive reading.	5	4	3	2	1
22. My attention in physics class improves my achievement.	5	4	3	2	1
23. My increased effort in physics learning produces little change in my achievement.	5	4	3	2	1
24. If my parents comment that I am showing more interest in physics at school, is probably due to my evident performance.	5	4	3	2	1
25. I wonder if I have the necessary readiness to learn physics.	5	4	3	2	1
26. I am motivated to learn physics.	5	4	3	2	1
27. I feel satisfied when I understand difficult scientific texts.	5	4	3	2	1
28. Learning physics will help me choose my future career.	5	4	3	2	1
29. I will study physics at university.	5	4	3	2	1
30. Understanding physics opens avenues for all good colleges in the future.	5	4	3	2	1

Appendix F: Survey of Physics Learning Self Efficacy (SPLSE) (Arabic)

استبانة الكفاءة الذاتية لتعلم الفيزياء

عزيزي الطالب

تهدف هذه الاستبانة إلى جمع المعلومات عن الكفاءة الذاتية لتعلم مادة الفيزياء. من أجل جمع بيانات حول فعاليتك الذاتية لتعلم الفيزياء وفهم الفيزياء والرغبة في تعلمها في مهن المستقبلية. تشير جميع العناصر أدناه إلى مستويات الفعالية المرتبطة بتعلم مادة الفيزياء.

كل الفقرات الواردة في النص أدناه تعود إلى كفاءة الطالب الذاتية لتعلم مادة الفيزياء. وكل فقرة يتبعها خمسة أرقام متدرجة (1، 2، 3، 4،5) وكل رقم يعني التالي:

1: أبداً لا أفعل هذا إطلاقا.

2: أفعل ذلك من حين إلى آخر.

3: غير متأكد.

4: عادة أفعل ذلك.

5: دائما أفعل ذلك

الرجاء وضع دائرة حول الرقم الذي يعبر عن رأيك. نود أن نلفت انتباهكم أنه لا توجد إجابة صحيحة أو خطأ للبنود الواردة في هذا النص. كما أن المشاركة في هذه الاستبانة اختيارية وليس إلزامية وسوف تستخدم المعلومات بغرض البحث العلمي فقط.

العبارة	أبدًا	من حين لآخر	غير متأكد	عادة	دائمًا
تعلم الفيزياء					
1. أجد باستمرار طرقًا أفضل لتعلم الفيزياء.	1	2	3	4	5
2. حتى عندما أحاول جاهدا، لا أتعلم دروسا لفيزياء جيدا كما اتعلم معظم المواد الدراسية الأخرى.	1	2	3	4	5
3. أنا لست فعالاً للغاية في إجراء التجارب العلمية.	1	2	3	4	5
4. عادة ما اتعلم الفيزياء بشكل جيد.	1	2	3	4	5
5. عندما أكون أفضل من المعتاد في الفيزياء، فذلك لأنني أبذل مجهودًا إضافيًا قليلًا.	1	2	3	4	5
6. حتى عندما أحاول جاهدا، أنا لا أتعلم العلم كما أفعل في معظم المواد الدراسية الأخرى.	1	2	3	4	5
7. أتعلم الفيزياء بشكل عام بطريقة غير فعالة.	1	2	3	4	5
8. أنا لست فعالاً للغاية في إجراء التجارب العلمية.	1	2	3	4	5
9. أنا مسؤول بشكل عام عن إنجازي في الفيزياء.	1	2	3	4	5
10. يرتبط إنجازي في الفيزياء ارتباطًا مباشرًا بفعالية أستاذي في تدريس الفيزياء.	1	2	3	4	5
فهم واستيعاب مادة الفيزياء					
11. يساعد ني درس الفيزياء في تحسين إنجازاتي الأكاديمية في جميع المواد الدراسية.	1	2	3	4	5
12. أعرف الخطوات اللازمة لاكتساب المفاهيم العلمية بفعالية	1	2	3	4	5
13. أجد صعوبة في فهم كيفية إجراء التجارب المخبرية في مادة الفيزياء.	1	2	3	4	5
14. عادة ما أكون قادرًا على الإجابة على أسئلة المعلم في مادة الفيزياء.	1	2	3	4	5
15. دروس الفيزياء مهمة لأنها توسع قدرتي العقلية.	1	2	3	4	5
16. دروس الفيزياء تساعدني على تنظيم أفكاري.	1	2	3	4	5
17. تزيد دروس الفيزياء من قدرتي على اتخاذ القرارات	1	2	3	4	5
18. يزيد درس الفيزياء من تنمية مهاراتي في التفكير العليا	1	2	3	4	5
الرغبة في تعلم مادة الفيزياء لمهن المستقبل					
19. عندما تتحسن درجاتي الفيزياء، فغالبًا ما يكون ذلك بسبب رغبتي في للتعلم.	1	2	3	4	5
20. سأحقق نتائج جيدة في الفيزياء العام المقبل.	1	2	3	4	5
21. يمكن التغلب على قصور الخلفية الفيزيائية عن طريق القراءة المكثفة.	1	2	3	4	5

22. اهتمامي في درس الفيزياء يحسّن من إنجازي.	5 4 3 2 1
23. جهدي المتزايد في تعلم الفيزياء ينتج عنه تغيير طفيف في تحصيلي الدراسي.	5 4 3 2 1
24. إذا علق والديّ بأنني أبدو اهتمامًا أكبر بالفيزياء في المدرسة، ربما يعود ذلك لأدائي الجيد .	5 4 3 2 1
25. أتساءل عما إذا كان لدي الاستعداد اللازم لتعلم الفيزياء.	5 4 3 2 1
26. أنا متحمس لتعلم الفيزياء.	5 4 3 2 1
27. أشعر بالرضا عندما أفهم النصوص العلمية الصعبة.	5 4 3 2 1
28. سوف يساعدني تعلم الفيزياء في اختيار مهنتي المستقبلية.	5 4 3 2 1
29. سأدرس الفيزياء في الجامعة.	5 4 3 2 1
30. فهم الفيزياء يفتح سبلاً لجميع الكليات الجيدة في المستقبل.	5 4 3 2 1

Appendix G: Jury of Referees for Validating Scientific Attitudes Survey

Name	Title	Department
Prof. Hassan Tirab	College of Education,	Curriculum & Instruction
Dr. Negmelden Alsheikh	College of Education, UAEU	Curriculum & Instruction UAEU
Dr. Sadiq Ismail	College of Education, UAEU	Curriculum & Instruction UAEU
Dr. Hala El Hwoeris	College of Education, UAEU	Curriculum & Instruction
Dr.Moh. Sadag Shaban	College of Education, UAEU	Curriculum & Instruction
Dr. Adeb Al Jarrah	College of Education, UAEU	Curriculum & Instruction
Dr. Khader Al hellow	Sworn Translator	Alain Legal Translation Office
Mr. Ali Al herbawi	Translator	ADEK
Mr. Hisham Al bukhari	Translator	SSAT Middle East

Appendix H: Modifying Some Items in the Scientific Attitudes Survey

Before	After modification
Attitudes to Scientific Inquiry	
6.I would rather find out about things by research than by doing an experiment.	6.I would rather find out about things by asking an expert than by doing an experiment.
9.I would prefer to do an experiment rather than reading about it in science magazines.	9.I would prefer to do an experiment on a topic than to read about it in science magazines.
Enjoyment of Science Lessons	
14.Science lessons are boring for all students.	14.Science lessons bore me.
15.Science is the most interesting school subject.	15. Science is one of the most interesting school subjects.
Career Interest in Science	
21.I would dislike being a scientist	21.I would dislike being a scientist after I leave school.
27.I would like to teach science	27. I would like to teach science when I leave school.

Appendix I: Survey of Science Related Attitude (SSRA)

Dear Students,

The purpose of this survey is to collect information about your attitude toward science learning. This survey contains a number of statements about science. You will be asked what you yourself think about these statements. Your opinion is what is wanted.

All of the items below refer to attitude levels associated with science. Each statement is followed by five numbers (1, 2, 3, 4, 5). Each number means the following:

1-Strongly disagree (1)

2- Disagree (2)

3- Neutral (3)

4- Agree (4)

5- Strongly Agree (5)

After reading each statement, circle the number (1, 2, 3, 4, or 5) which reflects your opinion.

Participating in this survey is voluntarily and your data will be used for research purposes ONLY.

Note that there is no right or wrong answer to any of the items on this survey.

Thank you

Statement	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Attitudes to Scientific Inquiry					
1- I would prefer to find out why something happens by doing an experiment than by being told.	5	4	3	2	1
2- Doing experiments is not as good as finding out information front teachers.	5	4	3	2	1
3- I would prefer about them. to do experiments than to read	5	4	3	2	1
4- I would rather agree with other people than do an experiment to find out for myself.	5	4	3	2	1
5- I would prefer to do my own experiments than to find out information from a teacher.	5	4	3	2	1
6- I would rather find out about things by asking an expert than by doing an experiment.	5	4	3	2	1
7- I would rather solve a problem by doing an experiment than be told the answer.	5	4	3	2	1
8- It is better to ask the teacher the answer than to find it out by doing experiments.	5	4	3	2	1
9- I would prefer to do an experiment on a topic than to read about it in science magazines.	5	4	3	2	1
10- It is better to be told scientific facts than to find them out from experiments.	5	4	3	2	1
Enjoyment of Science Lessons					
11- Science lessons are fun.	5	4	3	2	1
12- I dislike science lessons.	5	4	3	2	1
13- School should have more science lessons each week.	5	4	3	2	1
14- Science lessons bore me.	5	4	3	2	1
15- Science is one of the most interesting school subjects.	5	4	3	2	1
16- Science lessons are a waste of time.	5	4	3	2	1

17-	I really enjoy going to science lessons.	5	4	3	2	1
18-	The material covered in science lessons is uninteresting.	5	4	3	2	1
19-	I look forward to science lessons.	5	4	3	2	1
20-	I would enjoy school more if there were no science lessons.	5	4	3	2	1
Career Interest in Science						
21-	I would dislike being a scientist after I leave school.	5	4	3	2	1
22-	When I leave school, I would like to work with people who make discoveries in science.	5	4	3	2	1
23-	I would dislike a job in a science laboratory after I leave school.	5	4	3	2	1
24-	Scientists like sport as much as other people do.	5	4	3	2	1
25-	Working in a science laboratory an interesting way to earn a living.	5	4	3	2	1
26-	A career in science would be dull and boring.	5	4	3	2	1
27-	I would like to teach science when I leave school.	5	4	3	2	1
28-	A job as a scientist would be interesting.	5	4	3	2	1
29-	I would dislike becoming a scientist because it needs too much education.	5	4	3	2	1
30-	I would like to be a scientist when I leave school	5	4	3	2	1

Appendix J: Survey of Science Related Attitude (SSRA) (Arabic)

استبانة المواقف والاتجاهات من مادة العلوم

عزيزي الطالب

تهدف هذه الاستبانة إلى جمع المعلومات عن حول موقفك واتجاهك من تعلم مادة الفيزياء. من أجل جمع بيانات حول **المواقف و الاتجاهات من البحث العلمي** و **التمتع بدروس العلوم** و**الاهتمام الوظيفي في العلوم**. تشير جميع العناصر أدناه إلى مستويات المواقف والاتجاهات المرتبطة بتعلم مادة العلوم عامة الفيزياء خاصة.

كل الفقرات الواردة في النص أدناه تعود إلى مواقف واتجاهات الطالب المرتبطة بتعلم مادة الفيزياء.

وكل فقرة يتبعها خمسة أرقام متدرجة (1، 2، 3، 4،5) وكل رقم يعني التالي:

1: أبداً لا أفعل هذا إطلاقا.

2: أفعل ذلك من حين إلى آخر.

3: غير متأكد.

4: عادة أفعل ذلك.

5: دائما أفعل ذلك

الرجاء وضع دائرة حول الرقم الذي يعبر عن رأيك. نود أن نلفت انتباهكم أنه لا توجد إجابة صحيحة أو خطأ للبنود الواردة في هذا النص. كما أن المشاركة في هذه الاستبانة اختيارية وليس إلزامية وسوف تستخدم المعلومات بغرض البحث العلمي فقط.

العبارة	أبداً	من حين لآخر	غير متأكد	عادة	دائماً
المواقف والاتجاهات من البحث العلمي					
1- أفضل معرفة سبب حدوث شيء ما عن طريق تجربة من الكلام النظري	1	2	3	4	5
2- أن تحصيل المعرفة من إجراء بالتجارب أفضل من الحصول عليها من المعلم.	1	2	3	4	5
3 – أفضل تحصيل المعرفة من إجراء بالتجارب عن القراءة	1	2	3	4	5
4 - أفضل الاتفاق مع أشخاص آخرين لتحصيل المعرفة بدلاً من إجراء تجربة لاكتشاف بنفسي.	1	2	3	4	5
5- أفضل القيام بتجاربي الخاصة بدلاً من تحصيل المعرفة من المعلم	1	2	3	4	5
6- أفضل معرفة الأشياء عن طريق سؤال خبير بدلاً من إجراء تجربة.	1	2	3	4	5
7- أفضل حل مشكلة عن طريق إجراء تجربة بدلاً من الحصول الإجابة جاهزة.	1	2	3	4	5
8- من الأفضل أن تطلب من المعلم الإجابة بدلاً من معرفة ذلك بإجراء التجارب.	1	2	3	4	5
9- أفضل إجراء تجربة على موضوع ما بدلاً من القراءة عنه في المجلات العلمية.	1	2	3	4	5
10- من الأفضل إخباري بالحقائق العلمية بدلاً من اكتشافها من التجارب.	1	2	3	4	5
التمتع بدروس العلوم	1	2	3	4	5
11- دروس العلوم ممتعة.	1	2	3	4	5
12- لا أحب دروس العلوم.	1	2	3	4	5
13- يجب أن تزيد المدرسة من عدد دروس العلوم كل أسبوع.	1	2	3	4	5
14- دروس العلوم مملة.	1	2	3	4	5
15- يعتبر العلوم هي واحدة من أكثر المواد الدراسية إثارة للاهتمام.	1	2	3	4	5
16- دروس العلوم مضيعة للوقت.					
17- أستمتع حقًا بالذهاب إلى دروس العلوم.	1	2	3	4	5
18- المواد المشمولة في دروس العلوم غير مهمة.	1	2	3	4	5
19- أتطلع برغبة إلى دروس العلوم.	1	2	3	4	5
20- سأستمتع بالمدرسة أكثر إذا لم تكن هناك دروس في العلوم.	1	2	3	4	5
الاهتمام الوظيفي في العلوم					
21- لا أحب ان أكون عالما بعد أن أغادر المدرسة.	1	2	3	4	5

22- عندما أغادر المدرسة، أود أن أعمل مع أشخاص يقومون باكتشافات في العلوم.	1	2	3	4	5
23- لا أحب ان أن أعمل بوظيفة في مختبر علوم بعد أن أغادر المدرسة.	1	2	3	4	5
24- العمل في مختبر علمي وسيلة ممتعة لكسب الرزق.	1	2	3	4	5
25- المهنة في مجال العلوم ستكون مملة للغاية.	1	2	3	4	5
26- أرغب في تدريس العلوم عندما أغادر المدرسة.	1	2	3	4	5
27 - وظيفة كعالم ستكون مملة	1	2	3	4	5
28 - وظيفة كعالم ستكون مثيرة للاهتمام.	1	2	3	4	5
29-لا أرغب في أن أصبح عالماً لأنه يحتاج إلى الكثير من التعليم.	1	2	3	4	5
30- أود أن أكون عالمًا عندما أغادر المدرسة	1	2	3	4	5

Appendix K: Parent's Consent Form

Dear Parents:

Please read carefully before signing the Consent Form!

Topic of the research,

INVESTIGATING THE IMPACT OF POGIL-BASED INSTRUCTION ON GRADE 12 PERFORMANCE IN CIRCULAR MOTION UNIT, SELF-EFFICACY, AND ATTITUDES

You will be asked to provide or deny consent on behalf of your child after reading this form.

You have been invited to take part in a study to investigate the impact of Process Oriented Guided Inquiry Learning (POGIL)-based instruction on G12 performance in physics- CIRCULAR MOTION UNIT, SELF-EFFICACY, AND ATTITUDES

This study will be conducted by Saif Saeed Salem Al Neyadi, College of Education- UAE University

The study will take place at Secondary schools located at Alain. Participation in this study will take during the first trimester of the school year 2019/2020

Benefit of the research

Although you will receive no direct benefits from this study, this research may help us better understand, the effect of POGIL-BASED INSTRUCTION ON GRADE 12

PERFORMANCE

Procedure/setting

Description of the procedure: your child will be assigned to either a control group or an experimental group and will be taught either through POGIL or through traditional methods.

About the Experiment

Your child will sit for Pre-tests and post-tests to assess his performance in Circular Motion Unit, his self efficacy and attitudes

Safety Information

No protentional risk is expected

Confidentiality and Privacy Information

Your Child's private information is not revealed

Right to Withdraw

Your child can withdraw at any stage in the process without being penalized.

Informed Consent

1. I confirm that I have read and understood the above information sheet and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw.
3. I understand that my data will be kept confidential and if published, the data will not be identifiable as mine.

I agree to take part in this study:

(Name and signature of participant)	(Date)
(Name and signature of person taking consent)	(Date)
(Name and signature of witness (if participant unable to read/write)	(Date)
(Name and signature of parent/guardian/next of kin (when participant unable to give consent due to age or incapacity)	(Date)

Appendix L: Experiments-Circular-motion

Experiment Title: Centripetal Force

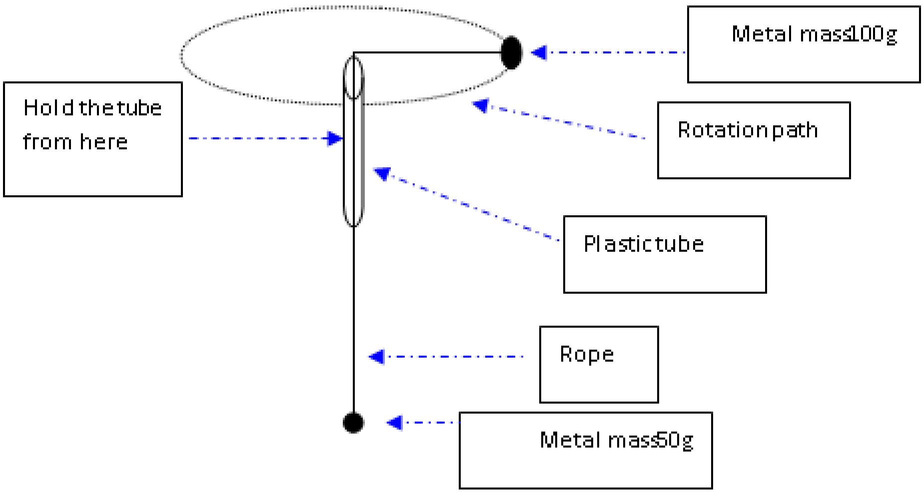
Objective: Investigate the relation between centripetal force and the velocity.

Apparatus:

1. Plastic tube (i.e. a pen, after removing the ink cartridge so that it is open from both sides)
2. One meter of string
3. Two hooked masses: 50g and M. (They can be tied with a rope)
4. A stopwatch

Procedure:

1. Tie the big hooked mass (M) with one side of the string.
2. Insert the other side of the string into the plastic tube.
3. Tie the small hooked mass (50g) with the other side of the string so that it is hanging from the plastic tube.
4. Choose the radius of the circular path i.e. the string length at the upper side (according to the table below) and hold the plastic tube from its edge to prevent the rope from sliding.
5. Rotate the big metal mass (M) in a horizontal circular motion above your head while keeping the hanging side without touching it.
6. When you feel that the motion is steady and uniform, release the rope from the plastic tube side to be free while rotating as in the figure below.


Metal mass 100g
Hold the tube from here
Rotation path
Plastic tube
Rope
Metal mass 50g

7. When the velocity is constant, ask your colleague to start timing at a certain point you agree upon and simultaneously count 10 completed cycles by the big metal (100g) mass.
8. Repeat the experiment for different values of hanging mass and record the results in the table below. Make sure that **the radius and hooked (rotating) mass are constant** for all trials in this part
   (Note: all the measurements are expressed in the International System of units (SI).

Safety Remarks:

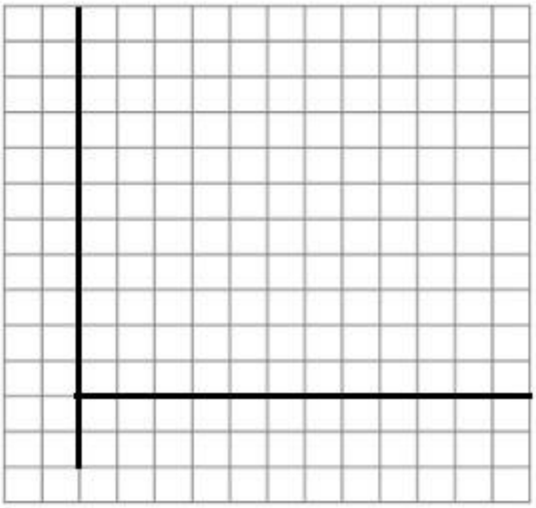
1. Ensure that you are at a safe distance from people, windows, doors, furniture…etc. inside the place in which the experiment is conducted.
2. Make sure that you tied the two masses firmly so that they cannot escape during motion.

Data Analyzing:

1. Record your data in the following table:

r = ………………							
Hanging Mass (m)	Centripetal Force ($F_C = mg$)	Time for 10 cycles (t)	Period ($T = \frac{t}{10}$)	Angular frequency ($\omega = \frac{2\pi}{T}$)	ω^2	Velocity ($v = \frac{2\pi r}{T}$)	v^2

2. Plot the graph to represent the relationship between the centripetal force (F_c) and the velocity (v^2)
3. Draw the best straight line represent the data.



4. Find the slope of the line and use it to calculate the value of the hooked mass M?

…………………………………………………………………
…………………………………………………………………
…..
…………………………………………………………………
…………………………………………………………………
….
…………………………………………………………………
…………………………………………………………………
…

5. Compare the experimental value of M with its real value by calculating the relative percentage error?

$$RPR = \left|\frac{M_{real} - M_{exp}}{M_{real}}\right| \times 100\%$$

Sources of error:

Discuss three sources of error:

………………………………………………………………………………………………
…………

………………………………………………………………………………………………
…………

………………………………………………………………………………………………
…………

Experiment #2

Experiment Title: Verifying Motion Direction of an Object in the Absence of Centripetal Force

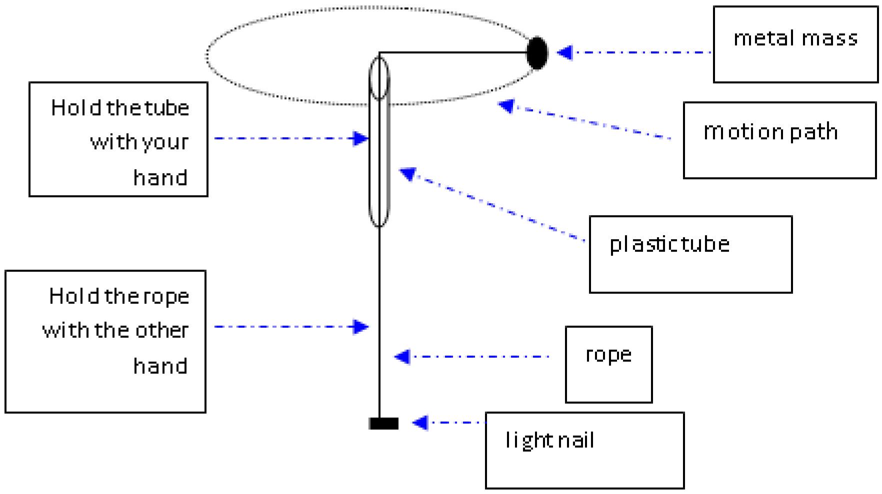
Objective: Determine the motion direction of an object in the absence of centripetal force (Proving non-existence of Centrifugal Force)

Apparatus:

1. Plastic tube (i.e. a pen, after removing the ink cartridge so that it is open from both sides)
2. Two meters of string
3. 50g OR 100g hooked mass (A mass that can be tied with a rope)
4. Small iron nail, a toothpick or a small plastic ball

Procedure:

1. Tie a hooked mass with a string.
2. Insert the other side of the string into the plastic tube until about half of the string is inserted.
3. Tie a light nail (or a toothpick or a small plastic ball) with the other side of the string. (The purpose of this is to prevent pulling the rope from the tube during the circular motion of the metal mass).
4. Hold the plastic tube from the middle of the string.
5. Rotate the metal mass in a horizontal circular motion above your head while keeping the hanging side with the nail steady in the other hand. (As in the figure).


metal mass
Hold the tube with your hand
motion path
plastic tube
Hold the rope with the other hand
rope
light nail

1. At a certain point the metal mass and while rotating, let go of the string. Observe the motion direction of the metal mass.
2. Repeat the experiment several times to confirm the correct direction.

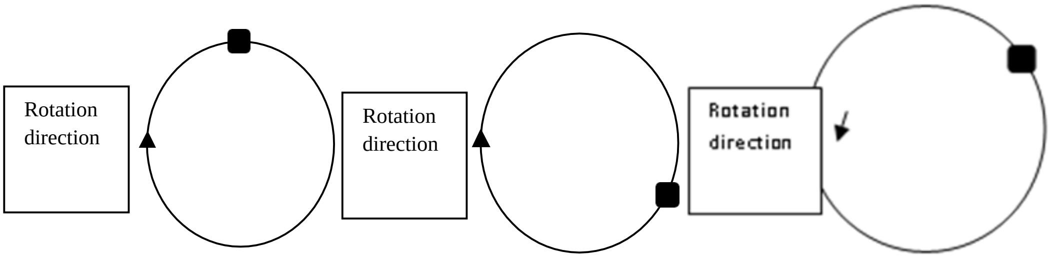
Safety Remarks:

1. Wherever you conduct the experiment, ensure that you are at a safe distance from people, windows, doors, furniture, etc.
2. Make sure that you tied the mass and the nail firmly so that it cannot escape during motion.

Conclusion: Write a description for the metal mass motion after releasing it from uniform circular motion.

Additional Question:

From this experiment, draw the direction of motion of the metal mass movement when releasing it in the following positions:



Lesson plan								Chapter 9 Section 2
School المدرسة			Teacher Name اسم المعلم					
Grade/Section الصف / الشعبة	12A	Date التاريخ	Topic الموضوع	**Dynamics of Circular Motion** **9.5 Centeripetal Force**				
LEARNING OUTCOME ناتج التعلم					2	**الحصة**	2	عدد الحصص المقترح

الأهداف objective	Solve problems by using the cenerpital force.
	To apply mathematics skills to solve problems involving conical pendulum equations .
	Explain everyday observations related to circular motion of an object in terms of fprces acting on it .
KEY WORDS **المصطلحات والمفاهيم**	angular acceleration , velocity , displacement , centrpital acceleration

STARTER ACTIVITY التهيئة الحافزة للدرس	**Differentiation** التعليم الممايز	**STRATEGIES** **الاستراتيجيات**	**TIME** **الوقت**
_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.	☐ Visual بصري ☐ Auditory سمعي ☑ Kinesthetic حركي ☐ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	5 min
RESOURCES المصادر: Student book and copybook			
_solve example 9.1 page 266 with the students Use think – pair - share strburegy to solve different level worksheet _divide the students into 5 groups according to their level _ask students to solve the questions that belong to their groups color. _ Give them answer sheet and asks them to switch their answers and use partner check strategy. **Experiment Group :**	☑ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☑ Scaffold Task	☐ Teacher Led ☑ Whole class ☐ Individual ☐ Pair Work ☑ Group Work	25 min.

	A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning. **Control group:** teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment.	مهمة متعمقة	☐ e-learning	
	RESOURCES المصادر: Student book – work sheet- calcolater -coloring pens			
CLASS Activities الأنشطة الصفية	**<u>Challenge question</u>:** **At the middle of the worksheet there is a challeng questions with pink color students going to solve it.**	☐ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☐ Individual ☑ Pair Work ☐ Group Work ☑ e-learning	5min.
	RESOURCES المصادر: Book – lms websit – video-			
PLENARY الخاتمة	Using exit card		☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.
	RESOURCES المصادر: Book- text book			
Assessment تقييم التعلم	**Observation & follow-up** **Teacher assessment -self assessment**		☑ Activities ☑ Oral Questions ☑ Observation ☐ Quiz ☐ Peer assessment	3 min.

	RESOURCES المصادر	**Online test**	☑ Self-assessment ☐ Presentation ☐ Other:____	
Reflection/What next? **متغيرات الحصة الصفية(إن وجدت)**				
Real life application **تطبيقات حياتية**	Wave swinger, roller coaster			
Links to heritage andenviroment **الربط بالتراث والبيئة**	Use the ropes to rise up the palm and taking dates			
Homeworkالواجب	9.56 PAGE 281			

Lesson plan

School المدرسة			Teacher Name اسم المعلم			Chapter 9 Section 3
Grade/Section / الصف الشعبة	**12A-**	Date التاريخ		Topic الموضوع	**Dynamics of Circular Motion** **9.5 Centeripetal Force**	

LEARNING OUTCOME ناتج التعلم		3	**الحصة**	2	عدد الحصص المقترح

الأهداف objective	Distinguish between centripetal force and centrifugal forces.
	Tell how centtrifugle forces seem to arise in rotationg reference frames
	Discuss the centrifugal with respect to Newtons law.
KEY WORDS **المصطلحات والمفاهيم**	angular acceleration , velocity , displacement , centrpital acceleration

STARTER ACTIVITY التهيئة الحافزة للدرس	**Differentiation** التعليم الممايز	**STRATEGIES** **الاستراتيجيات**	**TIME** **الوقت**
			5 min

	_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.	☐ Visual بصري ☐ Auditory سمعي ☑ Kinesthetic حركي ☐ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	
	RESOURCES المصادر: Student book and copybook			
	_solve example 9.2 page 270 with the students Use think – pair - share strategy to solve different level worksheet  _divide the students into 5 groups according to their level _ask students to solve the questions that belong to their groups color. _ Give them answer sheet and asks them to switch their answers and use partner check strategy. **Experiment Group :** A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning. **Control group:** teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment.	☑ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☑ Scaffold Task مهمة متعمقة	☐ Teacher Led ☑ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	25 min.
	RESOURCES المصادر: Student book – work sheet- calcolater -coloring pens			
CLASS Activities الأنشطة الصفية	**<u>Challenge question</u>:** **At the middle of the worksheet there is a challeng questions with pink color students going to solve it.**	☐ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☐ Individual ☑ Pair Work ☐ Group Work ☑ e-learning	5min.
	RESOURCES المصادر: Book – lms websit – video-			

PLENARY **الخاتمة**		Using exit card	☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.
	RESOURCES **لمصادر**	Book- text book		
Assessment **تقييم التعلم**		**Observation & follow-up** **Teacher assessment -self assessment**	☑ Activities ☑ Oral Questions ☑ Observation ☐ Quiz ☐ Peer assessment ☑ Self-assessment ☐ Presentation ☐ Other:____	3 min.
	RESOURCES **لمصادر**			
Reflection/What next? **متغيرات الحصة الصفية(إن وجدت)**				
Real life application **تطبيقات حياتية**		Dubai horse race field, Yas circuit,Dubai Sky Diving		
Links to heritage andenviroment **الربط بالتراث والبيئة**		Alain Oases and the method of watering palm trees.		
Homeworkالواجب		10.55 PAGE 283		

Appendix M: Lesson Plan

Lesson plan							
School المدرسة			Teacher Name اسم المعلم				Chapter 9 Section 4
Grade/ Section الصف / الشعبة	12A	Date التاريخ	Topic الموضوع	**Dynamics of Circular Motion** **9.6: Speed and Velocity PART1**			
LEARNING OUTCOME ناتج التعلم		4	**الحصة**	2	عدد الحصص المقترح		
الأهداف objective	distinguish between the concepts of speed and velocity.						
	describe the motion of objects in a circle.						
	identify and describe the direction of the velocity vector for an object moving in a circle						
KEY WORDS **المصطلحات والمفاهيم**	angular acceleration , velocity , displacement , centrpital acceleration						

STARTER ACTIVITY التهيئة الحافزة للدرس		**Differentiation** التعليم المميز	**STRATEGIES** **الاستراتيجيات**	**TIME** **الوقت**
	_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.	☐ Visual بصري ☐ Auditory سمعي ☑ Kinesthetic حركي ☐ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	5 min
RESOURCES المصادر	Student book and copybook			

	_solve example 9.3 page 280 with the students Use think – pair - share straregy to solve different level worksheet  _divide the students into 5 groups according to their level _ask students to solve the questions that belong to their groups color. _ Give them answer sheet and asks them to switch their answers and use partner check strategy. **Experiment Group :** A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning. **Control group:** teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment. **RESOURCE S المصادر**: Student book – work sheet- calcolater -coloring pens	☑ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☑ Scaffold Task مهمة متعمقة	☐ Teacher Led ☑ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	25 min.
CLASS Activities الأنشطة الصفية	**<u>Challenge question</u>:** **At the middle of the worksheet there is a challeng questions with pink color students going to solve it.** **RESOURCES المصادر**: Book – lms websit – video-	☐ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☐ Individual ☑ Pair Work ☐ Group Work ☑ e-learning	5min .
PLENARY الخاتمة	Using exit card **RESOURCES المصادر**: Book- text book		☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.

<table>
<tr><td rowspan="2">Assessment
تقييم التعلم</td><td colspan="2">Observation & follow-up
Teacher assessment -self assessment</td><td rowspan="2">☑ Activities
☑ Oral Questions
☑ Observation
☐ Quiz
☐ Peer assessment
☑ Self-assessment
☐ Presentation
☐ Other:____</td><td rowspan="2">3 min.</td></tr>
<tr><td>RESOURCES المصادر</td><td></td></tr>
<tr><td colspan="2">Reflection/What next? متغيرات الحصة الصفية(إن وجدت)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Real life application تطبيقات حياتية</td><td colspan="3">Dubai horse race field, Yas circuit,Dubai Sky Diving</td></tr>
<tr><td colspan="2">Links to heritage andenviroment الربط بالتراث والبيئة</td><td colspan="3">Alain Oases and the method of watering palm trees.</td></tr>
<tr><td colspan="2">Homeworkالواجب</td><td colspan="3">10.57 PAGE 284</td></tr>
</table>

Lesson plan							
School المدرسة		Teacher Name اسم المعلم				Chapter 9 Section 5	
Grade/ Section الصف / الشعبة	12A	Date التاريخ		Topic الموضوع	Dynamics of Circular Motion **9.6: Speed and Velocity PART2**		
LEARNING OUTCOME ناتج التعلم		5	**الحصة**	2	عدد الحصص المقترح		
الأهداف objective	describe the direction of the velocity vector for an object moving in a circle						
	identify the variables effecting the magnitude of the velocity.						
KEY WORDS **المصطلحات والمفاهيم**	angular acceleration , velocity , displacement , centrpital acceleration						

STARTER ACTIVITY التهيئة الحافزة للدرس			**Differentiation** التعليم الممايز	**STRATEGIES** **الاستراتيجيات**	**TIME** **الوقت**
	_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.		☐ Visual ☐ Auditory ☑ Kinesthetic حركي ☐ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	5 min
	RESOURCES **المصادر**	Student book and copybook			

	_solve example 9.5 page 285 with the students Use think – pair - share straregy to solve different level worksheet  _divide the students into 5 groups according to their level _ask students to solve the questions that belong to their groups color. _ Give them answer sheet and asks them to switch their answers and use partner check strategy. **Experiment Group :** A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning. **Control group:** teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment.	☑ Visual ☐ Auditory ☐ Kinesthetic ☑ Extension work نشاط إضافي ☑ Scaffold Task مهمة متعمقة	☐ Teacher Led ☑ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	25 min.
	RESOURCES المصادر Student book – work sheet- calcolater -coloring pens			
CLASS Activities الأنشطة الصفية	**Challenge question:** **At the middle of the worksheet there is a challeng questions with pink color students going to solve it.**	☐ Visual ☐ Auditory ☐ Kinesthetic ☑ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☐ Individual ☑ Pair Work ☐ Group Work ☑ e-learning	5min.
RESOURCES المصادر	Book – lms websit – video-			
PLENARY الخاتمة	Using exit card		☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.
RESOURCES المصادر	Book- text book			

Assessment **تقييم التعلم**	**Observation & follow-up** **Teacher assessment -self assessment**	☑ Activities ☑ Oral Questions ☑ Observation ☐ Quiz ☐ Peer assessment ☑ Self-assessment ☐ Presentation ☐ Other:____	3 min.
RESOURCES لمصادر			
Reflection/ What next? **متغيرات الحصة الصفية(إن وجدت)**			
Real life application **تطبيقات حياتية**	Dubai horse race field, Yas circuit,Dubai Sky Diving		
Links to heritage andenviroment **الربط بالتراث والبيئة**	Alain Oases and the method of watering palm trees.		
Homeworkالواجب	10.58 PAGE 285		

Lesson plan						Chapter 9 Section 6
School المدرسة			Teacher Name اسم المعلم			
Grade/Section الصف / الشعبة	**12A**	Date التاريخ	Topic الموضوع	**Dynamics of Circular Motion** **9.7: : Acceleration and Net Force**		
LEARNING OUTCOME ناتج التعلم			6	**الحصة**	2	عدد الحصص المقترح

الأهداف objective	To recognize that objects moving in circles have an acceleration. Explain the cause of this acceleration. describe the magnitude and direction of the acceleration and net force vector of an object moving in a circle at a constant speed.			
KEY WORDS المصطلحات والمفاهيم	angular acceleration , velocity , displacement , centrpital acceleration			
	STARTER ACTIVITY التهيئة الحافزة للدرس	**Differentiation** التعليم الممايز	**STRATEGIES الاستراتيجيات**	**TIME الوقت**
	_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.	☐ Visual ☐ Auditory ☑ Kinesthetic حركي ☐ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	5 min
RESOURCES المصادر	Student book and copybook			
	_solve example 9.9 page 290 with the students Use think – pair - share straregy to solve different level worksheet _divide the students into 5 groups according to their level _ask students to solve the questions that belong to their groups color. _ Give them answer sheet and asks them to switch their answers and use partner check strategy. **Experiment Group :** 	☑ Visual ☐ Auditory ☐ Kinesthetic ☑ Extension work	☐ Teacher Led ☑ Whole class ☐ Individual ☐ Pair Work ☑ Group Work	25 min.

	A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning. **Control group:** teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment.	نشاط اضافي ☑ Scaffold Task مهمة متعمقة	☐ e-learning	
	RESOURCES المصادر — Student book – work sheet- calcolater -coloring pens			
CLASS Activities الأنشطة الصفية	**<u>Challenge question</u>:** **At the middle of the worksheet there is a challeng questions with pink color students going to solve it.**	☐ Visual ☐ Auditory ☐ Kinesthetic ☑ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☐ Individual ☑ Pair Work ☐ Group Work ☑ e-learning	5min.
RESOURCES المصادر	Book – lms websit – video-			
PLENARY الخاتمة	Using exit card		☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.
RESOURCES المصادر	Book- text book			
Assessment تقييم التعلم	**Observation & follow-up** **Teacher assessment -self assessment**		☑ Activities ☑ Oral Questions ☑ Observation ☐ Quiz	3 min.

RESOURCES **المصادر**		☐ Peer assessment ☑ Self-assessment ☐ Presentation ☐ Other:____	
Reflection/ What next? **متغيرات الحصة الصفية(إن وجدت)**			
Real life application **تطبيقات حياتية**	Dubai horse race field, Yas circuit,Dubai Sky Diving		
Links to heritage andenviroment **الربط بالتراث والبيئة**	Alain Oases and the method of watering palm trees.		
Homework **الواجب**	11.50 PAGE 286		

Lesson plan						Chapter 9 Section 7
School المدرسة		Teacher Name اسم المعلم				
Grade/Section الصف / الشعبة	**12 A**	Date التاريخ		Topic الموضوع	**Dynamics of Circular Motion** **9.8: Centripetal Force and Inertia** **9.9:The Centripetal Force Requirement**	

LEARNING OUTCOME ناتج التعلم		7	**الحصة**	2	عدد الحصص المقترح

objective الأهداف	should be able to use the concept of inertia to explain the reason that objects moving in circles have a tendency to move tangent to the circle.
	Should be able to use the centripetal force requirement to identify the force which act centripetally in order to cause an object to move in circular motion.
	should be able to analyze a physical situation involving circular motion and compare the magnitude of the individual forces which act upon an object.
KEY WORDS **المصطلحات والمفاهيم**	angular acceleration , velocity , displacement , centrpital acceleration

STARTER ACTIVITY التهيئة الحافزة للدرس			**Differentiation** التعليم الممايز	**STRATEGIES** **الاستراتيجيات**	**TIME** **الوقت**
	_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.		☐ Visual بصري ☐ Auditory سمعي ☑ Kinesthetic حركي ☐ Extension work نشاط اضافي ☐ Scaffold Task	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	5 min
	RESOURCES **المصادر**	Student book and copybook			

<table>
<tr><td></td><td></td><td></td><td>مهمة متعمقة</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">_solve example 10.4 page 310 with the students
Use think – pair - share strargey to solve different level worksheet


_divide the students into 5 groups according to their level
_ask students to solve the questions that belong to their groups color.
_ Give them answer sheet and asks them to switch their answers and use partner check strategy.
Experiment Group :
A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning.
Control group:
teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment.</td><td rowspan="2">☑ Visual بصري
☐ Auditory سمعي
☐ Kinesthetic حركي
☑ Extension work نشاط اضافي
☑ Scaffold Task مهمة متعمقة</td><td rowspan="2">☐ Teacher Led
☑ Whole class
☐ Individual
☐ Pair Work
☑ Group Work
☐ e-learning</td><td rowspan="2">25 min.</td></tr>
<tr><td></td><td>RESOURCES
المصادر</td><td>Student book – work sheet- calcolater -coloring pens</td></tr>
<tr><td rowspan="2">CLASS Activities الأنشطة الصفية</td><td colspan="2"><u>Challenge question</u>:
At the middle of the worksheet there is a challeng questions with pink color students going to solve it.</td><td rowspan="2">☐ Visual بصري
☐ Auditory سمعي
☐ Kinesthetic حركي
☑ Extension work نشاط اضافي
☐ Scaffold Task مهمة متعمقة</td><td rowspan="2">☑ Teacher Led
☐ Whole class
☐ Individual
☑ Pair Work
☐ Group Work
☑ e-learning</td><td rowspan="2">5min.</td></tr>
<tr><td>RESOURCES
المصادر</td><td>Book – lms websit – video-</td></tr>
</table>

PLENARY **الخاتمة**	Using exit card		☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.
	RESOURCES **المصادر**	Book- text book		
Assessment **تقييم التعلم**	**Observation & follow-up** **Teacher assessment -self assessment**		☑ Activities ☑ Oral Questions ☑ Observation ☐ Quiz ☐ Peer assessment ☑ Self-assessment ☐ Presentation ☐ Other:____	3 min.
	RESOURCES **المصادر**			
Reflection/What next? **متغيرات الحصة الصفية(إن وجدت)**				
Real life application **تطبيقات حياتية**	Dubai horse race field, Yas circuit,Dubai Sky Diving			
Links to heritage andenviroment **الربط بالتراث والبيئة**	Alain Oases and the method of watering palm trees.			
Homeworkالواجب	11.60 PAGE 290			

Lesson plan						Chapter 9 Section 8
School المدرسة			Teacher Name اسم المعلم			
Grade/Section الصف / الشعبة	**12 A**	Date التاريخ		Topic الموضوع	**Dynamics of Circular Motion** **10.1: Mathematical Analysis of Circular Motion**	
LEARNING OUTCOME ناتج التعلم		8	**الحصة**	2	عدد الحصص المقترح	

objective الأهداف	To analyze the motion of an object moving in a horizontal circle and to determine the values of the acceleration, net force and individual forces.
	To determine the values of the acceleration, net force and individual forces.
	utilize Newton's laws to analyze the motion of an object moving in a vertical circle.
KEY WORDS المصطلحات والمفاهيم	angular acceleration , velocity , displacement , centrpital acceleration

STARTER ACTIVITY التهيئة الحافزة للدرس		**Differentiation** التعليم الممايز	**STRATEGIES** **الاستراتيجيات**	**TIME** **الوقت**
	_Discuss success criteria with students _ Assigning one of the students to write the centerpital force and the conical pendulum equations.	☐ Visual بصري ☐ Auditory سمعي ☑ Kinesthetic حركي ☐ Extension work نشاط إضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☑ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	5 min
RESOURCES المصادر	Student book and copybook -solve example 10.6 page 315 with the students Use think – pair - share strategy to solve different level worksheet _divide the students into 5 groups according to their level _ask students to solve the questions that belong to their groups color. _ Give them answer sheet and asks them to switch their answers and use partner check strategy.			

	Experiment Group : A typical POGIL lesson may begin with a short introductory lecture of no more than ten minutes. 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 gives a report of 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 short background at the beginning and guided questions to steer the inquiry, the students are responsible for their learning. **Control group:** teacher use traditional method for teaching and learning such as always intervene for problem solving, teacher most of time explain the whole lesson. Also, only display the experiment and did not encourage students to practice the experiment.		☑ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☑ Scaffold Task مهمة متعمقة	☐ Teacher Led ☑ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☐ e-learning	25 min.
	RESOURCES المصادر	Student book – work sheet- calcolater -coloring pens			
CLASS Activities الأنشطة الصفية	**<u>Challenge question</u>:** **At the middle of the worksheet there is a challeng questions with pink color students going to solve it.**		☐ Visual بصري ☐ Auditory سمعي ☐ Kinesthetic حركي ☑ Extension work نشاط اضافي ☐ Scaffold Task مهمة متعمقة	☑ Teacher Led ☐ Whole class ☐ Individual ☑ Pair Work ☐ Group Work ☑ e-learning	5min.
	RESOURCES المصادر	Book – lms websit – video-			
PLENARY الخاتمة	Using exit card			☑ Teacher Led ☐ Whole class ☐ Individual ☐ Pair Work ☑ Group Work ☑ e-learning	2 min.
	RESOURCES المصادر	Book- text book			
Assessment تقييم التعلم	**Observation & follow-upTeacher assessment -self assessment**			☑ Activities ☑ Oral Questions ☑ Observation ☐ Quiz ☐ Peer assessment ☑ Self-assessment ☐ Presentation	3 min.
	RESOURCES المصادر				

			☐ Other:____	
Reflection/What next? **متغيرات الحصة الصفية(إن وجدت)**				
Real life application **تطبيقات حياتية**		Dubai horse race field, Yas circuit,Dubai Sky Diving		
Links to heritage andenviroment **الربط بالتراث والبيئة**		Alain Oases and the method of watering palm trees.		
Homeworkالواجب				11.64 PAGE 295

Appendix N: Boxplots for the sub-scales of the Surveys

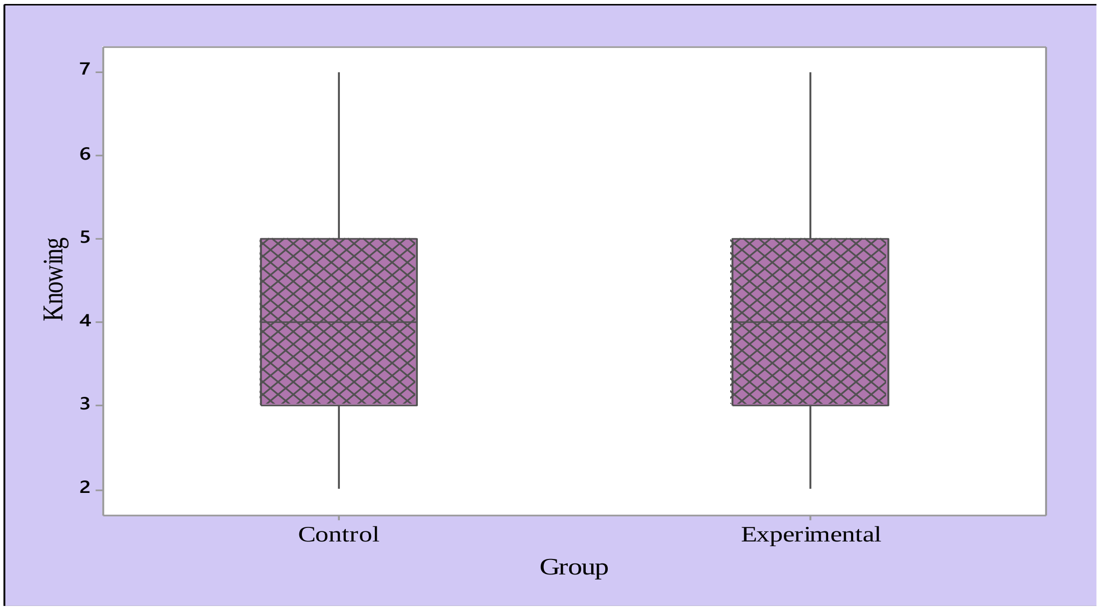


Figure 20: Boxplot for Knowing -Pretest

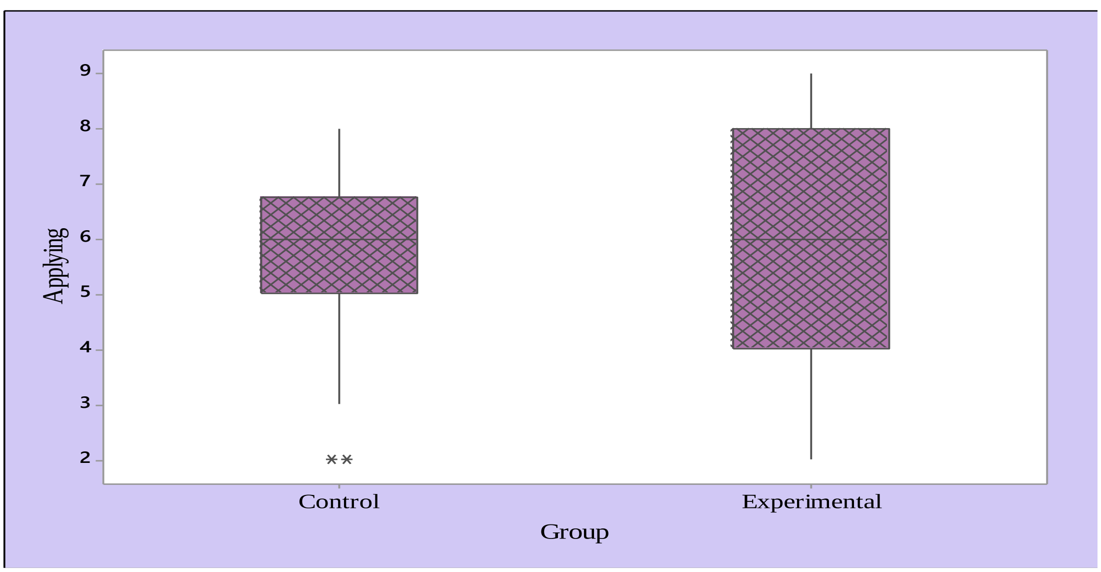


Figure 21: Boxplot for Applying -Pretest. Note: Number showed the extreme values in applying domain in control group.

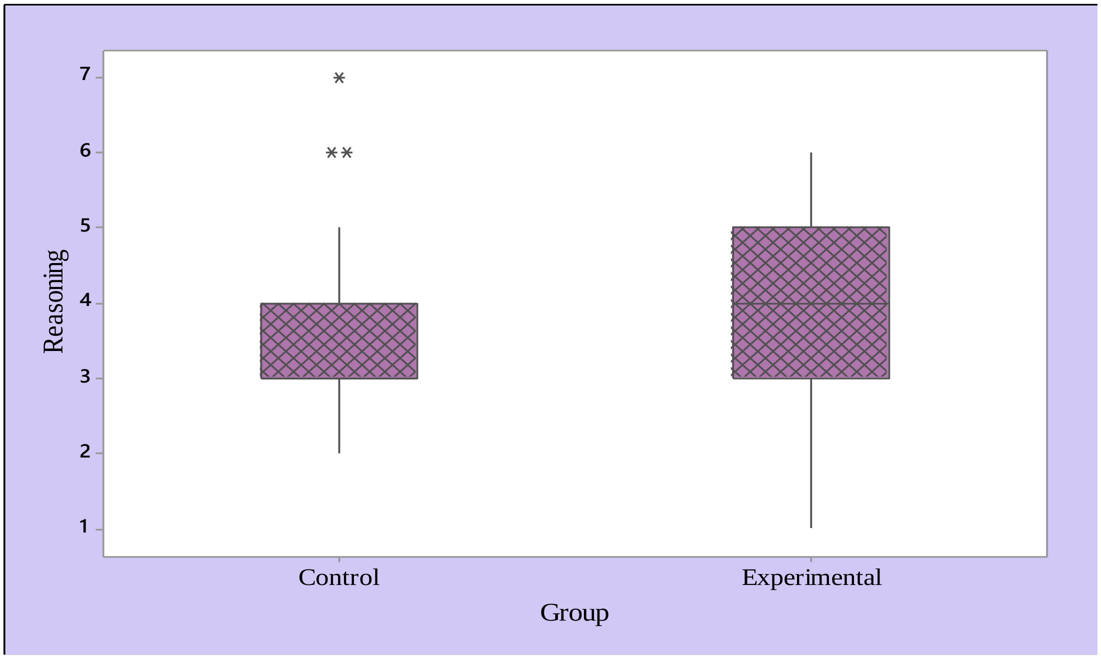


Figure 22: Boxplots for Reasoning -Pretest. Note: Numbers showed the extreme values in reasoning domain in control group.

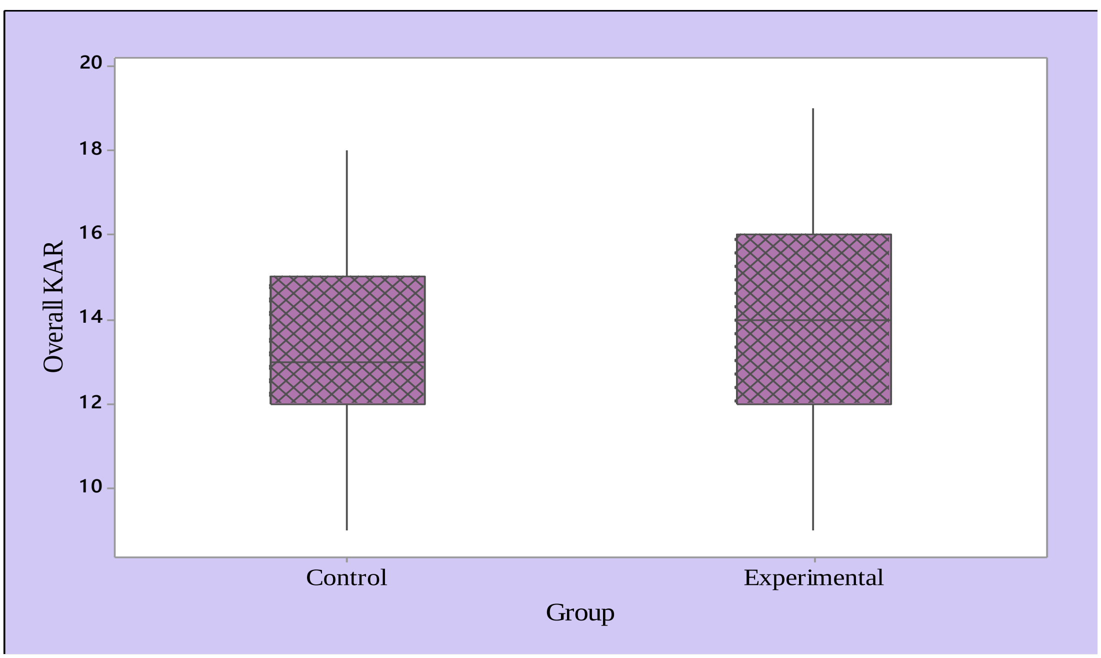


Figure 23: Boxplots for overall KAR -Pretest

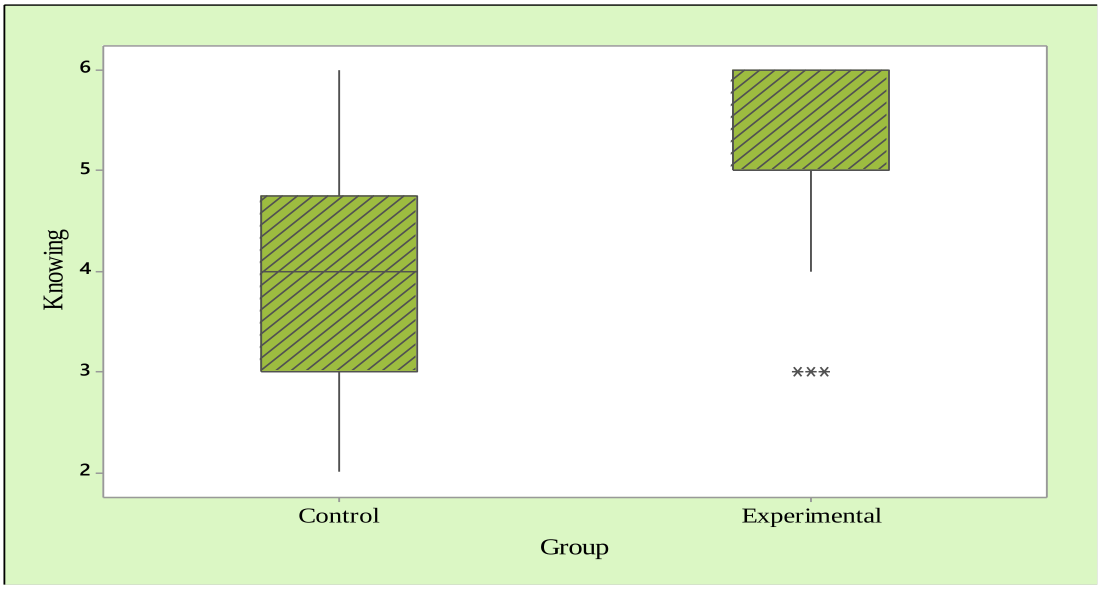


Figure 24: Boxplots for Knowing –Post-test. Note: Numbers showed the extreme values in knowing domain in experimental group.

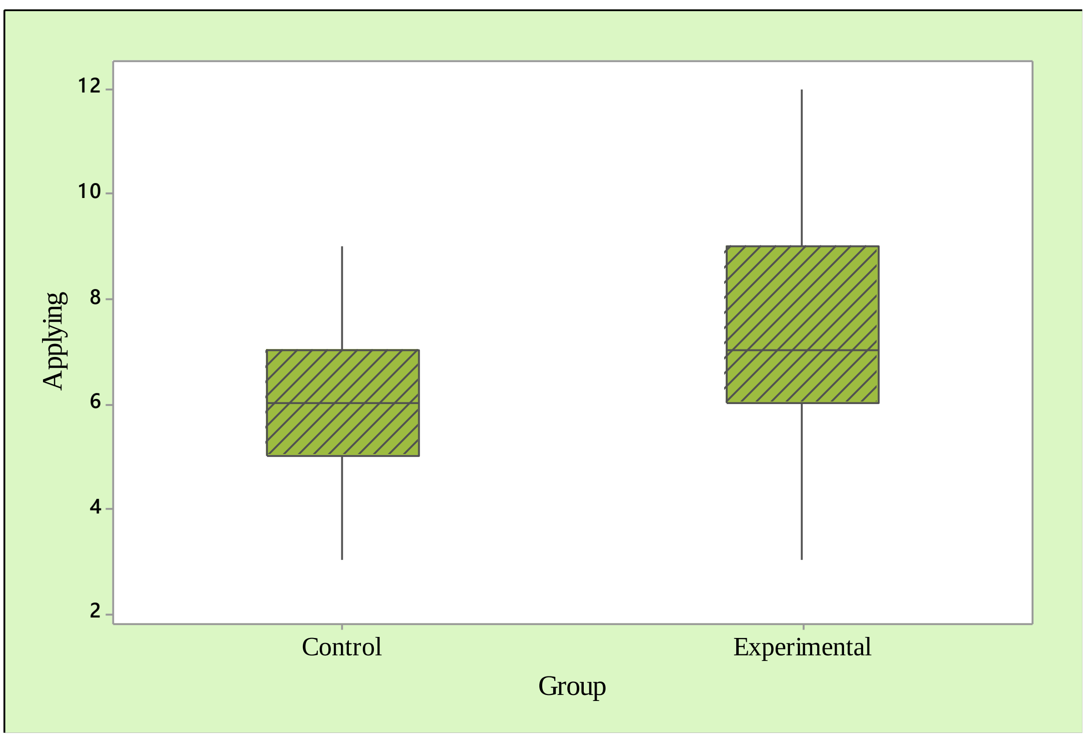


Figure 25: Boxplots for Applying -Post-test

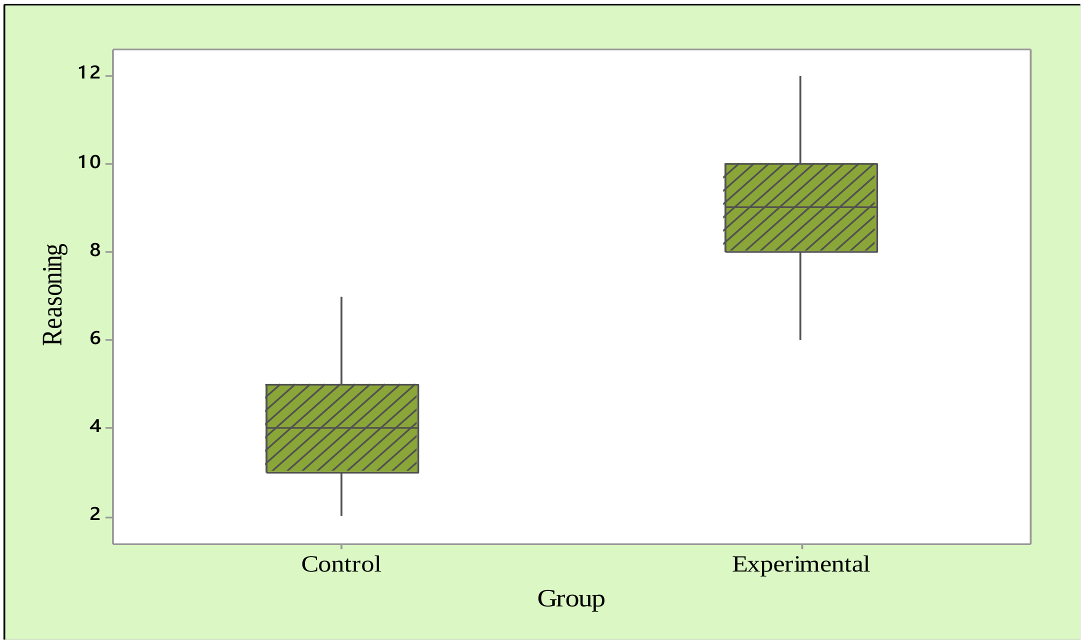


Figure 26: Boxplots for Reasoning -Post-Test

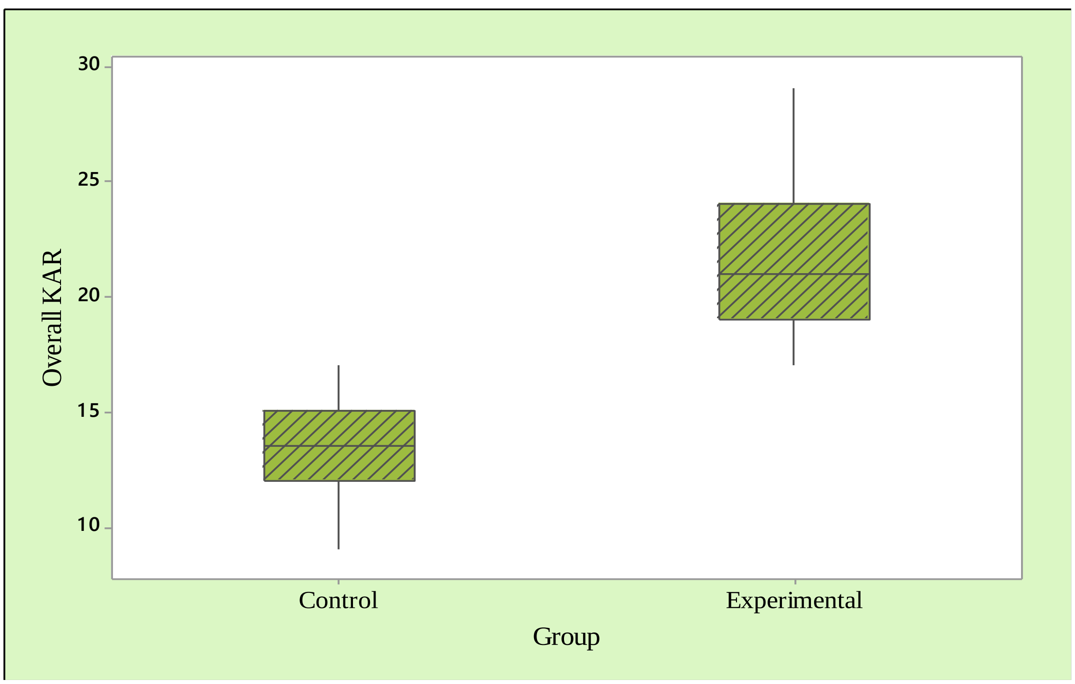


Figure 27: Boxplots for KAR – Post-Test

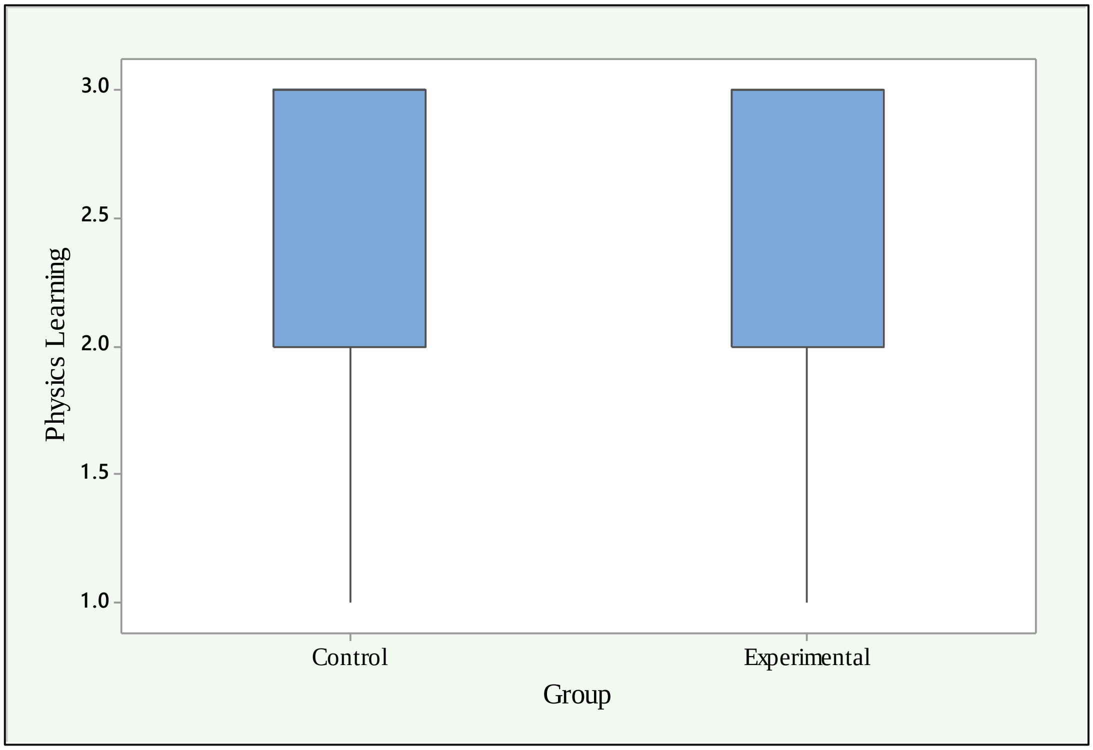


Figure 28: Boxplots for Physics Learning: Pretest

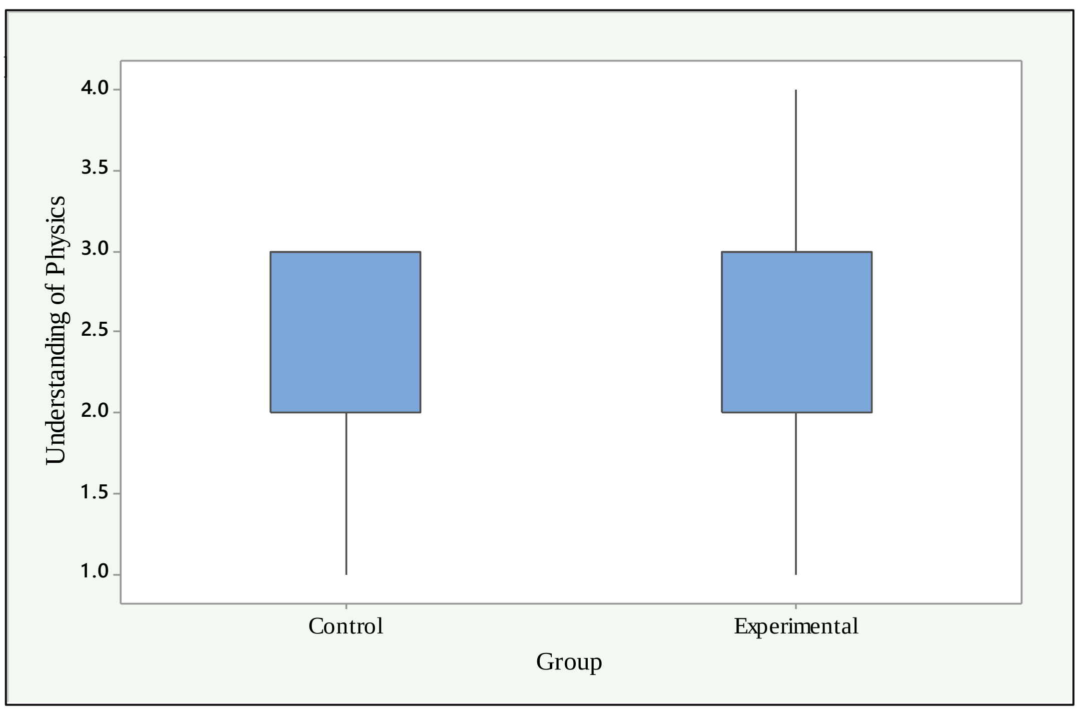


Figure 29: Boxplots for Understanding of Physics: Pretest

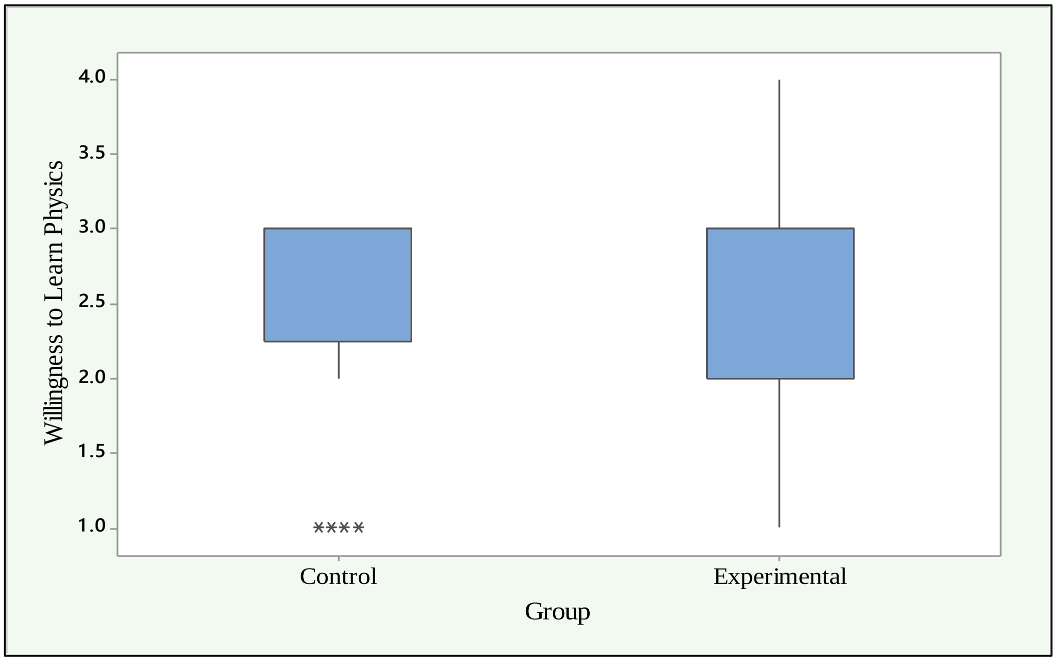


Figure 30: Boxplots for Willingness to Learn Physics: Pretest. Note: Stars showed the extreme scores in Willingness to learn physics domain in control group.

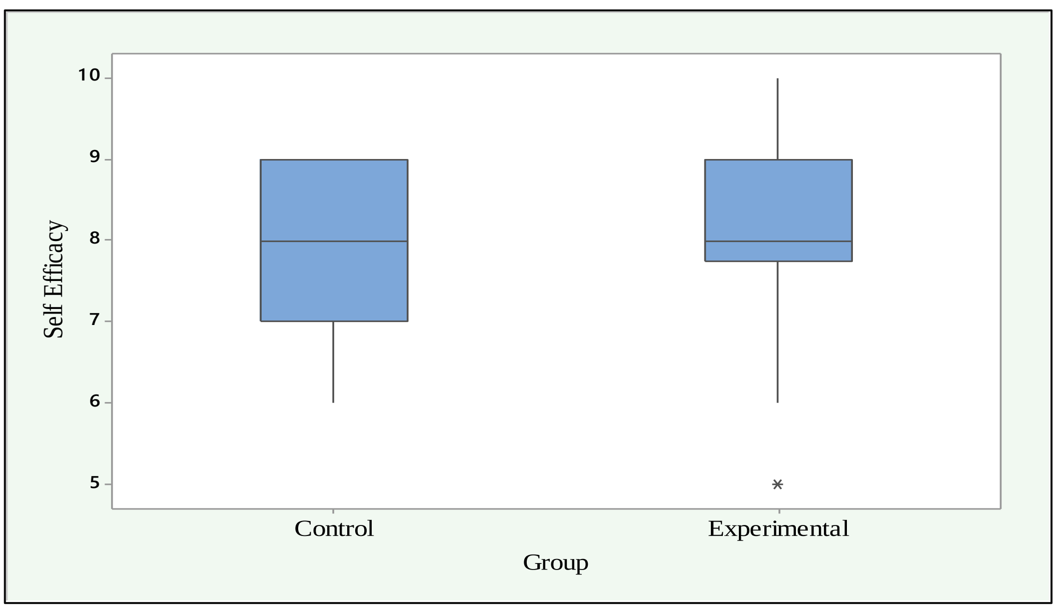


Figure 31: Boxplots for Self-Efficacy: Pretest. Note: Stars showed the extreme values in the overall Self-efficacy in experimental group.

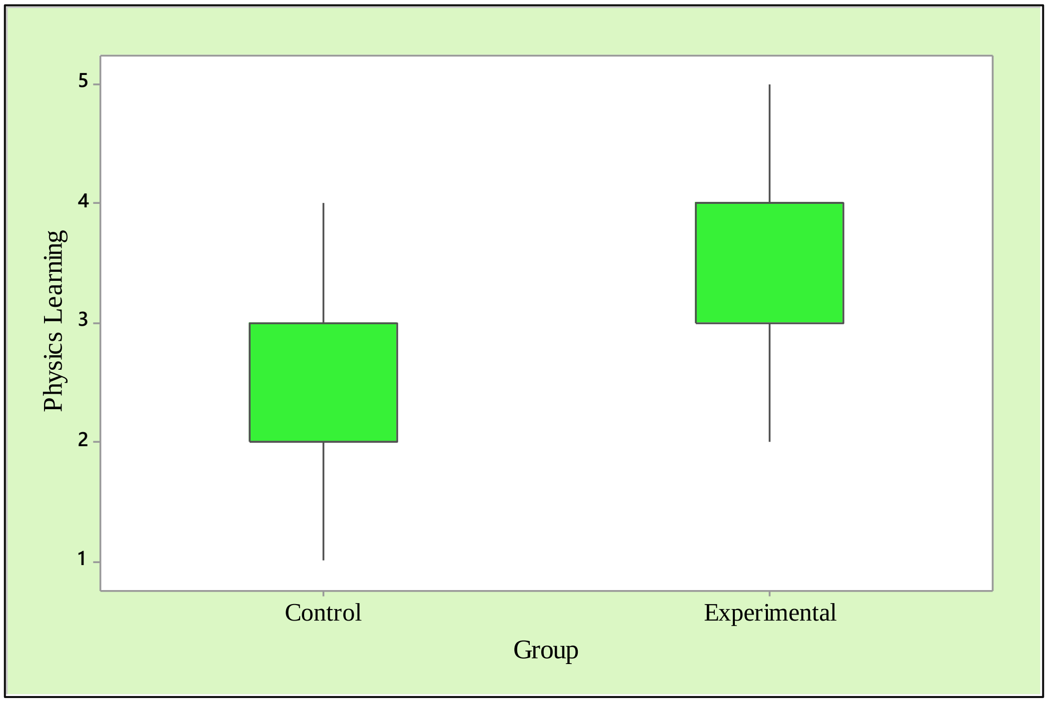


Figure 32: Boxplots for Physics Learning: Post-Test

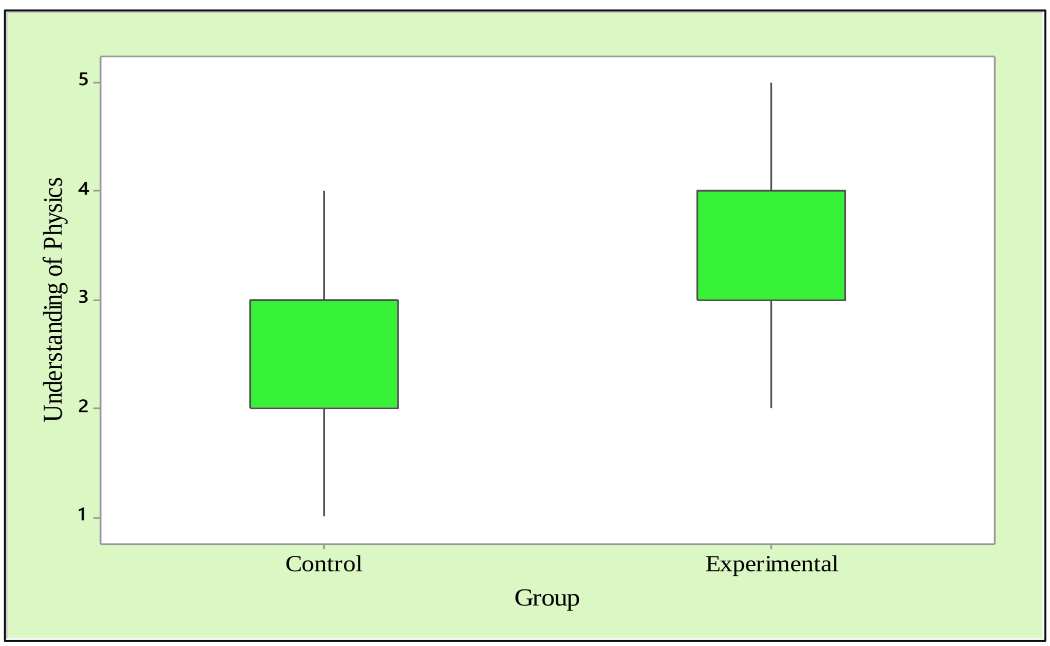


Figure 33: Boxplots for Understanding of Physics -Post-Test

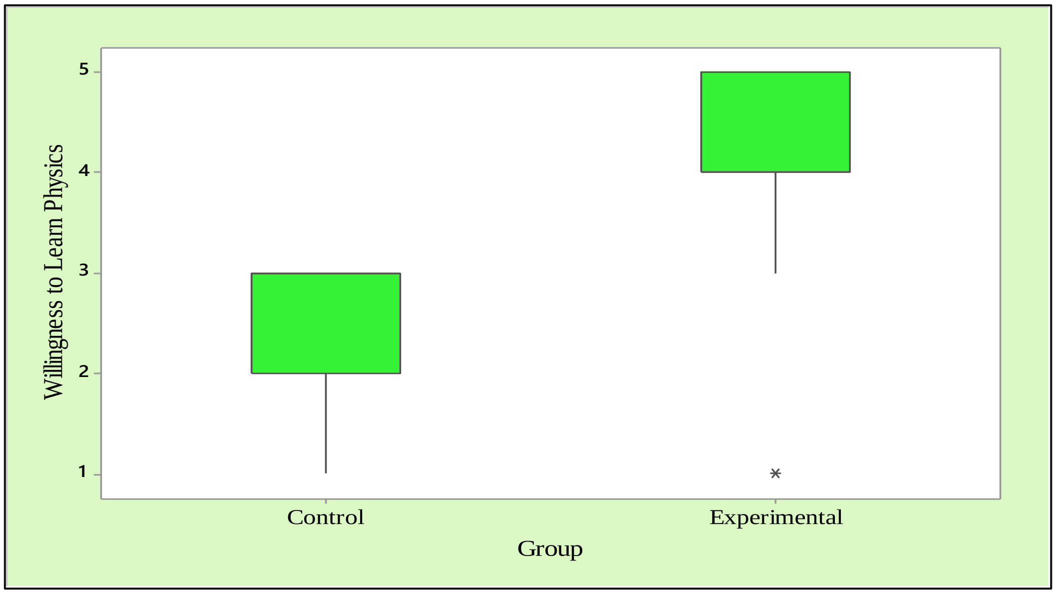


Figure 34: Boxplots for Willingness to Learn Physics -Post-Test

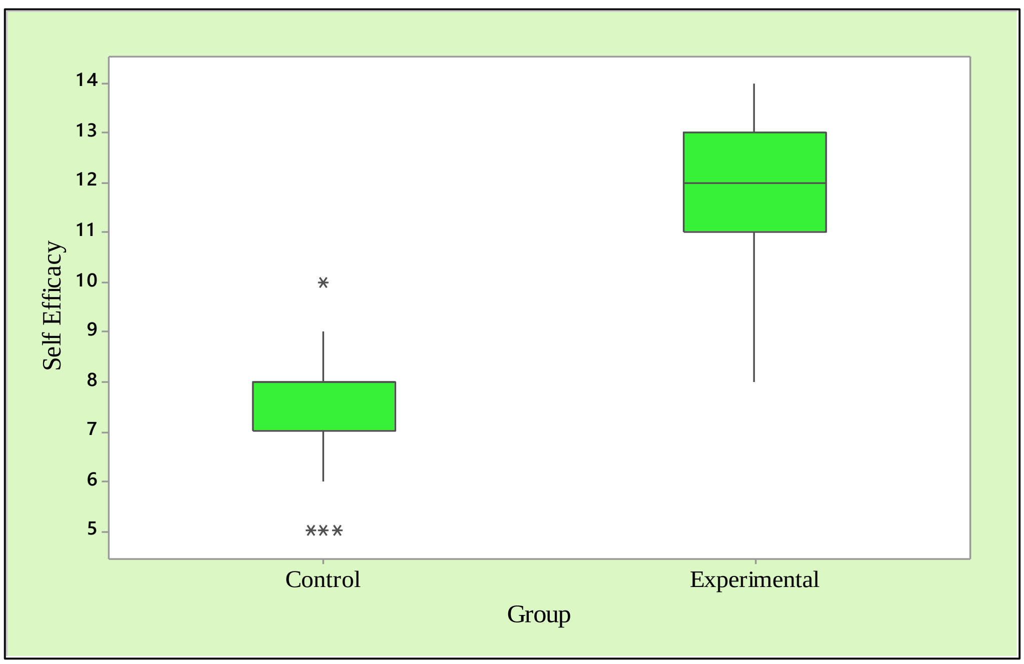


Figure 35: Boxplots for Self-efficacy: Post-Test. Note: Stars showed the extreme values in the overall Self-efficacy in control group.

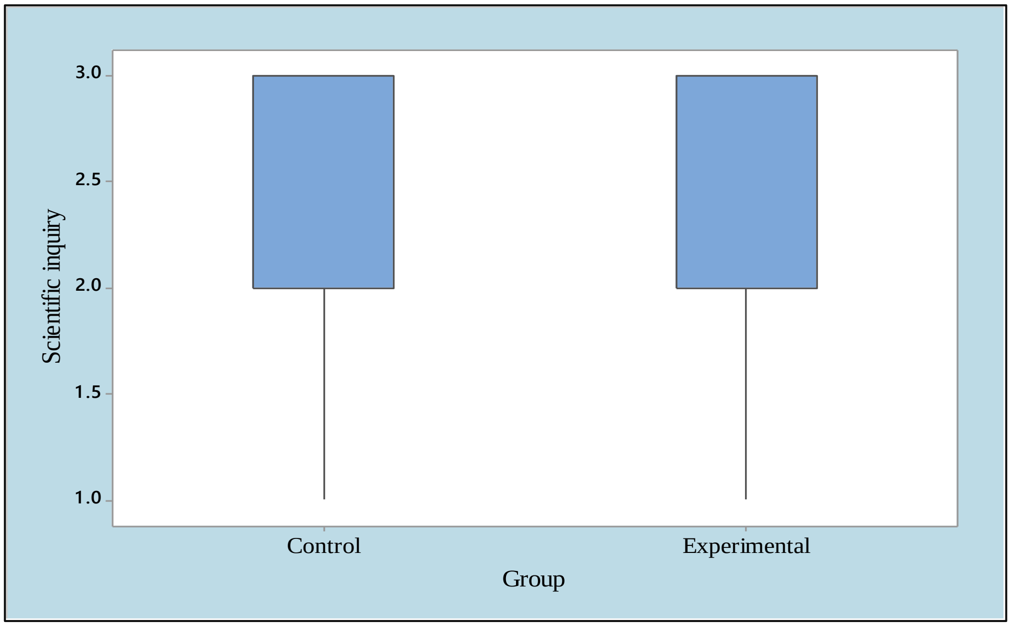


Figure 36: Boxplots for Scientific Inquiry –Pretest

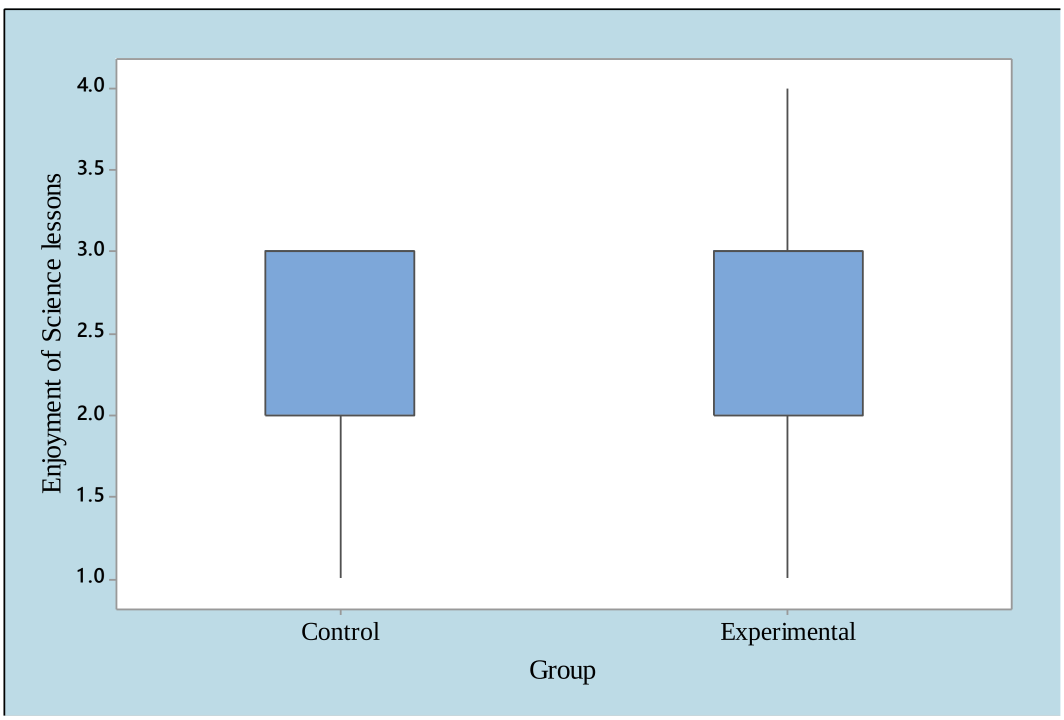


Figure 37: Boxplots for Enjoyment of Science Lessons –Pretest

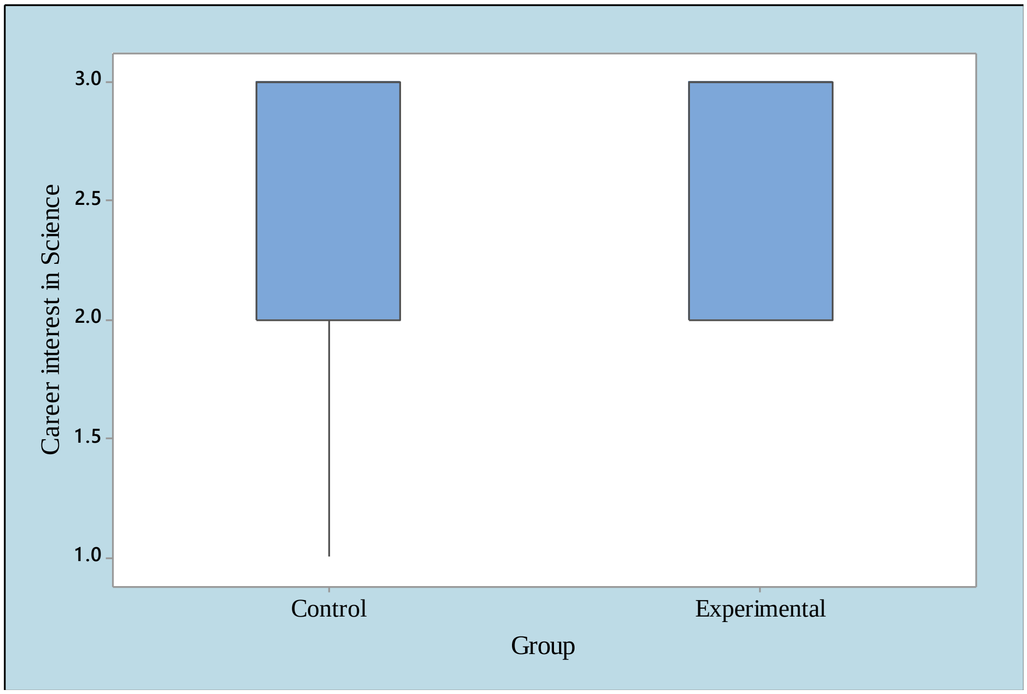


Figure 38: Boxplots for Career Interest in Science -Pretest

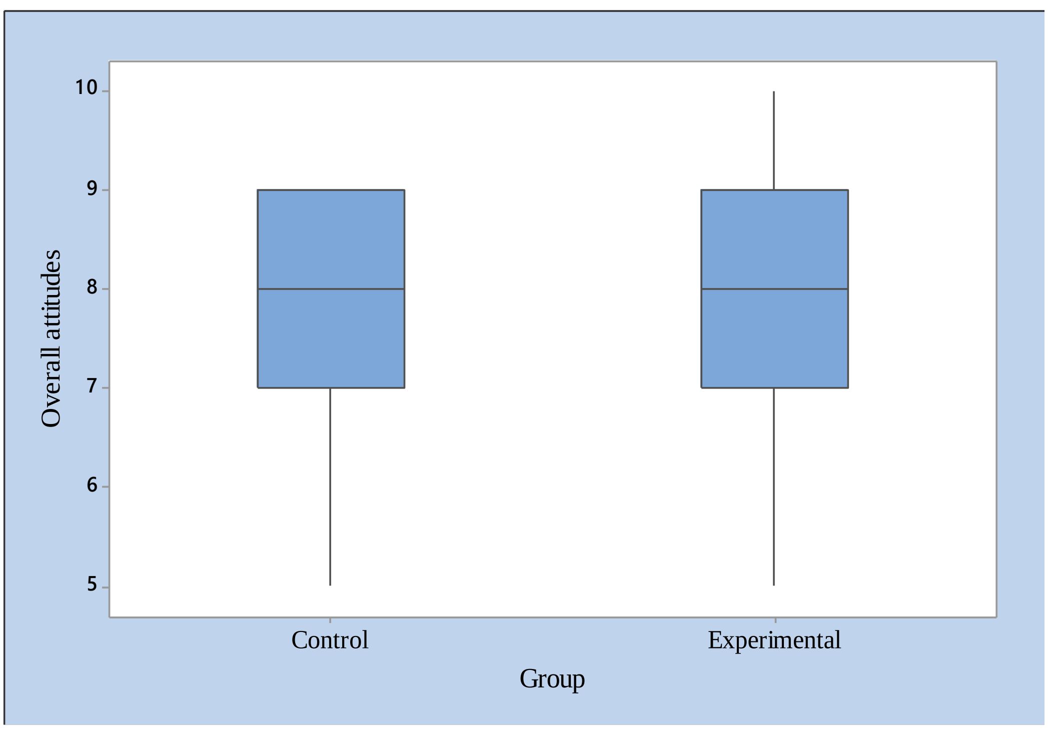


Figure 39: Boxplots for Students' Attitudes Towards Scientific Inquiry -Pretest

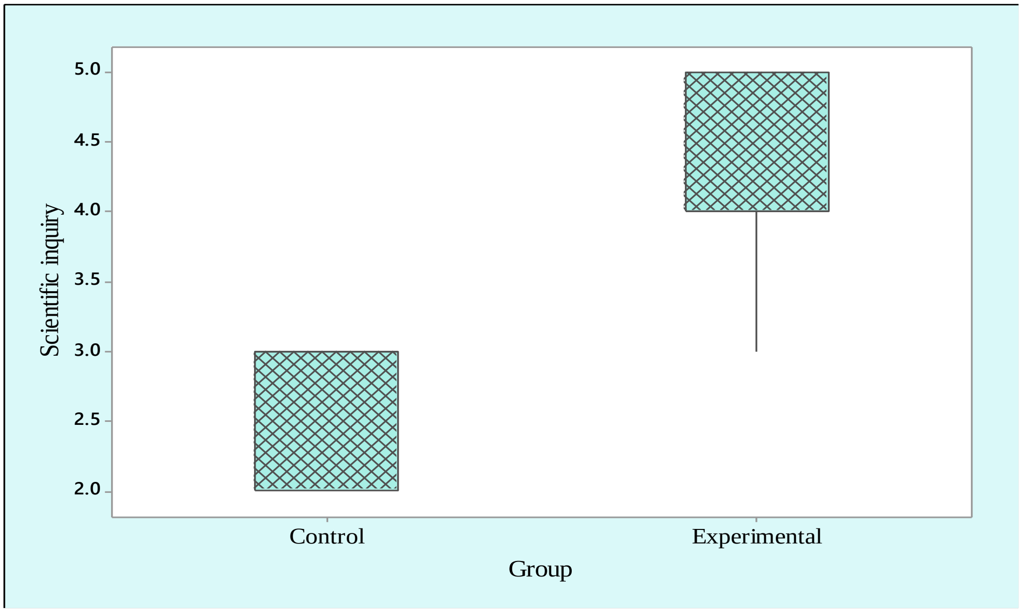


Figure 40: Boxplots for Scientific Inquiry –Post-Test

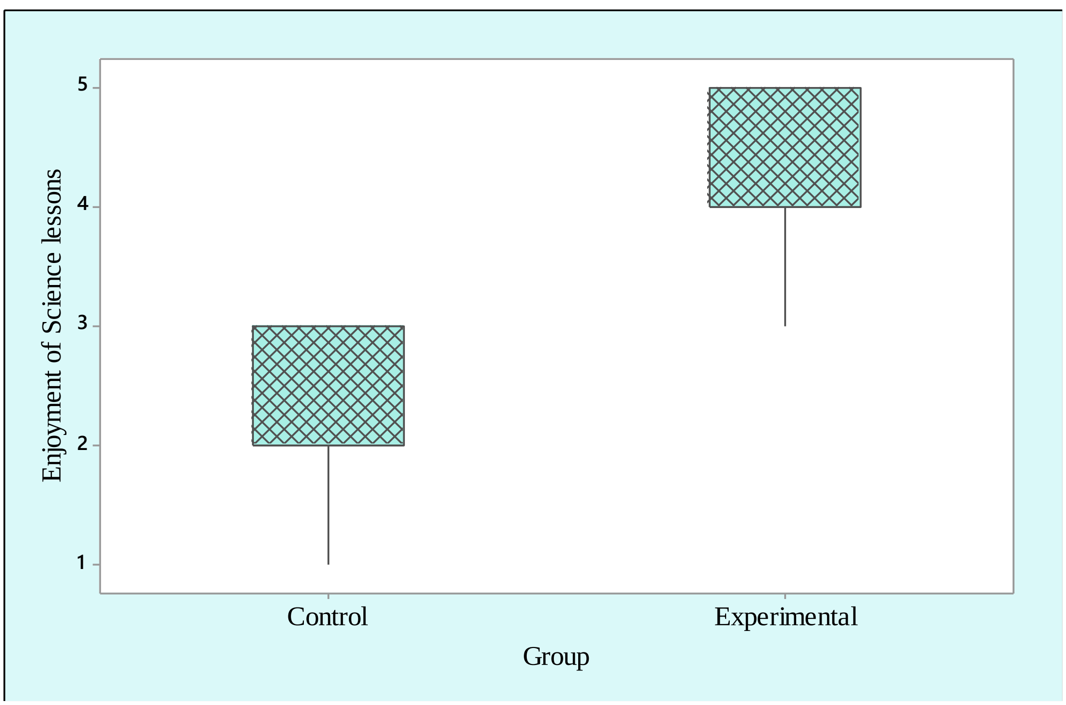


Figure 41: Boxplots for Enjoyment of Science Lessons -Post-Test

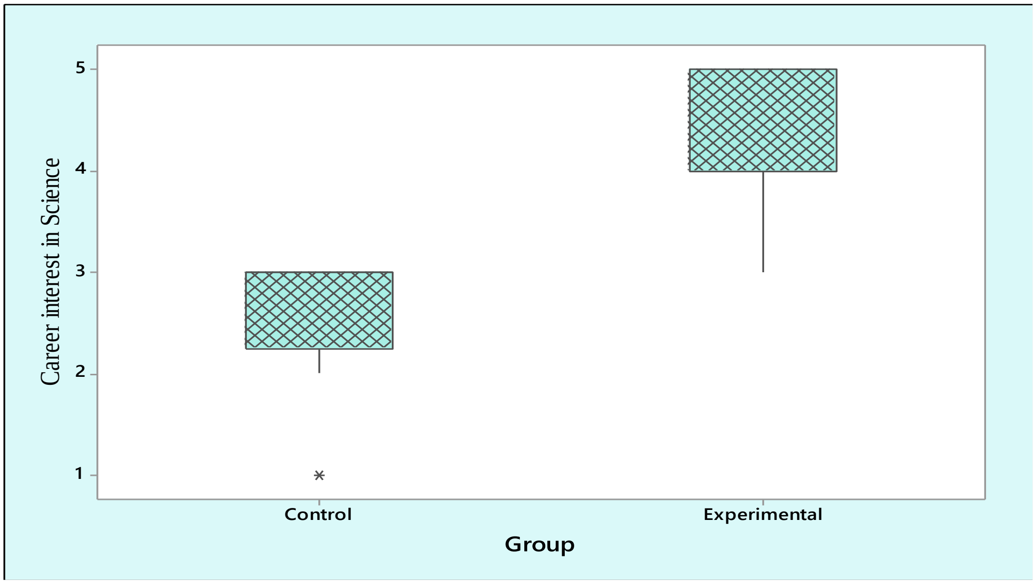


Figure 42: Boxplots for Career Interest in Science -Post-Test. Note: Stars showed the extreme values in the Career interest in Science scale in control group.

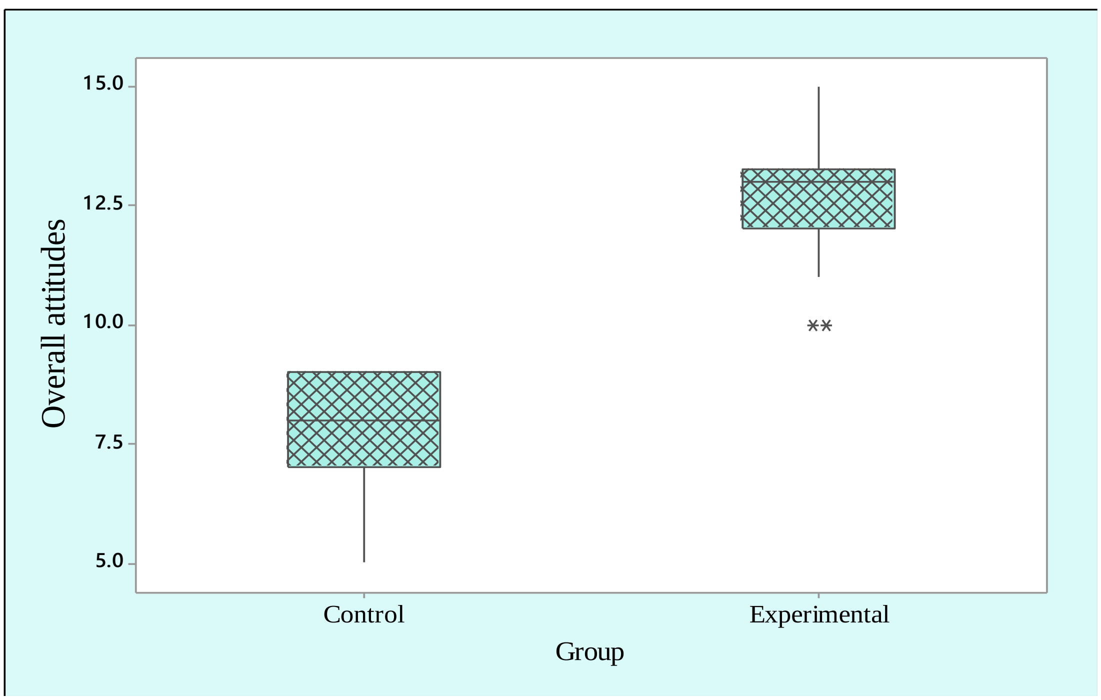


Figure 43: Boxplots for Students' Attitudes towards Scientific Inquiry -Post-Test. Note: Stars showed the extreme values in the overall students' attitudes towards scientific inquiry in experimental group.