United Arab Emirates University

College of Education

IMPACT OF COMPUTER SIMULATIONS ON UAE STUDENTS' LEARNING OF NEWTON'S SECOND LAW OF MOTION AND ATTITUDES TOWARD PHYSICS WITHIN THE CONTEXT OF SCIENTIFIC INQUIRY

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This dissertation is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Under the Supervision of Professor Hassan Tairab

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Declaration of Original Work

I, Khaleel Shehadeh Ali Alarabi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this dissertation entitled "*Impact of Computer Simulations on UAE Students' Learning of Newton's Second Law of Motion and Attitudes Toward Physics within the Context of Scientific Inquiry*", 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 Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my dissertation have been properly cited and acknowledged in accordance with appropriate academic conventions.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

Unlike traditional instructional strategies, Computer Simulations (CSs) have lately been receiving increasing attention and applications within the international physics education community. This study aims to investigate the impact of CSs within an inquiry-based learning environment on the UAE grade 11 students’ performance in Newton’s Second Law of Motion (NSLOM). The study also investigates the impact of CSs within an inquiry-based learning environment on students’ Attitudes towards Scientific Inquiry (ASI), Enjoyment of Science Lessons (ESL), and Career Interest in Science/physics (CIS). The sample of the study consisted of 90 male and female students chosen from a population comprised of public-school grade 11 students from one of the major cities in the UAE. The study employed a pre-test and post-test quasi-experimental design involving four equally-distributed grade 11 Physics classes: two as experimental groups (including 45 CSs-bound students studying under scientific inquiry instructions), and the other two as control groups (including 45 CSs-free students studying under traditional face-to-face instructions). Two instruments were developed to collect data: (1) The Newton’s Second Law of Motion Achievement Test (NSLMAT), which is a two-tier multiple choice assessment test used to evaluate students’ understanding of NSLOM, and (2) The Test of Science-Related Attitudes (TOSRA), which is a questionnaire survey canvassing students' attitudes towards learning physics. Descriptive analysis was conducted making use of Hake’s normalized gain factor, Effect sizes, one- way ANOVA, a paired-sample t-test, and multivariate analysis of variance (MANOVA). Overall, results suggested that, in comparison with face-to-face instruction, CSs were more successful in promoting students understanding of NSLOM topics. Even though both males (d = 2.44) and females (d = 1.49) benefited rather invariably from the CSs, male students seemed to have benefited marginally more from the CSs. Moreover, experimental groups showed noticeable conceptual and procedural understanding gains. The results indicated that CSs within an inquiry-based learning environment helped female (d = 2.10) and male (d = 2.94) students acquire a better understanding of NSLOM conceptual topics, and CSs within an inquiry-based learning environment also helped male (d = 0.88) and female (d = 0.72) students acquire a better understanding of NSLOM procedural topics. Results revealed that CSs- based inquiry learning highly impacted the attitudes towards ASI, ESL and CIS. For CIS and ESL, females rated significantly higher than male students. Finally, it is suggested that if properly designed, CSs within an inquiry-based learning environment can greatly improve student learning of NSLOM.

Keywords: Computer Simulations, Newton's Second Law of Motion, Inquiry-based Learning, Scientific Attitude, Conceptual Understanding, Procedural Understanding, UAE, High School Students, Physics Education.

Title and Abstract (in Arabic)

أثر المحاكاة الحاسوبية في سياق الاستقصاء العلمي على تعلم طلبة دولة الإمارات العربية المتحدة لقانون نيوتن الثاني للحركة واتجاهاتهم نحو الفيزياء

الملخص

على عكس الاستراتيجيات التعليمية التقليدية، نالت المحاكاة الحاسوبية (CSs) وتطبيقاتها مؤخراً اهتمامًا عالمياً من قبل المشتغلين بتعليم الفيزياء؛ لذلك هدفت هذه الدراسة إلى معرفة أثر المحاكاة الحاسوبية في سياق الاستقصاء العلمي على تعلم طلبة الصف الحادي عشر في دولة الإمارات العربية المتحدة قانون نيوتن الثاني للحركة (NSLOM)، وكذلك أثرها على اتجاهات الطلبة نحو الفيزياء (اتجاهاتهم نحو الاستقصاء العلمي (ASI)، والاستمتاع بدروس العلوم والفيزياء (ESL)، وكذلك العمل في مجال العلوم / الفيزياء (CIS)) مقارنة بالطلبة الذين لم يعتمدوا في تعلمهم على المحاكاة الحاسوبية.

تكوّن مجتمع الدراسة من طلبة الصف الحادي عشر بالمدارس الحكومية في إحدى المدن الرئيسة في دولة الإمارات العربية المتحدة. ولقد تم تطبيق الدراسة على عينة من (90) طالباً وطالبة. استخدمت الدراسة تصميمًا شبه تجريبي بتطبيق اختبار قبلي واختبار بعدي على أربعة صفوف دراسية من طلبة الصف الحادي عشر موزعة بالتساوي: صفين دراسيين كمجموعة تجريبية (45 طالباً وطالبة تم تدريسهم باستخدام المحاكاة الحاسوبية في سياق الاستقصاء العلمي)، والفصلين الأخرين كمجموعة ضابطة (45 طالباً وطالبة تم تدريسهم بالطريقة التقليدية وجهاً لوجه). لأغراض الدراسة تم تطوير أداتين لجمع البيانات: (1) اختبار تحصيلي في موضوع قانون نيوتن الثاني للحركة (NSLMAT)؛ وهو من نوع الاختيار من متعدد ومكون من مستويين (two-tier multiple choice) لتقييم مدى فهم الطلبة لقانون نيوتن الثاني، و (2) استبانة اتجاهات الطلاب نحو العلوم (TOSRA) للكشف عن اتجاهات الطلاب نحو الفيزياء. تم تحليل البيانات باستخدام: الإحصاء الوصفي، معامل الزيادة في التحصيل بين الاختبار القبلي والاختبار البعدي (Hake's normalized gain factor)، فاعلية طريقة التدريس (Effect sizes)، تحليل التباين الأحادي (ANOVA)، واختبار t للعينات، وتحليل التباين المتعدد (MANOVA).

لقد توصلت الدراسة إلى وجود دلالة إحصائية بشكل عام، حيث أشارت النتائج إلى أنه مقارنةً بالتعليم التقليدي وجهًا لوجه، كانت المحاكاة الحاسوبية أكثر فاعلية في تحسين فهم الطلبة لقانون نيوتن الثاني للحركة، مع أفضلية نسبية للطلبة الذكور مقارنة مع الطلبة الإناث. إضافة إلى ذلك أظهرت النتائج أن المحاكاة الحاسوبية أسهمت في تطوير المعرفة المفاهيمية والمعرفة الإجرائية لكل من الذكور والإناث على حد سواء. بيّنت نتائج الدراسة أن اتجاهات الطلبة نحو الاستقصاء العلمي، الاستمتاع بدروس العلوم والفيزياء، والعمل بوظيفة مستقبلية لها علاقة بالعلوم / الفيزياء تأثرت بشكل كبير بالمحاكاة الحاسوبية. مقارنة بالطلبة الذكور فإن اتجاهات الطلبة الإناث نحو الاستمتاع بدروس العلوم والفيزياء، والعمل بوظيفة مستقبلية لها علاقة بالعلوم / الفيزياء كان أكبر. أخيرًا، تقدم نتائج هذه الدراسة دليلاً على أنه إذا تم تصميم أنشطة المحاكاة الحاسوبية في سياق الاستقصاء العلمي بشكل جيد، يمكن أن يسهم ذلك في تطوير تعلم الطلبة لقانون نيوتن الثاني للحركة بشكل كبير.

مفاهيم البحث الرئيسية: المحاكاة الحاسوبية، قانون نيوتن الثاني للحركة، التعلم القائم على الاستقصاء العلمي، الاتجاهات العلمية، المعرفة المفاهيمية، المعرفة الإجرائية، دولة الإمارات العربية المتحدة، طلبة الحلقة الثالثة (التعليم الثانوي)، تعليم الفيزياء.

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Dedication

To my parents, I hope I will always make you proud.

To my family who have always supported and encouraged me to pursue my dreams.

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List of Abbreviations

ADEK	Abu Dhabi Department of Education and Knowledge
ANOVA	Analysis of Variance
ASI	Attitude toward Scientific Inquiry
CG	Control Group
CIS	Career Interest in Science
CSs	Computer Simulations
d	Cohen's effect sizes
DV	Dependent Variable
EG	Experimental Group
ESL	Enjoyment of Science/physics Lessons
G	Average Normalized Gain
IBL	Inquiry-Based Learning
IBT	Inquiry-Based Teaching
IV	Independent Variable
M	Mean
MANOVA	Multivariate Analysis of Variance
MCQ	Multiple-Choice Question
MOE	Ministry of Education
N	Number
NSLOM	Newton's Second Law of Motion
NSLMAT	Newton's Second Law of Motion Achievement Test
PhET	Physics Education Technology
PISA	Programmed for International Student Assessment
SD	Standard Deviation
Sig.	Significant
SPSS	Statistical Package for the Social Sciences
TIMSS	Trends in International Mathematics and Science Study

TOSRA	Test of Science Related Attitudes
UAE	The United Arab Emirates
UAEU	United Arab Emirates University
VAR	Variance
%	Percentage
α	Cronbach's Alpha Coefficient Value
η^2	Partial Eta Squared
χ^2	Chi-Square

Chapter 1: Introduction

1.1 Overview

This chapter introduces the essential components of the research; a background about Computer Simulations (CSs) in teaching and learning physics in the United Arab Emirates (UAE) context, the research problem, the purpose of the study, the research questions and its significance. The chapter also presents and discusses the operational definitions, and the identification of variables.

1.2 Background

The twenty-first century has witnessed a tremendous revolution in technology that continues to develop. The field of education is also significantly affected by this revolution and its technological expansion in such a world where students need to be equipped with meaningful knowledge and skills in order to cope with such an ever-changing technology and even changing society. Research studies that dealt with the use of technology and computers in education were very common during the last few years. There were several previous attempts to use computers and technology to improve school learning, Bransford, Brown and Cocking (1999) speculated on previous research findings on the science of learning to enhance student understanding in science and to bring about interest and motivation, and they said that new technologies offer the possibility of creating learning environments that increase the chances of "old" - but still useful - technologies; Blackboard, and one-way linear communication media, such as television broadcasts. Yet there are many aspects of technology that make it easier to create environments that match the principles of learning.

Physics has been and continue to be a source of concern to both students and teachers (Jimoyiannis & Komis, 2001; Erinosho, 2013). Because physics is theoretical in nature (Stern, Echeverría & Porta, 2017; Radlović-Čubrilo, Lozanov-Crvenković, Obadović, & Segedinac, 2014; Alexanian, 2013; Bajpai, 2013). Recent trends in teaching and learning suggest that the solution to this negative image of physics depends on finding alternative effective teaching methods that maintain student achievement and improve student attitudes (Balfakih, 2003). Therefore, it was noted that only by actively engaging, specific visual representations and models students can improve their understanding of basic physics concepts (Stern & Huber, cited in Batuyong & Antonio, 2018).

Based on data from the third cycle of Programmed for International Student Assessment (PISA), Cairns and Areepattamannil (2019) found that inquiry-based science education is very important. It is positively and highly related to the personality of science, such as interest and enjoyment of learning science, effective future scientific motives, scientific self-concept, and self-efficacy. NGSS (2013) suggests that teaching of science should generally be inquiry-based. Meaningful practice and the use of science processes should become a constituent part of instructions in classrooms, not only to motivate students but also to visualize their own learning. Inquire-based experiments serve to lead students to question the contradictions they form in their minds and attach meaning to concepts in this way (Gunstone & Champagne, 1990).

Within this framework, CSs play a major role in the education of physics as using CSs to teach physics concepts can enhance students' understanding by providing a level of reality which is not possible with traditional teaching methods (Mengistu & Kahsay, 2015). For example, CSs provide learners with a realistic experience through which knowledge can be acquired and manipulated to better understand the relationship between the concepts studied, CSs also can combine animation, interactive laboratory experience, and visualization (Widiyatmoko, 2018). Visualization of physics learning may result in better understanding of natural phenomena, identification and understanding of cause-and-effect relationship of natural phenomena, development of concepts based on the principle from simple to complex, adoption of permanent knowledge concerning traditionally acquired knowledge, and transformation of the acquired knowledge into skills and habits (Obradović & Rančić, 2012, cited in Radulović, Stojanović & Županec, 2016). When CSs are used as an inquiry lesson, it enables students to manipulate multiple variables that produce different results digitally. Inquiry-based lessons are similar to hands-on practice in that they provide students with an opportunity to manipulate variables (Wilson, 2016). Podolefsky, Perkins, and Adams (2010) found that CSs greatly improved students' understanding of basic concepts that are difficult to understand. In addition, compared to non-simulated instructions, computer-based simulations have advantages in achievement (Smetana & Bell, 2012; D'Angelo et al., 2014). Moreover, CSs can not only provide powerful benefits in science education by encouraging constructive learning activities, but also by supporting different types of learners (such as visually oriented students) (Mengistu & Kahsay, 2015).

Using CSs to teach physics concepts can enhance students’ understanding by providing a level of reality that is not possible with traditional teaching methods (Mengistu & Kahsay, 2015).

Several studies that dealt with CSs emphasize the importance and effectiveness of CSs in teaching and learning physics because of its capability to enhance practicing (Smetana & Bell 2012). Jimoyiannis and Komis (2001) and Clark (1994) found that students working with CSs exhibited significantly higher scores in the research tasks and that CSs might be used as an alternative instructional tool. Furthermore, they strongly supported CSs as an alternative learning tool to help students in meeting their cognitive limitations and develop a functional understanding of physics.

CSs can improve teaching and learning practices particularly those associated with classroom activities (Wieman, Adams, Loeblein & Perkins, 2010). Other researchers suggested that CSs allow students to learn physics concepts and apply them in a virtual environment with manual skills that can only be obtained in real-world labs (Bozkurt, & Ilik, 2010; Rutten, Van Joolingen & Van der Veen, 2012; Quellmalz, Timms, Silberglitt & Buckley, 2012).

Previous research studies dealing with student attitudes toward physics suggest that there is a positive significant correlation between students’ learning in physics and their attitudes towards physics (Sari, Pektaş, Çelik & Kirindi, 2019; Kattayat, Josey & Asha, 2016; Pyatt & Sims, 2012). For example, Sari, Pektaş, Çelik and Kirindi (2019) found that computer-based laboratory applications and virtual applications have been identified to have a positive impact on students' attitudes and motivations. In addition, compared to virtual lab applications, computer-based lab applications are more effective in improving student communication, collaborative work, and stimulating participation. Other studies also found that if laboratory technology or methods are included in teaching, these students will become better learners and their attitudes will improve (Oymak & Ogan-Bekiroglu, 2017; Aşıksoy & İşlek, 2017). Additionally, Bozkurt and Ilik (2010) found that CSs have a positive impact on students' beliefs in physics and physics achievement.

It seems that CSs are likely to enhance students’ performance and attitudes when they are integrated into the teaching learning processes. They are most likely to create an interactive learning environment that can help teachers and students engage in meaningful activities, and hence, facilitate learning.

Unfortunately, learning physics is a difficult endeavor to many students which leads some of them to take a negative stance toward physics (Sarı, Hassan, Güven & Şen, 2017; Erinosho, 2013). This is related to several reasons: firstly, physics by its nature is considered a difficult subject, as it is often perceived as a discipline that focusses on acquisition of abstract physical knowledge, meanwhile many concepts are abstract and require high cognitive demand. In addition, basic mathematical complexity can quickly overcome students’ intuition (Dori & Belcher, 2005; Huppert, Lomask & Lazarowitz, 2002; Trey & Khan, 2008; Aina, 2013). Secondly, Bagnoli, Guarino and Pacini (2018) and Hadzigeorgiou and Schulz (2017) contend that the main problem in physics is that it does not depend on what to learn, but on what to do and practice in proper contexts in life. Örnek, Robinson and Haugan (2008) found that students find physics difficult because they face different representations at the same time, such as experiments, formulas, calculations, charts, and conceptual explanations.

Thirdly, according to Sirait and Mursyid (2018) what makes Newton's laws and other physics' concepts so tricky is that they are related to other important concepts such as velocity and acceleration, and the learners need to have them conceptualized before attempting to conceptualize Newton's Second Law of Motion (NSLOM). In addition, a study conducted by Obaidat and Malkawi (2009) found that most students might have wrong and naïve models about basic concepts of kinematics and Newton's laws of motion and indicates that students' grasp of these concepts is weak which consequently leads to have difficulties in solving the physics test (Sirait & Mursyid, 2018; Camarao & Nava, 2017). Finally, in traditional and teacher-based instruction, students spend time listening to lectures, performing scheduled "recipe" laboratory activities, and remembering scientific facts highlighted in the test which dampen their interest as they find no enjoyment in doing these activities (Cairns & Areepattamannil, 2019; Hadzigeorgiou & Schulz, 2017).

For many students who have a negative attitude toward physics, learning physics is a challenge (Sari, Pektaş, Çelik & Kirindi, 2019; Erinosho, 2013). For instance, in a study conducted in the United States, three types of factors were identified as students' physical difficulties, one of which was the student's attitude (Erinosho, 2013). Similarly, according to Balfakih (2003), students in the UAE show similar problems; these include poor academic achievement and negative attitudes towards scientific subjects, which have led to high dropout rates for students in high school science. Therefore, students often consider physics difficult, abstract and boring, and it is still the least popular scientific subject among the average students. As only a very small number of students choose to study physics (Erinosho, 2013).

Despite the government's substantial investment in teaching and learning resources for the students, the performance of students in physics in national examinations remains low as attested by the UAE Certificate of Secondary Education (MOE, 2000). Moreover, results of international examinations in science over the years have been dismal, as shown by Trends in International Mathematics and Science Study (TIMSS) and PISA (Martin, Mullis, Foy& Hopper, 2015; OECD, 2015a). For example, the UAE in its first participation in the TIMSS 2011, achieved average scores in science in grades 4 and 8, were well below the international average at both grade levels. Fourth graders in the UAE were ranked as 43rd in science, while eighth graders achieved the 24th position. A significant area of weakness for both grade levels was in one cognitive domain, which is "Applying." According to TIMSS results in 2015, fourth and eighth graders performed below the international average of science and earned less than 500 points in content and cognitive domains. grade 4 students in the UAE achieved an overall score of 451 in science, 49 points below the international average, and ranked 35 in the international league. The UAE grade 8 students achieved an overall average of 477 in science, only 23 points below the international average, and occupied the 21st position in the international league (Martin, Mullis, Foy& Hopper, 2015; OECD, 2015a). Moreover, statistics obtained from the analysis of the Ministry of Education (MOE) Department of Assessment showed that there is a persisting need to improve the conceptual understanding of the UAE students in science education (Kamal & Trines, 2018).

Students often do not choose to learn physics due to its perceived difficulty (Erinosho, 2013; Council, 2011). According to Hadzigeorgiou and Schulz (2017), what students see as interesting does not necessarily help them to study physics. For example, Wilson (2016) claimed that teaching physics is a difficult task because most physics labs are interactive, where students can employ and allocate things to better understand the concepts being taught. This is a real sight in a physics classroom environment and needs to be addressed by teachers (Wilson, 2016). It is easy to find and utilize laboratories for humbler concepts. However, finding and using the right laboratory is more difficult when teaching more intangible concepts (Wilson, 2016).

The concern about physics-learning and teaching has been documented in research studies. For example, Batuyong and Antonio (2018) found some problems in teaching physics today: first, the textbooks are insufficient and lack the laboratories and tools to conduct practical experiments. Secondly, studies show that a lack of models or representation of invisible concepts is one of the reasons why students have difficulty understanding scientific concepts. Finally, the biggest challenge for science teachers is to design or devise ways to make teaching and learning interesting and meaningful.

Based on the evidence mentioned in previous research (Sarı, Hassan, Güven & Şen, 2017; Bagnoli, Guarino & Pacini, 2018; Örnek, Robinson & Haugan, 2008; Sirait & Mursyid, 2018; Obaidat & Malkawi, 2009; Camarao & Nava, 2017; Cairns & Areepattamannil, 2019; Sari, Pektaş, Çelik & Kirindi, 2019; Erinosho, 2013; Balfakih, 2003; Martin, Mullis, Foy & Hopper, 2015; OECD, 2015a), it seems that there is an urgent need to overcome the difficulties students face in learning physics, MOE recommended that physics teachers must improve their teaching methods to make physics more attractive and less abstract, and proposed that teachers should actively involve students in the teaching and learning process and added that rote learning should be excluded as possible (MOE, 2000; Sahoo, 2016, cited in Ridge, Kippels, & El Asad, 2015). Therefore, teachers must follow methods that may likely to enhance student's participation and understanding in the teaching and learning process by linking physics examples to their real-life and environment and enabling students to gain practical experience, such as using CSs as a technological tool (NGSS, 2013). In addition, for physics teaching to be operative, physics teachers must encourage learning that leads to conceptual understanding, as well as teach physics through exploration, discovery, demonstration, simulations, practical work, laboratory-based experience, and other practical experiences to understand these abstract concepts (Stern & Huber, cited in Batuyong & Antonio, 2018; Lamina, 2019).

1.3 Problem Statement

Despite the importance of physics that is not only tantamount with success at school, but also in life, physics instruction is still ineffective, and the resources used in the classroom and laboratories are difficult to manipulate and uninteresting for many students (Bagnoli, Guarino & Pacini, 2018; Cairns & Areepattamannil, 2019; Erinosho, 2013; Wilson, 2016; Batuyong & Antonio, 2018; MOE, 2000; Sahoo, 2016, cited in Ridge, Kippels, & El Asad, 2015; NGSS, 2013). However, finding from recent research studies have also shown that mere interest in using computers in schools are not enough for effective learning (Council, 2000).

It has been documented that the UAE students are experiencing difficulties in physics which are attributed to the ineffective instructional strategies and lack of motivation (Balfakih, 2003). For example, current practices in teaching and learning physics do not match the MOE expectations, as most of the teaching learning processes are guided by the traditional approaches to learning, in which a teacher explains to students the rules and principles with little emphasis on knowledge construction and critical reasoning and reflection. In most UAE schools, the primary mode of physics education focuses on teaching, memorizing definitions and formulas, and applying them to standard problems (Balfakih, 2003). Consequently, students are accustomed to rote memorization of formulas. Many students often try to avoid problems that require qualitative reasoning and oral interpretations. This traditional method of lecture-based teaching does not help students improve their thinking skills, which reflected in the international comparative study TIMSS 2011 and 2015 for the lowest scientific classification for the UAE students in the eighth grade (Martin, Mullis, Foy& Hopper, 2015; OECD, 2015a). For example, according to OECD (2010) the Pisa standardized test for 2009 ranked the participating UAE students in science 42 out of 65 countries with average 466 points.

Taking this research-based evidence for problems of the UAE students, it is believed that CSs, within the context of scientific inquiry can be an appropriate alternative to remedy this problem and make student learning more effective. From this perspective, CSs have great potentials to stimulate learning and interest. They are more likely to enable learners to see and interact with natural phenomena, stimulate learners' challenges, and prompt reactions (Council, 2011).

Another focal point is that, although, there has been a growing interest in the use of CSs in the classroom, their effectiveness at school level has not been fully researched locally and globally. However, the results from the growing interest in CSs research studies has provided conflicting results. Nevertheless, most of these studies have found that CSs have a positive effect on students (Mengistu & Kahsay, 2015; Wilson, 2016; Podolefsky, Perkins & Adams, 2010; Smetana & Bell, 2012; D'Angelo et al., 2014; Jimoyiannis & Komis, 2001; Clark, 1994; Quellmalz, Timms, Silberglitt & Buckley, 2012; Bozkurt, & Ilik, 2010; Sari, Pektaş, Çelik & Kirindi, 2019; Kattayat, Josey & Asha, 2016; Pyatt & Sims, 2012; Oymak & Ogan-Bekiroglu, 2017; Aşıksoy & İşlek, 2017). On the other hand, some studies have shown that the use of CSs is less effective than traditional instruction (Marshall & Young, 2006; Regan & Sheppard, 1996; McKagan, Handley, Perkins & Wieman, 2009). However, there were few studies that did not find any advantages of using CSs over traditional instructions (Winn et al. 2006; Hannel & Cuevas, 2018; Keller, Finkelstein, Perkins & Pollock, 2007; Steinberg, 2000; Kelly, Bradley & Gratch, 2008; Winn et al, 2006).

Within these conflicting findings of past research, the present study is a response to the call of researchers for further research on the effectiveness of CSs in teaching physics (Jimoyiannis & Komis, 2001; Hadzigeorgiou & Schulz, 2017; Radlovic-Cubrilo, Lozanov-Crvenkovic, Obadovic, & Segedinac, 2014; Batuyong & Antonio, 2018). Moreover, this study is an attempt to fill the gap in the lack of research in the efficacy of CSs in teaching physics specifically NSLOM within the context of scientific inquiry instruction and students' attitudes toward physics at the secondary school level in the UAE context.

1.4 Purpose of the Study

The purpose of this study is to examine the impact of computer simulations on the UAE students' learning of Newton's second law of motion and attitudes toward physics within the context of scientific inquiry instruction of grade 11. Specifically, the study will, therefore, seek to examine the following:

I. Assess grade 11 physics students' overall performance in Newton's second law of motion when taught with CSs within authentic inquiry instruction compared to traditional face-to-face instruction.

II. Assess grade 11 students' conceptual and procedural knowledge of Newton's second law of motion when taught with CSs within authentic inquiry instruction compared to traditional face-to-face instruction.

III. Assess grade 11 students' attitudes towards physics when taught with CSs within an authentic inquiry instruction compared to traditional face-to-face instruction.

1.5 Research Questions

To explore the impact of computer simulations on the UAE students' learning of Newton's second law of motion and attitudes toward physics within the context of scientific inquiry instruction, the research study addresses the following seven research questions:

1- What impact do computer simulations have on grade 11 students' student performance in Newton's second law of motion within an inquiry context?

2- Are there any statistically significant differences in performance in Newton's second law of motion between grade 11students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instruction?

3- Is there any statistically significant difference in performance regarding conceptual understanding in Newton's second law of motion, between grade 11 students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instruction?

4- Is there any statistically significant difference in performance regarding procedural understanding in Newton's second law of motion, between grade 11 students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instruction?

5- What impact do computer simulations have on grade 11 student attitudes towards physics when taught within the context of scientific inquiry?

6- Is there any statistically significant difference in attitudes towards physics between students who studied through using CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instruction?

7- What is the interaction, if any, between students' gender and the use of CSs as a teaching method in teaching NSLOM within the context of scientific inquiry on performance and attitudes toward physics?

1.6 Significance of the Research

The significance of this study can be seen as the possibility of helping to support teachers of physics and stakeholders who are responsible for adapting and modifying the curriculum. As for teachers, the results may provide opportunity to address the teaching of physics in a more meaningful ways and help students to develop higher order understanding. For example, in a context of inquiry similar to the context of this study, students not only construct knowledge actively, but also learn the use of interactive CSs will contribute to meaningful and higher order understanding of students. Likewise, through shedding light on CSs within an inquiry-based learning environment, a shift towards effective student-centered pedagogy can be established. Therefore, the role of the teacher can be more productive from being mere knowledge disseminator to becoming a facilitator who focuses on teaching students how to think and how to use the technical resources properly to learn new information. Kattayat, Josey and Asha (2016) suggest that when teachers integrate education with CSs into classroom instruction, they enable students to increase their positive attitude toward physics. As a result of this increase, students can achieve better results in the field of physics. Another important point in this study is the development and use of a two-tier test as a diagnostic instrument. Because designing a two-tier test to assess students' difficulties about force and motion can contribute to the literature because there are few two-tier tests for assessing students' difficulties in physics in the literature.

Second, this research seeks to explore practices that enhance excellence in the teaching of physics in the education system in the UAE and aims to develop strategies for teaching physics to the Emirati environment. Thus, this will guide students to participate effectively in meaningful teaching and learning processes and will help teachers to compare these strategies with international standards. In addition, due to various limitations, it is often difficult for teachers to apply inquiry learning in physics classrooms. Therefore, through the suggested teaching unit and lesson plans provided in this study, this research study provides a demonstrable example of how inquiry learning is implemented and integrated with a technology environment and with interactive simulations in the context of the UAE. Moreover, the findings of this study could propose a new pathway for the teaching of the NSLOM in the secondary schools of the UAE, where physics education is an important as part of science learning.

Finally, the study may also attract stakeholders and curriculum developers' attention towards the effects of technology integration in creating opportunities for active learning of science through infusing hands-on activities. This integration can be achieved through dedicating more learning activities through CSs when teaching science in general and specifically physics instructions.

1.7 Limitations of the Study

This study has some limitations. First, the participants in this study were mostly Emirati and eleventh grade male and female students from schools in one city in the UAE. Although participants were randomly assigned to the simulations group or control group, the convenient sampling procedure and size of the sample might have impacted the findings across grade and ability levels of students.

Secondly, the posttest was administered five weeks after the time of the actual intervention, it is possible that learning occurred between the posttest and the beginning of the study. It is also possible that taking the pretest might influenced posttest scores. This potential influence may mean that data obtained from the study were negotiated to situations in which pretests are not used. Future research should use different versions of conceptual understanding measurements to ensure that participants are not exposed to the same questions more than one time. Moreover, although the students studied the same topic included in the same textbook "NSLOM" and followed the same study plan, they were taught by different teachers (i.e., male and female teachers) and the assessment tool designed for this study was a modification of a test used by a classroom teacher which may have influenced the results.

Another limitation is that the study was conducted using Physics Education Technology (PhET) simulations to learn NSLOM which is not designed specifically for the UAE curriculum. For example, the graphs and the objects were not consistent with curriculum. This may influence the results, since the students manipulate the simulations by themselves.

1.8 Operational Definitions

This study uses frequently the following terms, concepts, and key words.

Computer Simulations (CSs) are programs that allow users to interact with a computer representation of a scientific model of the natural or physical world and allow users to change a particular set of variables or parameters, which then builds a virtual environment using those variables or parameters (Holec, Spodniaková Pfefferová & Raganová, 2004; Wilson, 2016; D'Angelo et al., 2014). Therefore, CSs within an inquiry-based learning environment may be defined as an instructional strategy that offers the opportunity to control representation of real-world phenomena, as students' use CSs to support authentic inquiry practices that include formulating questions, hypothesis development, data collection, and theory revision.

PhET is a suite of research-based interactive computer simulations for teaching and learning physics, chemistry, math, and other sciences (Wilson, 2016).

Conceptual knowledge is students' ability to comprehend and solve physics problems that do not involve computation or calculations. These types of problems generally involve written descriptions or equations involving only variables (Nieswandt, 2007).

Procedural knowledge is the way of doing something. It encompasses the methods of inquiry as well as criteria for using skills, algorithms, techniques, and methods, including knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods, and knowledge of criteria for determining when to use appropriate procedures (Anderson, Krathwohl, & Bloom, 2001).

Inquiry-based learning is hands-on activities in which learners are responsible for their own learning. It is a form of active learning that best enables learners to construct knowledge, where progress is assessed by how well students develop experimental and analytical skills rather than how much knowledge they possess (Wilson,2016; Avsec & Kocijancic, 2014).

Newton's Second Law of Motion is how much an object will accelerate for a given net force (Itza-Ortiz, Rebello & Zollman, 2004). The acceleration of an object (a) is proportional to the net force (F_{net}) acting upon the object and is inversely proportional to the mass of the object (m).

Attitudes "is a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly & Chaiken, 1993, p.1).

It is measured for students by the total student responses to the items of the Student Attitudes Scale TOSRA.

Traditional method of teaching (face-to-face) is “the method that makes little or no use of interactive engagement and rely primarily on passive-student lectures, recipe laboratory activities, and students made observations outside.” (Hake, 1998).

1.9 Identification of Variables

The variables of this study are divided into two types, the main independent variable in the seven research questions, is the medium of teaching physics. It has two levels: (1) CSs within an inquiry-based learning environment (2) Traditional face-to-face- based instruction. The dependent variable for Research Questions One, Two, Three and Four is students’ performance that include conceptual and procedural knowledge. This dependent variable is measured by performance in Newton’s Second Law of Motion Achievement Test (NSLMAT), specifically developed for the purpose of this study (see Appendix D). As for Research Questions Five and Six, the dependent variable is students’ attitudes towards physics. This dependent variable is measured by three scales developed from Test of Science Related Attitudes (TOSRA) (see Appendix G), the survey comprises of three subscales including Attitude toward Scientific Inquiry (ASI), Enjoyment of Science/physics Lessons (ESL), and Career Interest in Science (CIS). Finally, the seventh question tackles the interaction between gender and the use of CSs as a teaching method in teaching NSLOM within the context of scientific inquiry and its effect on performance and attitudes toward physics.

1.10 Organization of the Study

Chapter one is an introduction of this study, which highlights the background of the study, the statement of the problem, the purpose of the study, research questions, the significance of the study, its limitations, operational definitions, and identification of variables. The remaining chapters of the thesis are organized as follows: Chapter two, firstly, discusses the literature related to the study. The review involves theoretical and empirical studies related to the problem under study. Specifically, the chapter is shedding light on the theoretical framework, which is based on constructivist approach, conceptual change approach, and information process theory, the UAE context, impact of CSs on students' learning and students' attitudes, aside from CSs and physics teaching. Secondly, this chapter also discusses inquiry-based instruction approach and, studies that tackle teaching NSLOM with CSs. The third chapter describes the methodology used in the study. Specifically, the research design with a full description of the quasi-experimental design, the research instrument, and its validity and reliability, sample and sampling technique, in addition, PhET simulations, and 5E model were discussed.

The analysis and presentation of the data were presented in chapter four where attempts to answer research questions were made. Finally, in Chapter five, the focal focus is the discussion of the research questions concerning the findings, the summary, conclusions, implications, recommendations, and areas for further research were presented.

Chapter 2: Literature Review

2.1 Chapter Overview

The main objective of this chapter is to review the literature focusing on the impact of CSs on students' learning and scientific attitudes, with particular emphasis on using CSs to teach grade 11 UAE students about NSLOM within the context of scientific inquiry instruction in physics classes. The purpose of the review is to analyze previous studies in order to identify and pursue gaps in the literature. This chapter is divided into four sections. The first section provides an overview of the theoretical framework used in this study which was based on constructivist, conceptual change, and information process approaches, and their relevance to the principles of CSs learning. The second section reviews the studies of how CSs help students gain a deeper understanding of physics concepts, which reflects their learning and attitudes. This section also tackles studies on how the use of an inquiry-based instruction helps students enhance their understanding of physics concepts. At the end of this section, the chapter explores studies about teaching NSLOM with CSs, as well as studies that do not found statistically significant benefit when using CSs as part of a physics instruction. In summary, this chapter focuses on how CSs and inquiry-based learning activities combine to improve students' attitudes towards physics and enhance their performance.

2.2 Theoretical Framework

The theoretical framework of this study is of threefold: it is based on a constructivist approach, an information process approach, and a conceptual change approach. These approaches have influenced the design of educational interventions used in this study, specifically integrating CSs into the learning design, and are closely and consistent with student needs.

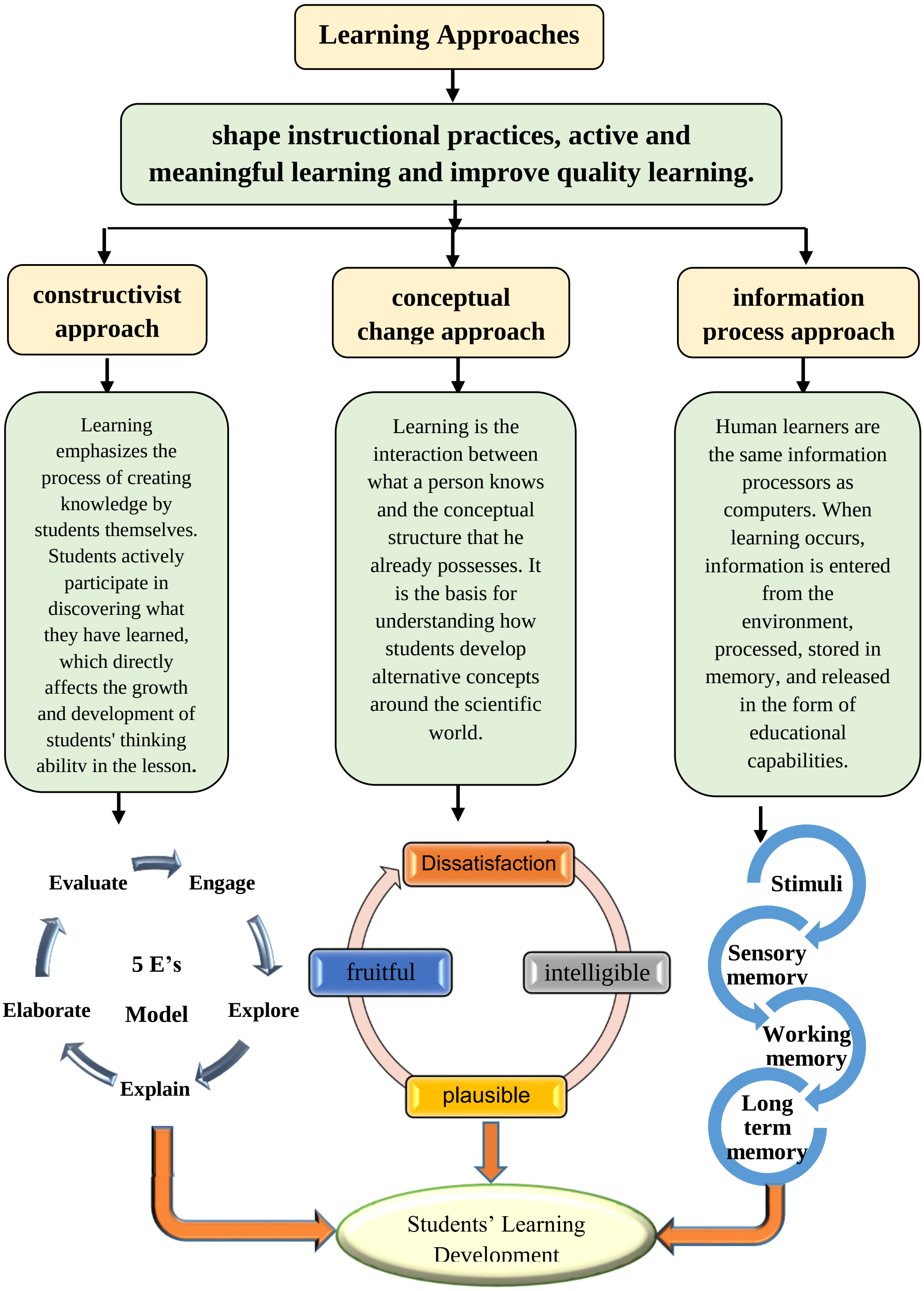

Figure 1: The Theoretical Framework of this Study

The three approaches provide a framework for understanding how knowledge is structured and learned as shown in Figure 1. Each approach provides a different perspective to viewing learning and provides essential elements that make student learning active and meaningful, as well as improve quality learning. Furthermore, each approach has influenced and shaped instructional practices.

2.2.1 Constructivist Approach

The basic idea of constructivism is that knowledge construction takes place in one's mind (Dory & Belcher, 2005; Robottom, 2004; Asan, 2007). Knowledge in constructivism cannot be obligatorily transported from one students' mind to another's mind (Papert, 2020). According to the constructivist approach, instruction must enable learners to be actively involved in knowledge construction and active in the learning process (Philips, 1997; Hirshman & Bjork, 1988). Konicek-Moran and Keeley (2015) stated that when students understand the concept, they can make it their own and they can think about it and use it again in areas other than what they have learned before. Furthermore, they are able to paraphrase it, express it metaphorically or analogically, and form its mental or a physical model of it (Konicek-Moran & Keeley, 2015).

Constructivism not only focuses on knowledge but also has a fundamental impact on the concept of learning and teaching. The constructivist approach promotes meaningful learning and deeper understanding of physical phenomena (Dori & Belcher, 2005, p. 246) and provides students with the opportunity to construct, test, and evaluate their own learning (Papert, 2020; Hirshman & Bjork, 1988; Stieff, Bateman & Uttal, 2005). The constructivist view is conducive to learner-centered education that relies on student activity rather than teacher activity (Philips, 1997;

Papert, 2020). Constructivist teaching leads to meaningful learning and understanding and encourages learners to generate knowledge in their minds (Philips, 1997; Dori & Belcher, 2005). In this way, learners become "owners" of knowledge. This ownership allows students to enthusiastically understand knowledge that cannot be achieved only by memory (Dori & Belcher, 2005). The constructivist teaching method places greater responsibility in the hands of the student than the teacher (Hirshman & Bjork, 1988; Dori & Belcher, 2005; Stieff, Bateman & Uttal, 2005). Teachers must be facilitators to help students develop the ability to understand and perform difficult tasks in a meaningful environment, develop different teaching materials and strategies for different learners based on their abilities and teaching style (Papert, 2020).

Constructive learning environment allow students to form their internal representation of phenomena to resolve their cognitive conflicts (Srisawasdi & Panjaburee, 2015). Therefore, CSs are considered an effective learning tools due to its ability to integrate graphics and animation that allows students to experience nuanced processes and procedures (Husain, 2010; Stieff, Bateman & Uttal, 2005). CSs create a unique way of visualizing phenomena and allow users to interact with the dynamics of the model system, which help students visualize the phenomenon (Srisawasdi & Panjaburee, 2015). The use of visualization tools supports students to create separate models of scientific phenomena and to develop deep understanding and improve their problem-solving skills (Stieff, Bateman & Uttal, 2005, p. 110). Wherefore, Stieff, Bateman and Uttal (2005) suggested two education approaches based on constructivist theory to support the use of visualization tools. The first education approach is inquiry and the second approach emphasize interactive processes of science learning (Stieff, Bateman & Uttal, 2005, p. 110).

CSs through visualization will help establish contacts and attract attention, and that is why students become active participants. Well-designed simulated structural applications allow students to make assumptions about the phenomena associated with the problem-solving method. The ability to repeat situations and test can provide consistency in predicting outcomes in parallel to classroom discussions (Hirshman & Bjork, 1988; Stieff, Bateman & Uttal, 2005), and it provides a variety of tools that support the student to construct their own knowledge in a way that leads to efficient learning and facilitates building knowledge (Husain, 2010). For example, PhET simulation is designed to display multiple charts and quantitative information windows at the same time. The window in Figure 2 shows an active simulation of the force and motion of selected objects. The design provides students with a visualization of phenomena associated with force and motion to help them develop a more scientific approach to the concepts of force and motion. Students then calculate the applied force, friction, position, velocity, and acceleration. These readouts and graphical representations help students understand motion-related math.

Within the inquiry-based environment, CSs offer great potential as an intermediary to contribute to constructivism. This is because CSs aim to simulate the reality closest to the small world and include real relationships with many in the reference system (Hirshman & Bjork, 1988; Stieff, Bateman & Uttal, 2005). CSs are consistent with the constructive assumptions that suggest that learning is an active process in which students actively participate in the construction of coherent and structured meanings of knowledge (Husain, 2010; Philips, 1997; Stieff, Bateman & Uttal, 2005).

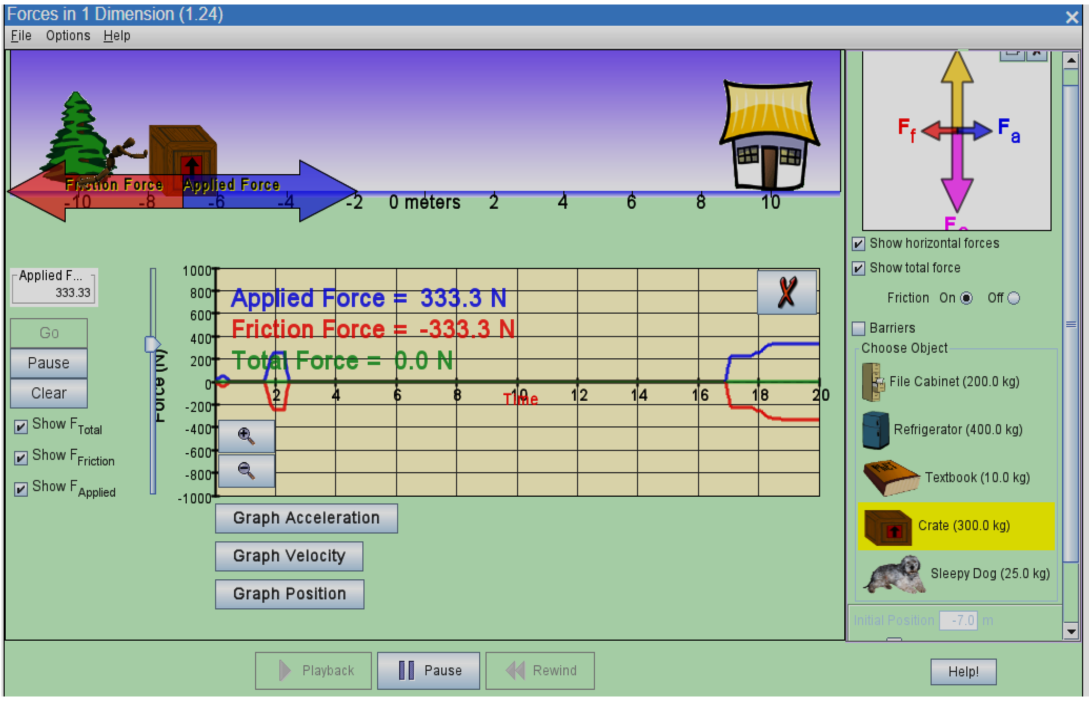

Figure 2: Active Simulation of Force and Motion of Selected Objects

CSs encourage independent, experimental, and discovery learning, meanwhile, students can interact with the system by changing parameters and monitoring its effects accordingly (Husain, 2010; Philips, 1997; Stieff, Bateman & Uttal, 2005). Students actively engage in CSs-assisted data collection and analysis, will enable them to recognize their existing thinking gaps (Srisawasdi & Panjaburee, 2015; Philips, 1997). Additionally, constructive learning with CSs carried out successfully when students associate prior knowledge and experience with the large amount of material provided by classroom simulations to develop or infer explanations and principles (Srisawasdi & Panjaburee, 2015; Dori & Belcher, 2005).

In summary, the constructivist approach is an important framework to this study that considers learning takes place through experience, which is the key to this approach, as experience affects thinking and thinking affects knowledge. CSs emphasize that the intellectual buildings of students will actively construct new knowledge based on what they know or can do by interacting with their surroundings to understand the world. CSs support constructivism by promoting independence, experimentation, and learning through discovery. Meanwhile, students can interact with the system by changing parameters and tracking their effects accordingly.

2.2.2 Conceptual Change Approach

The origins of the conceptual change as a method of learning are in the thinking of Thomas Kuhn, who suggested that science operates on a set of common beliefs, assumptions, obligations, and practices that make up the paradigm (Gafoor & Akhilesh, 2010). Conceptual change approach suggests that the way the change is defined in the concept indicates that the schema has been modified (or reorganized) to change the concept or the process by which new schema is formed. But the individual remembers their previous pattern (Nadelson et al., 2018; Posner, Strike, Hewson & Gertzog, 1982). Dole and Sinatra (1998) found that conceptual changes show that when new concepts are formed, they become dominant, and that previous concepts can no longer be considered and may even be lost.

As Crawford (2007) pointed out that, the role of students in the learning process is more important than that of teachers, where students become independent by creating ideas in their minds and finding solutions to problems. Therefore, a combination of practice, discussion, and reflection promotes conceptual change, and learning is enhanced if students find important topics amusing and relevant to their daily lives or experiences (Wafer, 1996, cited in Lederman & Abell, 2014).

Additionally, observations for empirical evidence that support conceptual understanding should be clear and accurate (Posner, Strike, Hewson & Gertzog, 1982).

In his theory, Hennessey's (1993) mentioned that the process of learning in a conceptual change approach depends on the extent to which the individual's conceptions are integrated with new information. If learners are dissatisfied with previous concepts and the available alternatives conception are intelligible, plausible and/or fruitful, accommodation of the new conception may follow (Dole & Sinatra, 1998; Posner, Strike, Hewson & Gertzog, 1982). Renken and Nunez (2013) stated that the process of understanding scientific concepts requires the existence of direct and long-term cognitive mechanisms that affect the structure of individual knowledge.

Short interactions such as CSs facilitate the acquisition of complementary knowledge and conceptual changes (Chang et al., 2008). CSs provide a rich environment that eliminate distractors and constrain learning to relevant evidence (ChanLin, 2001; Posner, Strike, Hewson & Gertzog, 1982), thus promoting conceptual change. It is well suited to reduce complexity through tools such as slow-motion experimental observations in the process of hypothesis formation, experimentation, and data interpretation (Chang et al., 2008; Posner, Strike, Hewson & Gertzog, 1982), as well as clarifying observations (Renken & Nunez, 2013; Coştu et al., 2017). For example, CSs-consistent learning about how nuclear fission works; it is difficult for students to observe interaction, in addition, students can deal directly with variables (e.g., mass, temperature, etc.), and they can immediately see the effects of these variables on the predetermined exploration and provide productive feedback to dispel the student misconceptions.

CSs provide a bridge between knowledge before and after learning physics, and students actively develop an understanding of science by rewriting, reducing misunderstandings, and introducing conceptual changes (Samsudin, Suhandi, Rusdiana, Kaniawati & Coştu, 2016). CSs make visual modeling more realistic, abstract systems are more tangible, or a graphical representation of abstract systems (Wibowo et al., 2016). CSs are a powerful tool with valuable educational capabilities to help students understand scientific concepts and facilitate conceptual change (Adams et al., 2008). Additionally, Trundle and Bell (2010), emphasized the importance of integrating CSs within an inquiry based learning environment to promote conceptual change. As a result, CSs appear as promoters of conceptual change with great potential. Due to its ability to visualize the learning and allow users to interact with the dynamics of the model system, it creates a unique method that can help students visualize the learning context. Through CSs, students can monitor interconnected systems, make changes to the systems, tolerate the effects of these changes, and then make the system effective to see results.

In summary, CSs are an important tool for initiating conceptual change. It provides insights that provide a deeper understanding of the learning process. It shows how learning takes place and how cognitive strategies improve students' learning processes. It helps students to organize the information to retrieve it later based on the information formerly attained, plausibility of a new concept based on intelligibility. It also guides the CSs, which are under investigation in the present study. In CSs, elect cases were tested quickly, and these fruitfulness assumptions made elect cases retrospective. If students set simulations conditions to validate predictions and students can understand what they are doing with the system, they can improve their understanding of the event.

2.2.3 Information Process Approach

Information processing approach is a cognitive approach to understanding how the human mind transforms sensory information (Brown, 2015). According to information processing approach, human students are information processors just like computers, because the information from the environment is subject to mental processes beyond the simple stimulus-response pattern (Brown, 2015). Terry (2009) and Brown (2015) assume that information processing is involved in all cognitive activities; perceive, practice, think, solve problems, remember, and imagine. The information processing approach states that the construction of knowledge represents the outside world (Brown, 2015). This point of view assumes that information from the environment is limited to intellectual processes rather than simple models of response to stimuli.

Information processing approach has three phases: sensory memory, working memory, and long-term memory, as shown in Figure 1 above. Additionally, information processing approach work as follows; first, sensory memory is where information is collected from the environment. Environmental stimuli (i.e., images, sounds, tastes, smells and feelings) enter sensory memory, where they are converted into information, and this information is stored for a short time (Slavin, 2015; Zhou & Brown, 2015; Lawless, 2019; Baker, 2016; Artino, 2008; Lutz & Huitt, 2003). Second, short-term memory is called working memory (Sweller, van Merriënboer & Paas, 1998; Lutz & Huitt, 2003), that’s where awareness exists, the world meets, and it is also a place to think. Limited information can be stored in a matter of seconds (Zhou & Brown, 2015; Lutz & Huitt, 2003). Finally, long-term memory involves storing and recalling information over a long period of time, such as hours, days, weeks, or years (Zhou & Brown, 2015; Lutz & Huitt, 2003; Artino, 2008). Information should be combined with prior knowledge and encoded for permanent storage in long-term storage (Zhou & Brown, 2015; Lutz & Huitt, 2003; Artino, 2008). As a result, lack of any aspect of memory can prevent children from acquiring the skills and knowledge necessary for a successful life (Dehn, 2008).

Learning is more than just sharing information. It is a process by which knowledge is linked and organized into a conceptual framework. The information processing approach does not focus on the results of the behavior, but on the conception and process inward in human learning. Therefore, as learning takes place, information is entered from the environment, processed, stored in memory, and released in the form of educational capabilities (McLeod, 2008; Zhou & Brown, 2015). CSs Provide an ideal environment to promote student's attention and awareness of the information received, make suggestions about and contribute to students using retrieve stored information, teach skills to stay active in working memory, and ways to store information (Tangen & Borders, 2017).

In summary, CSs provide a supreme environment for easily assisting in student attention and awareness of the information received, using retrieved stored information to advise students, teaching skills to stay active in working memory, and how to store information.

Based on the contribution of the approaches (Constructivism, Conceptual Change, and Information Process), Figure 3 represents how CSs contributes to the three approaches to improve students' active and meaningful learning. CSs act as powerful tools that allow students to add and connect new knowledge to present knowledge buildings. This help students to understand these common mistakes when they face a particular problem.

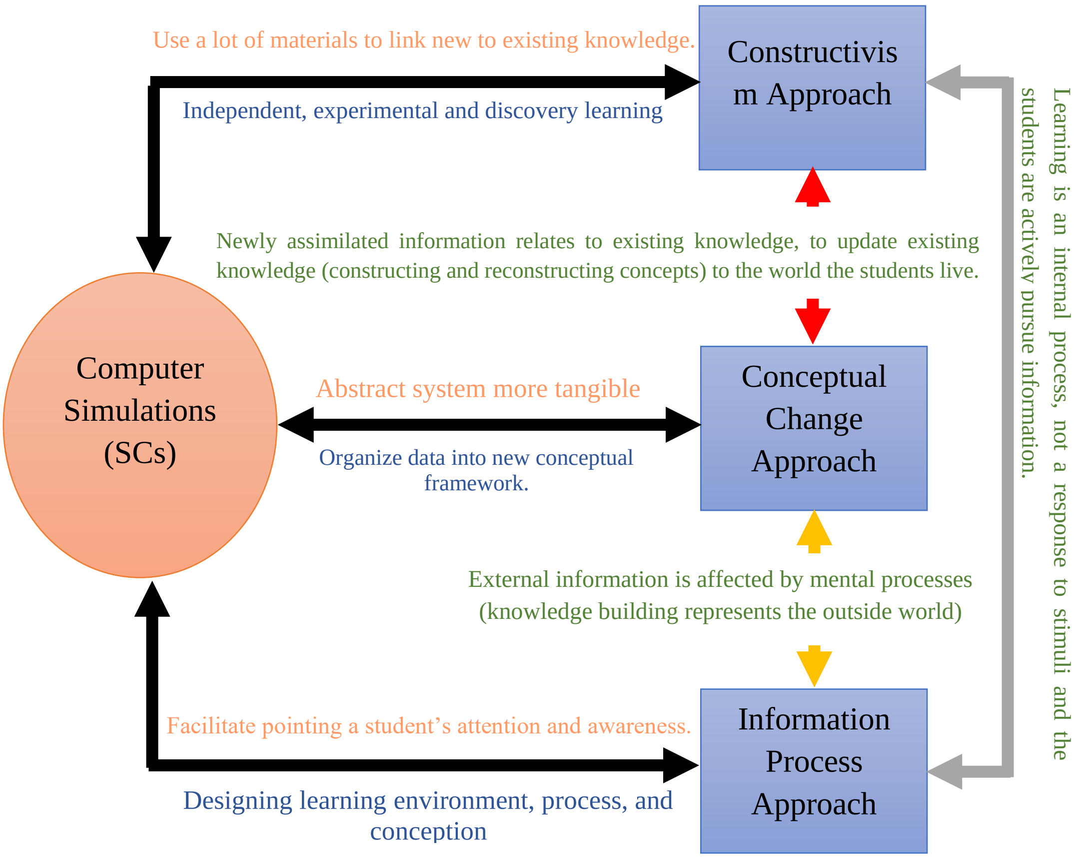

Figure 3: Relationships Between the Components of the Theoretical Framework

Based on the connections presented in Figure 3, CSs make visual modeling and abstraction systems more realistic. Because they mimic the closest little world reality and include a lot of real things, and relationships in the frame of reference. CSs promotes students' active and meaningful learning. This allows the students to engage with content in meaningful ways, such as easily collecting data, performing complex analyses, and providing specific feedback necessary for learning (Brown, Hinze & Pellegrino, 2008), which reflect a reduction in the cognitive burden (Sokolowski, 2013). CSs allow students to develop their knowledge internally and use it effectively to solve problems and support their learning process, as well as a kind of interaction between students and programs.

2.3 Computer Simulations

The word simulation in Etymology dictionary, means "a false spectacle, false profession," from the Latin simulationem (nominative simulatio) "an imitating, feigning, false show, hypocrisy". Meaning "a model or mock-up for purposes of experiment or training" (Etymonline.com, 2020). In practice, however, the term "simulation" has several meanings, which differ depending on the context and the specific goal. The most commonly used methods are understanding, prediction, decision support, design and modeling, training, and entertainment (Landriscina, 2013, p.4).

CSs are programs that have a representation of real systems or phenomena, and they have many functions that are particularly useful in science education (Blake & Scanlon 2007; De Jong & van Joolingen, 1998). CSs can be developed by providing dynamic theoretical models or simplified models of phenomena or processes by encouraging students to observe, discover, reconstruct, and instantly receive feedback about objects, events, and processes (McDonald, 2016; Perkins, et al., 2006; Wieman, Perkins & Adams, 2008; Council, 2011; Widiyatmoko, 2018). CSs can individualize learning according to each student's speed, interests, and abilities, and contextualize learning in an interactive virtual environment (De Jong & Van Joolingen, 1998).

CSs are designed to facilitate teaching and learning through visualization and interaction with dynamic models of natural phenomena. Holec, Spodniaková Pfefferová and Raganová (2004), argued that CSs can communicate dynamic information more accurately and help students to visualize various phenomena. They enable students to see things that are usually too fast, too slow, or hidden (Holec, Spodniaková Pfefferová & Raganová, 2004, p. 230; Widiyatmoko, 2018). Furthermore, according to Council (2011), CSs have great potential to stimulate students' interest and help them deepen their understanding of scientific concepts and scientific processes. It enables learners to see and interact with the expression of a natural phenomenon, which stimulate learners' challenges and immediate reactions (Council, 2011; Widiyatmoko, 2018). CSs show simpler versions of the natural world; They can make students focus more on the desired phenomenon (Perkins, et al., 2006; Wieman, Perkins & Adams, 2008; Widiyatmoko, 2018). Consequently, CSs may benefit when multiple experiments have to be repeated, for example, from rolling the ball down the slope while changing mass, tilt angle, or friction coefficient (Widiyatmoko, 2018). In addition, CSs may allow students to visualize objects and processes that are normally beyond the student' control in the natural world (De Jong, Linn & Zacharia 2013). Finally, CSs provide students with a realistic experience through which knowledge can be acquired and manipulated to better understand the relationship between the concepts studied (NGSS, 2013; Widiyatmoko, 2018).

A number of studies have shown that students who used CSs were more successful than students who did not (Bozkurt, & Ilik, 2010; Zacharia & Anderson, 2003; Çetin, 2018; Abou Faour & Ayoubi, 2017; Oymak & Ogan-Bekiroglu, 2017; Sari, Pektaş, Çelik, & Kirindi, 2019; Sari, Hassan, Güven & Şen, 2017; Kattayat, Josey & Asha, 2016). Consequently, incorporating CSs into school physics will have a positive effect on students' level of physics knowledge, that they will be interested in using CSs, and that research has shown that CSs can increase students' motivation and interest in learning (Holec, Spodniaková Pfefferová & Raganová, 2004). Similarly, Bakaç, Kartal and Akbay (2011), investigated the impact of CSs-based instruction on adolescent students' attitudes towards physics and they found that CSs-based instruction improves students' academic achievement in physics. However, it has been noticed that little research has been done on the impact of CSs on students' learning, particularly on NSLOM and attitudes toward physics. Thus, this study will help to better understand how students learn physics with CSs within an inquiry-based learning environment.

2.3.1 Impact of Computer Simulations on Students' Learning

The integration of CSs and its various resources has enriched the learning and teaching environment of physics learning, increasing the effectiveness of physics teachers in the classroom, as well as the learning and achievement of students (Mengistu & Kahsay, 2015; Smetana & Bell, 2012; D'Angelo et al., 2014; Wieman, Adams, Loeblein & Perkins, 2010; Sari, Pektaş, Çelik & Kirindi, 2019; Oymak & Ogan-Bekiroglu, 2017; Aşıksoy & İşlek, 2017).

CSs have great potential to improve science learning in elementary, secondary, and undergraduate science curricula. They can adapt learning according to the pace, interests, and capabilities of each student, and set the learning context in an attractive virtual environment (Honey & Hilton, 2010). According to Honey and Hilton (2010) using CSs in informal settings can provide students with opportunities to develop very personal interests and pursuits. Moreover, Honey and Hilton (2010, p. 85) lists five reasons why the CSs have become so dominant and have the potential to influence students:

- Significantly increase the "time on task" aspect of learning.
- Provide new forms of engaging with science.
- Help show students how science is relevant to their daily lives.
- Increase the transfer of learning by exposing the student to knowledge in a different context.
- Provide opportunities for children to explore and develop "passion topics" that might serve as gateways to further science study.

There was a great interest in studying the impact of CSs on secondary school students learning on various topics in physics. These studies have considered the relationship between CSs and other factors that affect secondary school students' learning, such as cooperative learning, students' beliefs, student participation, critical thinking, science process skills, etc. (Smetana & Bell, 2012; D'Angelo et al., 2014; Mirana, 2016). Research has shown that, compared to non-simulated instructions, when CSs are used as part of a teaching strategy to learn about abstract concepts in physics, it has advantages in students' achievement, and it can help these students better understand these concepts (Smetana & Bell, 2012; D'Angelo et al., 2014; Mirana, 2016).

A recent study carried out by Dervić, Glamočić, Gazibegović-Busuladžić and Mešić (2018) compared the effects of teacher-centered to student-centered Physlet-based classes about one-dimensional kinematics at the level of upper-secondary school. The sample consisted of 43 students (mostly 15-year-olds). As part of a teacher-centric approach, teachers performed and controlled the simulations, and students observed the simulation on a projected screen. The results showed that progress from a teacher-centric approach to a student-centric approach may be optimal for learning new concepts.

Çetin (2018) found similar results in two quasi-experimental groups of studies investigating the effectiveness of simulation-based cooperative learning in student's achievement in physics, science process skills, attitudes towards physics, and usage interactive whiteboards. In the experimental group (N = 24), students taught with Student Teams Achievement Division (STAD) method with the integration of simulations in electricity subject, in the control group (N = 25), traditional learning supported by simulations. The results showed that cooperative simulation-based learning had a more positive impact on student achievement in physics than traditional learning.

Bakaç, Kartal and Akbay (2011) conducted a study to observe the effect of Computer-Assisted Instruction (CAI) with simulation techniques on students' success in learning "electric current." Quasi-experimental methods were used. A research group was formed by a group of 28 students in the eleventh grade of the Chemistry department at Izmir Konak Technical School; These students then formed an experiment (N = 14) and a control group (N = 14). The CAI technology was used to teach the experimental group's "electric current" and the control group's traditional learning method. The study concluded that CAI could improve students' academic achievement in " electric current." One of the weaknesses of this study was that the sample size was too small, so it would be difficult to generalize the results. Nevertheless, Bakaç Kartal and Akbay (2011) indicated also that regardless of topic, CAI with simulation techniques can help students improve their achievement of various physics concepts. This view is supported by Dilshad, Malik, Tabassum and Latif (2016) who claimed that CSs improve students' achievement level.

A detailed study of the methods of computer-based simulations by Hannel and Cuevas (2018) showed that, both the control group and the experimental group had academic gains, while there were statistically significant differences in the concept of density of the control group. The results also showed a statistically significant correlations between self-efficacy and scientific learning value, self-efficacy and active learning strategies, effectiveness and self-achievement goals, self-efficacy, and performance goals. These results indicated that while learning the concepts of density and the greenhouse effect, students benefited from the use of CSs as they could improve academic performance in the areas of density, scientific learning value, and self-efficacy. One of the benefits of this study was the huge number of participants. However, one of the weaknesses was that the sample consisted of students from the working class and from the lower socioeconomic status of the middle school. The demographics are predominately Hispanic, Asian, and Caucasian. In addition, the participants were also 6th grade students, whose education mainly focused on density and the greenhouse effect in two different learning units. Finally, among the students were special education and gifted students, which may have influenced the results.

A recent study by Batuyong and Antonio (2018), explored the effects of electromagnetic activity based on the interactive simulations of PhET on students' performance and learning experience. Simulated interactive activities based on Physics Education Technology Interactive Simulation-based Activities (PhET.ISbA) were tested by 200 tenth graders to determine their effectiveness in teaching physics concepts, especially electromagnetism, by a set of a quasi-experiment designed for pre and posttest. The data collected showed that PhET.ISbA was developed to be relatively effective in terms of learning outcomes, teaching characteristics, and assessment. The test results showed that students' performance in learning physics has been significantly improved. Replies to informal interviews and comments in student science journals showed that when using PhET.ISbA in teaching, they have gained important learning experiences that are summarized in three main topics: "Learning physics is fun, learning real physics, and learning physics is simple and easy, so PhET.ISbA was developed to be an effective educational subject for physics teaching, especially electromagnetism.

Riaz and Morote (2015) identified student engagement, critical thinking, cooperative learning, and use of CSs as the major factors that can predict student performance as reported in secondary school physics classes. The results indicated that student performance may be predicted through student engagement, critical thinking, and simulations. In addition, how teachers use CSs as an honorable variable for collaborative learning, and how teachers' value CSs in physics classes to influence student performance.

The research has shown that using CSs is effective approach to enhance conceptual understanding of physics concepts. For example, Abou Faour and Ayoubi (2017), investigated the impact of the use of CSs on the conceptual understanding of 10th graders about DC circuit. The study sample consisted of 50 students from 10th grade at an official secondary school in Mount Lebanon. students were randomly divided into two groups, the experimental group, CSs were used for teaching, and experimental activities were carried out through the Circuit Construction Kit developed by the PhET simulation. However, the control group was taught using real laboratory equipment. Both groups were pre and post-tested. Data analysis showed that, the concepts of DC circuits were significantly improved in both groups. But the mean score for the experimental group was significantly higher than that for the control group.

Other study conducted by Mirana (2016) examined the effects of a developed lessons integrating CSs and constructivist approach on students' epistemological beliefs, motivation, and conceptual understanding in electricity. The study used the pre-experimental single-group pretest and posttest study. The study was conducted by using PhET and other web-based simulations. The results showed that the use of CSs can be effectively promote students' understanding of physics.

These results indicated that using CSs help students to understand different abstract physics in different situations, such as electricity (Abou Faour & Ayoubi, 2017; Mirana, 2016) and buoyancy phenomena (Srisawasdi & Panjaburee, 2015). However, the use of CSs is only a fragment of the physics class. It is important to note that the improvement of students' conceptual understanding may be due to other factors. For example, (1) constructivist approach (Mirana, 2016), (2) simulation-based inquiry (Srisawasdi & Panjaburee, 2015; Abou Faour & Ayoubi, 2017), and (3) cooperative learning (Riaz & Morote, 2015).

Several studies have been conducted to compare the effectiveness of CSs with that of the traditional laboratories. For example, Psycharis (2011) found that a well-designed CSs allow student to predict the outcome of a particular action, understand why observed events occur, evaluate ideas, gain insight, and stimulate critical thinking. Sarabando, Cravino and Soares (2014) investigated the impact of CSs on teaching and the way children learn. The results showed that the overall benefits were higher when students used CSs, alone or in "practical" activities. McKagan, Handley, Perkins and Wieman (2009) researched the implications of reforming the physics curriculum. Among other changes, CSs of the photoelectric effect were performed in the classroom. As shown by improved test results, the modified method has improved the ability to predict experimental results of photoelectric effects.

Sreelekha (2018) designed and conducted a study to determine the effectiveness of CSs in achieving practical physics for high school students in the third education area in Lagos State, Nigeria. This study used a pre-test and post-test design for a quasi-experimental study group. Using the multi-stage sampling method, 219 high school student physics samples were taken from six joint educational schools in the third education district. Three research instruments were used to collect research data: A practical physical achievement test, a practical skills assessment scale, and a student attitude scale (SAIS), were used to collect research data. The study showed that students in the experimental group (CSs teaching strategy) had a higher average level of the acquisition of practical skills and mastery of students in the teaching strategy of the control group (traditional).

Adesina (2013), studied the effects of CSs experiments on the results of students learning in physics practice. The sample included students from 359 high schools randomly selected from six schools in Owerri and Orlu Districts in Imo State, Nigeria. There were three treatment groups: CSs experience only, CSs experience with hands-on experiment, and hands-on experiment only. Students' level of mathematical reasoning is also presented as a host variable. Combined scores of Students' operational skills were used in physical practice and physical achievement test as dependent variables. The results showed that the students who received CSs and practical experiments performed better in the three groups. Results showed that CSs experiments are better than hands-on experiments.

The interest in the impact of CSs has gone beyond the general education level to undergraduate students. For example, Bayrak (2008) examined the effect of CSs on undergraduate students' learning in geometric optics. By comparing between students who receiving computer-assisted education with students who received direct education, the results of the study showed that there was a positive relationship between student achievement and CSs in improving physical understanding. Similarly, Bozkurt and Ilik (2010) conducted a study to find the impact of interactive simulations teaching on undergraduate students' beliefs in physics and physics achievements. The study examined 152 students who received a General Physics 1 course in the 2008-

2009 academic year. In this study, a survey entitled "Colorado Learning Attitudes for Scientific Investigations" was used. In addition, achievement tests were used to measure Students’ success in physics. The results indicated that interactive simulations lessons have a positive impact on Students’ beliefs in physics and physics achievements.

Hazelton, Shaffer and Heron (2013), sought to investigate the impact of using real-world circuits or an interactive circuit simulation on undergraduate students’ understanding. Based on the understanding of the concept after mentoring, three groups of students were compared, and they completed the tutorial on multiple-loop circuits in the introductory physics tutorial, where one of the groups was taught using real circuits and two experimental groups were taught using simulations. Results showed that students who used simulations completed this tutorial faster and scored higher on conceptual questions than students who used actual circuits.

Finkelstein, Perkins, Adams Kohl and Podolefsky (2005b) investigated the implications of using CSs to replace actual laboratory equipment. The direct current circuit laboratory has been modified to compare the effects of CSs use with the effects of using real lighting lamps and wire meters. Three groups of students were compared, and their competence in physical concepts and skills with real equipment was also compared: Students using physical equipment, students using CSs, and students without laboratory experience. The results revealed that students who used the simulated equipment outperformed their counterparts both on a conceptual survey of the domain and in the coordinated tasks of assembling a real circuit and describing how it worked.

Sari, Pektaş, Çelik and Kirindi (2019), studied the use of computer-based laboratory. In this case, the effects of computer-based laboratory applications on students' graphing skills, comprehending and interpreting, attitudes towards the physics laboratory, and the motivation of science learning were examined. The experiments involved 60 college students. The control group conducted experiments on the laws of motion in a computer-based laboratory, and the experimental group conducted similar experiments in a virtual laboratory. Research data is collected through attitude measures, motivational measures, graphical tests, understanding and interpretation test. The results showed that computer-based laboratory methods were more effective in enhancing students' ability to draw, understand, and interpret drawings than in virtual laboratory applications. In addition, compared to virtual lab applications, computer-based lab applications are more effective in improving student communication, collaborative work, and stimulating participation. Moreover, the results of the study also indicated that computer-based laboratory applications in physical laboratories are more effective than virtual laboratory applications.

Tawil and Dahlan (2017) analyzed the impact of PHET computer simulations on the development of students' creativity in learning quantum physics. There were 120 students in the department of physics education at Makassar State University. A pre-test and post-test experimental design was used, with students randomly divided into experimental or control groups. Interview forms, observation forms and questionnaires were used to obtain qualitative data. The results showed that there was a significant difference in creativity between the experimental and the control groups. Interview results showed that students earning through computer simulation-based learning believed that it helped them to improve creativity in quantum physics. Students in the experimental group showed that they preferred to use CSs as an educational tool, and the program, which could help teachers teach quantum physics.

So far, CSs provide students with the opportunity to manipulate variables and monitor results in an open environment, as well as easier to learn and perform tasks in a relatively realistic environment (Bayrak, 2008; Hazelton, Shaffer & Heron, 2013; Finkelstein et al., 2005b; Tawil & Dahlan, 2017). Unfortunately, this research is limited to the subjects of geometric optics, electricity, and quantum physics, as well as the beliefs and achievements of the students. However, there has been scarcity of research on the use of CSs at the high school level and NSLOM instruction, as most studies tackle undergraduate students in topics such as: electricity (Hazelton, Shaffer & Heron, 2013; Bozkurt & Ilik, 2010), optics and quantum physics (Bayrak, 2008; Tawil & Dahlan, 2017). Therefore, the goals of this study were to investigate the impact of CSs on students' NSLOM learning and attitudes toward physics within the context of scientific inquiry instruction.

2.3.2 Computer Simulations and Physics Instruction

Physics is essential to understanding the world around us (Hannel & Cuevas, 2018; Lamina, 2019; Adams et al., 2008; Posner, Strike, Hewson & Gertzog, 1982; Çetin, 2018; Batuyong & Antonio, 2018). It is also considered one of the most difficult subjects in school (Radulović, Stojanović & Županec, 2016; Dori & Belcher, 2005; Sari, Pektaş, Çelik & Kirindi, 2019; Sarı, Hassan, Güven & Şen, 2017). Abdi (2014) argued that traditional classrooms are usually dominated by one-sided teaching, and the student is largely non-participatory. To make physical learning effective, it should encourage learning that leads to conceptual understanding (Stern & Huber, cited in Batuyong & Antonio, 2018).

Studies have shown that the use of CSs instruction provides better results compared to traditional instruction in students' attitudes, scientific knowledge, and achievements (Kattayat, Josey & Asha, 2016; Bakaç, Kartal & Akbay, 2011). Bozkurt and Ilik (2010) found that the interactive simulations courses have had a positive effect on students' beliefs about physics. In addition, the results showed that the use of CSs is more effective in improving students' learning and attitudes toward physics when learning most physics concepts (Holec, Spodniaková Pfefferová & Raganová, 2004; Rutten, Van der Veen & van Joolingen, 2015; Sari, Pektaş, Çelik & Kirindi, 2019; Aşıksoy & İşlek, 2017, Pyatt & Sims, 2012; Almeqdadi & Halar, 2017). CSs are particularly important applications in physics education because it can support a robust modeling environment that incorporates the concepts and processes of physics (Jimoyiannis & Komis, 2001).

Mengistu and Kahsay (2015) examined the use of CSs as an educational tool to help students understand the concept of electrical force and electrical fields. One hundred students participated in the study and were divided into an Experimental Group (EG), which was studied by CSs; a Control Group (CG), which was studied using traditional lecture methods. Results showed that students in EG, showed better progress than CG. Similarly, Rutten, Van Joolingen and Van der Veen (2012) reported that all studies comparing instructions with or without CSs had yielded positive results that use CSs to replace or improve traditional lectures, Rutten, Van Joolingen and Van der Veen (2012) also reviewed empirical studies on the effects of CSs on science education in the past decade, the researchers focused on two issues: how to use CSs to enhance traditional education, and how best to use CSs to improve the learning process and grades. They reported on CSs research to replace or enhance traditional education. The researchers looked at the impact of the change in how information is visualized, how teaching is supported, and how CSs are integrated into course scenarios. The reviewed literature provided strong evidence that CSs can improve traditional teaching, especially in laboratory activities. This results consistence with Bozkurta and Ilika (2010), who found that students who studied with the CSs are more successful than those who studied with traditional methods.

Many researchers like; Bozkurta and Ilika (2010), Mengistu and Kahsay (2015), Rutten, Van Joolingen and Van der Veen (2012), and Eveline, Wilujeng and Kuswanto (2019) found that CSs are more effect than traditional instruction in teaching physics. Thus, Falloon (2020) argued that with the support of appropriate teachers, careful selection of CSs can effectively introduce students to simple physics concepts and provide them with opportunities to participate in higher order thinking processes.

Furthermore, CSs appear to meet the standards of constructive learning theory and knowledge construction (Mengistu & Kahsay, 2015). By building this new knowledge and by allowing students to make connections between ideas and concepts, they can improve their grades and deepen their understanding of concepts (Wieman, Adams, Loeblein & Perkins, 2010; Couch, 2014). Ghadiri, Norouzi and Fardanesh (2016) studied the effects of CSs based on a constructive approach to eliminating misunderstandings in physics lessons. The study used a quasi-experimental approach using pre-test and control design. The study included 216 students in the second year of high school in Yazd Province. The results of the data analysis showed that CSs based on the constructive approach have significant differences in and eliminates misunderstandings of physical processes among physics courses.

Jimoyiannis and Komis (2001) examined the effects of various educational interventions designed to help students' transform alternative conceptions. Two groups of students (control group and experimental group) were studied to determine the role of CSs in the development of a functional understanding of the concepts of velocity and acceleration in projectile motions. Both groups received traditional classroom instruction on these topics. The experimental group also used CSs. The results showed that the students involved in the CSs show a significantly higher degrees in research tasks. Also, the results strongly support the use of CSs as an alternative educational tool to help students overcome cognitive limitations and deepen their functional understanding of physics.

Various research studies showed that when using CSs with or without traditional lab experiments gives students a deeper understanding of the concepts being studied (Zacharia, 2007). For example, Oymak and Ogan-Bekiroglu (2017) conducted a study aimed to compare students' conceptual knowledge and attitudes with physics lessons (technology supported teaching, laboratory-based teaching, and curriculum-based teaching) using three different methods. Using 144 9^{th} male students in high school as a sample. The results showed these students would be better students if CSs laboratory or laboratory-based teaching was included in teaching. Finkelstein et al. (2005b), compared the use of actual experimental equipment with the use of CSs to model the flow of electrons in a simple circuit. They found that students who used CSs instead of real equipment performed better on conceptual questions related to simple circuits and developed a greater facility at manipulating real components. In addition, the CSs have proved to be a valuable tool for facilitating student learning if properly designed.

Studies of physics in various context have revealed the important of CSs as a tool for teaching physics. For example, in Indonesia, Eveline, Wilujeng and Kuswanto (2019) explored the effects of scaffolding learning with PhET simulations on understand conceptual physics and independence in high school classrooms. The study design used the quasi-experimental of pre and post-test design. The sample was 27 high school students in grade 10. The results of this study showed that in the PhET simulation-assisted scaffolding method, the learning of the student concept is different before and after learning. The results also indicated that PhET simulations learning using the scaffolding method has an impact on students' learning independence. These results indicate that in high school, the PhET simulations scaffolding method can be used to enhance student autonomy in learning. In Taiwanese schools, Chang, Chen, Lin, and Sung (2008), compared the learning and abstract thinking abilities of Taiwanese high school students who completed traditional optical lab exercises with students who completed similar simulations labs. The results showed that students who used simulations performed better than students who completed traditional laboratories.

In summary, research studies on physics education have found that the use of CSs not only encouraged learning activities in scientific learning, but also improved instruction, met the students' learning styles, personal needs, improved achievement in the field of physics, and supporting different types of students (such as visually oriented students) (Kattayat, Josey & Asha, 2016; Mengistu & Kahsay, 2015). Additionally, researchers suggest that CSs can be used as an accessory or alternative to other forms of teaching to enhance students' understanding of physics concepts (Rutten, Van Joolingen & Van der Veen, 2012). According to Podolefsky, Perkins and Adams (2010), teachers found that CSs greatly improved students' understanding of basic concepts that are difficult to understand.

2.3.3 Computer Simulations and Inquiry- Based Learning

Scientific inquiry refers to the multiple ways in which scientists study the natural world and provide interpretations based on the evidence obtained from their work. Kassir (2013) claimed that guided scientific inquiry investigations are designed to help students obtain specific answers through higher-order thinking processes and scientific activity skills. Mullis and Martin (2017) mentioned that there are five practices that are fundamental to scientific inquiry are represented in TIMSS 2019: 1) asking observational questions, 2) obtaining evidence, 3) working with data, 4) answering research questions and 5) making an argument from evidence.

Inquiry-Based Teaching (IBT) is a learner-centered method of teaching (Kunnath & Kriek, 2018). It can be implemented that can effectively resolve confusion, generate new ideas, motivate students, and help them learn from each other (Mirana, 2016). From a teaching perspective, Pedaste et al. (2015) claimed that complex scientific processes are divided into smaller, logically connected units (orientation, conceptualization, investigation, conclusion and discussion) that can guide students, and draw attention to the important features of scientific thinking.

Inquiry-Based Learning (IBL) is an educational technique where students can develop knowledge in a manner like professional scientists (Keselman, 2003; Rutten, Van der Veen & Van Joolingen, 2015). IBL is an educational strategy that allows students to discover knowledge through experiments, CSs, and investigations (Abdallah, 2018; Avsec & Kocijancic, 2014). Abdi (2014) argued that students who are guided by investigative IBL achieved a higher score than students who were guided by traditional methods. In IBL, Secker (2002) and Radulović, Stojanović and Županec (2016) have noted that, children participate in the many activities and thought processes that scientists use to create new knowledge. Some definitions are used for the inquiry. Tairab and Al-Naqbi (2017) viewed the inquiry as a form of teaching that allows students to develop their own scientific knowledge through active learning rather than acquired learning. The inquiry also indicates the activities students undertake as they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, 1996; Secker, 2002).

Several studies support the effectiveness of IBL as an instructional approach (Pedaste et al., 2015; Mullis & Martin, 2017; Rutten, Van der Veen & Van Joolingen, 2015; Radulović, Stojanović & Županec, 2016). For example, Cairns and Areepattamannil (2019) conducted a study using three-level Hierarchical Linear Modeling (HLM) as an analytical strategy to study the relationship between inquiry-based science teaching, scientific achievement, and personality. Out of 4,780 schools in 54 countries of the world, 170,474 15-year-old students are all interested in science. The results of the HLM analysis showed that inquiry-based science education is very important. It is highly positively related to the personality of science, such as interest and enjoyment of learning science, effective future scientific motives, scientific self-concept, and self-efficacy.

A study conducted by Abdi (2014) found that the use of inquiry-based learning methods in science classes gave students a better understanding of scientific principles. The study included 40 fifth graders, 20 in the control group, and 20 in the experimental group. Overall, the study found that students who used inquiry-based approach to learning were more successful on achievement tests than traditional methods.

Students should understand the process of scientific inquiry. They should be mastered in the science room and understanding through the process of learning outside of school (Pedaste et al., 2015; Radulović, Stojanović & Županec, 2016). IBL uses also concern of TIMSS, for example, in TIMSS 2019, some items in grades 4 and 8 evaluated one or more of these important scientific practices of IBL, as well as specific thinking processes in the content and cognitive areas (Mullis & Martin, 2017). As such, the MOE of the UAE is committed to implementing IBL in public schools (Al-Naqbi, 2015), as Kassir (2013) claimed that scientific inquiry may become a way to improve the level of learning for students if it becomes a dominant strategy in science classes in the UAE.

CSs can also be used as scaffolding to help students perform complex tasks that are often based on real-world inquiries (Peffer, Beckler, Schunn, Renken & Revak, 2015). Within the context of IBL, Peffer et al. (2015) found that the use of CSs in the classroom provides new opportunities for students to learn science in practice, allowing them to undertake investigative activities that are not normally possible in the classroom, and providing teachers and students with a greater flexibility to perform scientifically realistic inquiries. For example, Tairab and Al-Naqbi (2004) found that computer aided construction allows students to see the relationship between the variables represented on a graph which requires students to use hands-on minds-on skills to construct graphs and to review quickly and accurately with many other constituent graphs.

Cakir and Irez (2006) stated clearly and in detail that within the context of the inquiry-based science teaching and learning, with the support of CSs and collaborative contexts help learners to develop critical thinking and inquiry skills. CSs within the inquiry lesson instructional context not only have a positive effect on understanding the laws of physics, but also solves tasks that require a creative approach because students can deal with multiple variables that produce different results digitally (Wilson, 2016). Inquiry-based lessons are like practical practices because they provide students with opportunities to deal with variables (Wilson, 2016).

Radulović, Stojanović and Županec (2016), found that unlike traditional physics teaching, Laboratory Inquire-Based Experiments (LIBE) and Interactive Computer Based Simulations (ICBS) contribute in a similar way to improving student performance and reducing cognitive load. Radulović, Stojanović and Županec (2016) examined the extent to which different educational instructions focus on the use of LIBE and ICBS for high school students compared to traditional methods to improve understanding of physical content. The study also analyzed how the applied instructions influenced students' assessments of invested cognitive load. A convenience sample of this study included 187 high school students. The findings suggested that teaching instruction based on the use of LIBEs and ICBS contributes equally to enhancing students' performance and reducing cognitive load in contrast to traditional teaching of physics.

Computer Simulations-based inquiry learning could be considered as a pedagogical tool for promoting students' conceptual understanding (Sornkhatha & Srisawasdi, 2013; Akpan, 1998). Fan, Geelan and Gillies (2018), investigated the effectiveness of a novel inquiry-based teaching hierarchy using interactive simulations to support students in developing conceptual understanding, investigation process skills, and confidence in learning. The study was conducted in Beijing with the participation of two teachers and 117 students in four classes. Teachers participated in professional research and were supported to develop one of two different training methods: Interactive simulation teaching (experimental group) or "traditional teaching" (control group). The findings indicated that the combination of interactive simulations and inquiry-based learning can enhance students' theoretical understanding and develop investigative process skills and learning confidence.

Abdullah and Shariff (2008), investigated the effect of inquiry-based CSs with heterogeneous-ability cooperative learning and inquiry-based CSs with friendship cooperative learning on (a) scientific reasoning and (b) conceptual understanding in smart schools in Malaysian. The sample consisted of 301 from 12 pure science classes in four smart schools, randomly selected and assigned to treatment and control groups. Results showed that the inquiry-based CSs with heterogeneous-ability cooperative learning method is effective in enhancing scientific reasoning and conceptual understanding for students of all reasoning abilities.

Zacharia and Anderson (2003), investigated the effects of interactive CSs which are presented prior to inquiry-based laboratory experiments on students' conceptual understanding of mechanics, waves/optics, and thermal physics. According to a semi-structured interviews and conceptual tests are presented to assess conceptual understandings of each topic. The results showed that the use of CSs has led to significant conceptual change in the physics content areas that were studied and has also improved students' ability to make reasonable predictions and explanations of phenomena in experiments.

Srisawasdi and Panjaburee (2015) investigated whether the combination of simulation-based inquiry (SimIn) and Formative Assessment (FA) was conducive to the conceptual learning of buoyancy-driven phenomena. The study investigated the conceptual achievement of Thai public-school students combined in two studies. A two-stage experiment was conducted: the study used 120 ninth graders as a sample who were approved to participate and divided into two experimental groups and a control group. The control group received only SimIn and not integrated FA. The first experimental group participated in SimIn integration with FA Agree (A) to the Disagreement (D) statement methods (SimIn-FAA & D); the second experimental group participated in SimIn integration with the Circuit (C) protocol method (SimIn-FAAC) and the group participated in this group. The second study compared the degrees of concept understanding of 39 of 12th graders and studied changes in the pattern and amount of concept change process based on a set of pre-test methods. The results showed that after participating in experiential learning, students' understanding scores improved significantly. Furthermore, the inclusion of FA in SIM is the result of a better scientific understanding without FA.

Pyatt and Sims (2012) assessed students' attitudes toward computer use in physics and with CSs inquiry-based laboratory investigations during their first year of high school chemistry lessons. The study lasted for two years and used an experimental crossover design involving two separate laboratory research experiments. The newly created Physical and Physical Experiment Questionnaire was used to measure students' attitudes over virtual experiences and physical lab experiences. The results showed that students exhibit a positive attitude towards inquiry-based experiences, physical or with CSs, and shown their preference for integrating computers in a laboratory environment.

Rutten, Van der Veen and Van Joolingen (2015) revealed that students' attitudes toward the inquiry-based role of teaching behaviors and their contribution to motivation and insight are positively related, and a positive correlation between teachers' attitudes about inquiry-based teaching with CSs and learning goal congruence between the teacher and his/her students. This result is consistence with Sari, Hassan, Güven and Şen (2017) which investigated the effects of inquiry-based instruction (5E Teaching Model) with interactive simulations on the academic performance and attitudes of students and their views on the use of CSs in teaching physics. Eighty students from two 11th grade classes in science participated in the research and a quasi-experimental design was used with the control group pre- and post-test. Findings revealed that interactive simulations integrated inquiry-based instruction (5E Teaching Model) caused significantly better acquisition of scientific concepts related to content taught.

Perkins, Moore and Chasteen (2014) focused their study on the effects of inquiry-based peer instruction and PhET simulations on levels of motivation and physical anxiety in ninth graders. Two groups of students were used with 65 students registered in the experimental group and 64 students registered in the control group. To determine the level of motivation, a physical motivation questionnaire was presented. On the other hand, the physical anxiety classification scale was used to determine the level of physical anxiety. In the experimental group, PhET simulations was used using inquiry-based peer instruction, while in the control group, traditional lecture methods were used. The study concluded that inquiry-based peer instruction and PhET simulations help reduce students' physical anxiety.

Hartoyo, Batlolona and Nilasari (2019) concluded that students who study inquiry model through real virtual Monte Carlo experiments are better at science literacy than students who study through traditional learning models.

Yuksel, Rebello and Bryan (2017) studied the evolution of student models during their learning experience through model-based instruction. They analyzed students' model transition process during a series of activities supported by computer-based physical models and mathematics, compared to the results obtained from students receiving traditional computer education. The results demonstrated that students who received model-based inquiry instructions increased the complexity of interpretation and gain a more accurate understanding of math-based instructional groups.

Regarding teachers' perspectives towards implementing inquiry-based teaching in science classes, some researchers In the UAE context, like Tairab and Al-

Naqbi (2017), studied the opinions of science students and teachers about providing and implementing inquiry-based teaching in science classes in Emirati high schools. 560 science students and science teachers chosen using cluster sampling techniques participated in this study. The results indicated that students and teachers believe that the course materials helped support inquiry teaching, and this was described by the basic characteristics of the inquiry from a relatively high average score for two groups of students in providing inquiry activities. However, compared to their students, science teachers showed a statistically higher average score in the course materials supporting the implementation of inquiry teaching.

Kassir (2013), examined the effect of teaching methods of scientific inquiry on students' performance and assessed the effectiveness of this method of students' participation in the UAE for Girls in the northern UAE for a period of four and a half months. The study was addressed by 52 Emirati students from the sixth grade following the scientific reform in their school, these schools are called "Madares Al Ghad". The results showed that the method of teaching scientific inquiry has achieved noticeably greater achievements in the sixth grade compared to the traditional teaching method. The results also showed that, compared to the control group, students in the experimental group developed a clear positive attitude towards science.

A note about the previous revised research studies. Despite the positive results of the previous studies, several main weaknesses were identified. First, the use of CSs differ from one study to another. In some studies, CSs are used to manipulate objects. In other cases, CSs are used to conduct experiments and test theory. Second, information about reliability and validity was not sufficiently clear. Finally, some studies may use inappropriate simulations of subjects, as well as that are limited to one topic related to electricity, magnetism, and optics. There is a need to study other subjects like NSLOM.

It was noted that students' understanding of basic physics concepts can be improved only through active participation of students in learning activities (Hannel & Cuevas, 2018; Lamina, 2019; Adams et al., 2008; Posner, Strike, Hewson & Gertzog, 1982). Therefore, physics teachers need to teach physics through exploration, discovery, demonstration, simulations, practical work, laboratory-based experience, and other practical experiences understanding (Stern & Huber, cited in Batuyong & Antonio, 2018; Lamina, 2019).

2.3.4 Impact of Computer Simulations on Students' Attitudes

Attitude is an expression of favor or disfavor toward a person, place, thing or event (Eagly & Chaiken, 1993). Prominent psychologist Gordon Allport once described attitudes as "the most distinctive and indispensable concept in contemporary social psychology." (Definitions.net, 2020). Attitude can be formed from a person's past and present. In non-professional language, the attitude can relate to a certain mood concept or, in particular, be synonymous for youthful rebellion (Definitions.net, 2020).

Science attitudes have been defined in many ways. George (2000) defines attitudes towards science as positive or negative feeling towards science, especially towards science lessons. Attitude is the tendency to evaluate an object in terms of favorable or unfavorable attribute dimensions (Ajzen, 2001). According to Pyatt and

Sims (2012), attitudes towards particular learning environments and teaching methods are important factors in learning.

Technological tools such as CSs can not only change students' attitudes towards physics, but also provide teachers with tools that can be used to help enhance teaching. In recent years, the use of interactive simulations has been investigated in order to examine its impact on attitudes toward learning (Zacharia & Anderson, 2003). Consequently, using CSs can provide science teachers with a tool that can help them improve students' attitudes in a positive direction and help them achieve success. For example, Kattayat, Josey and Asha (2016) argued that teachers can integrate education with the help of CSs in a classroom instruction to enable students to increase their positive attitudes toward physics. As a result of this increase, students can achieve better results in the field of physics.

CSs can accommodate different types of instructional approaches and promote students' attitudes. For example, Sarı, Hassan, Güven and Şen (2017), studied the effects of scientific inquiry with 5E simulations teaching on students' attitudes together with their views on CSs use in physics teaching. Two science stream classes at the 11^{th} grade, 80 students participated in the study and used a quasi-experimental design with pre- and post-test controls groups. Although the control group was taught using traditional methods, the experimental group was taught by the teacher himself, using the teaching model 5E in the context of scientific inquiry and interactive simulations methods. The results showed that compared to traditional teaching methods, interactive CSs combined in the context of scientific inquiry have a relatively high attitude towards physics.

Abou Faour and Ayoubi (2017), investigated the impact of the use of CSs on the conceptual understanding of 10th graders from DC circuit and their attitudes towards physics. The study sample consisted of 50 students from 10th grade at an official secondary school in Mount Lebanon. Participants were randomly divided into two groups, the experimental group, CSs were used for teaching, and experimental activities were carried out through the circuit construction kit developed by the PhET simulations. However, the control group was taught using real laboratory equipment. Both groups were pre and post-tested. Data analysis showed that, the students' attitudes toward physics were significantly improved in experimental group. Similarly, Aşıksoy and İşlek (2017) investigated of the effect of the CSs laboratory experiment on attitudes towards physics laboratories. The study included 42 students were randomly divided into two groups (21 treatments and 21 controls). The treatment group used CSs laboratory. In contrast, the control group used the physics laboratory. The results of this study indicated that CSs laboratory experience has a positive impact on students' attitudes towards physics.

Çetin (2018) investigated the effects of simulation based cooperative learning on students' physics achievements, science process skills, attitudes toward physics, and interactive whiteboards. In the control group (N = 24), students taught using traditional learning, while students taught in the experimental group (N = 25) with the method of the Student Teams Achievement Division (STAD) with the integration of simulations in the subject electricity. Results showed that the effect of cooperative simulation-based learning on the students' attitudes toward physics is much greater than that of traditional learning.

A systematic study of CSs inquiry-based laboratory was reported by Pyatt and Sims (2012) supported this view. The researchers assessed students' attitudes toward computer use that appeared in physical and with CSs inquiry-based laboratory investigations during the first year of high school chemistry lessons. The study lasted for two years and used an experimental crossover design consisting of two separate laboratory research experiments. The newly created Physics and Physical Experiment Questionnaire was used to measure student attitudes toward virtual experiences in comparison to physical lab experiences. Results showed that students exhibit a positive attitude toward inquiry-based experiences, physical or with CSs, and shown their preference for integrating computers in a laboratory environment.

Research findings indicated that there is a positive significant correlation between the achievements in physics of adolescent students exposed to simulations assisted instruction in their attitude towards physics (Kattayat, Josey & Asha, 2016; Sari, Pektaş, Çelik & Kirindi, 2019).

For example, Kattayat, Josey and Asha (2016) explored the effect of simulations assisted instruction on attitude towards physics of adolescent students. For this, the achievement scores in physics of adolescent students who were taught using simulations assisted instruction and others who followed traditional lecture method were correlated separately using Pearson 'r' with the scores obtained by administering the physics attitude scale. The findings indicated that there is a positive significant correlation exists between the achievements in physics of adolescent students exposed to simulations assisted instruction in their attitude towards physics.

Sari, Pektaş, Çelik and Kirindi (2019) investigated the relationship of undergraduate attitudes towards the physics laboratory. they studied the use of virtual laboratory and computer-based laboratory. In this case, the effects of computer-based laboratory applications and virtual laboratory applications on students' attitudes toward physical lab were studied. 60 College students participated in the experiment. Research data is collected through attitude measures, motivational measures, graphical tests, and understanding and interpretation test. The results showed that computer-based laboratory applications and virtual applications had a positive impact on students' attitudes.

Previous research studies have also shown that, compared to traditional practical methods, the teachers' attitude about using CSs for physics instruction can provide comparable results, thereby improving students' learning efficiency and reducing teaching time (Sari, Pektaş, Çelik & Kirindi, 2019; Kattayat, Josey & Asha, 2016; Pyatt & Sims, 2012). For example, Bozkurt and Ilik (2010) conducted a study to measure the impact of teaching with interactive CSs on students' beliefs about physics and achievement of physics. The sample consisted of 152 students who studied General Physics 1 Course. For the study, a survey called "Colorado Learning Attitudes about Science Survey" (CLASS) was used. As a result, it was seen that the courses with interactive simulations have a positive effect on students' beliefs about physics. Oymak and Ogan-Bekiroglu (2017) compared students' conceptual knowledge and attitudes with physics lessons (technology supported teaching, laboratory-based teaching, and curriculum-based teaching) using three different methods. The study was conducted on 144 9^{th} male students in high school. The results showed that the attitudes of these students improved when CSs laboratory or laboratory-based teaching was incorporated into education.

So far, the previous studies didn't provide a clear description to the role of the students and the teachers during the lessons, which may affect students' attitudes. The studies also didn't entail other factors that influence the attitudes like school, teachers' classroom management, and teachers' content knowledge. Additionally, most studies have explored computer-based simulations and physics, however, there has been little discussion about concepts related to mechanics nor explicit mention of NSLOM or topics related to the force.

2.4 Newton's Second Law of Motion

NSLOM is the central and the most important topic taught in classical mechanics (Mico, Mandili, Tahiri & Muco, 2010; Itza-Ortiz, Rebello, & Zollman, 2004; Sirait & Mursyid, 2018). Understanding NSLOM is likely to be the key to understanding mechanics (Sari & Madlazim, 2015).

According to the MOE curriculum guidelines, before the high school physics is over, students should be able to use Newton's second law of motion and describe the forces acting on objects in different states of motion (Bauer & Westfall, 2011).

NGSS (2013) describes the NSLOM as "The movement of an object depends on the sum of the forces acting on it. If the total force affecting an object is not zero, then its movement will change. The higher the mass of the object, the more force is needed to achieve the same change of motion. "For any given object, greater forces cause greater movement changes" (NGSS, 2013, p. 59). This means that an acceleration (a) of an object depends on two variables, namely, the net force (F) acting on an object and mass (m) of the object (NGSS, 2013).

It is vital to allow students to know the relationship between force and motion. The equation for this law is {F = m.a} [Net force = (mass)(acceleration)] (NGSS, 2013; Serwey & Jewett, 2014; Mico, Mandili, Tahiri &Muco, 2010; Coelho, 2018; Itza-Ortiz, Rebello, & Zollman, 2004; Sari & Madlazim, 2015). However, NSLOM in many textbooks is presented so abstractly that students cannot see the relationship between force and motion (Mico, Mandili, Tahiri & Muco, 2010).

2.4.1 Difficulties of Newton's Second Law of Motion

Many students have a different understanding of force, and some students cannot explain the meaning of the word " force " clearly (Sirait & Mursyid, 2018; Camarao & Nava, 2017; Obaidat & Malkawi, 2009). As a result, these difficulties may affect students' understanding of how force concepts are applied in other situations (Sirait & Mursyid, 2018). For example, Sirait and Mursyid (2018), conducted a study to analyze the difficulties faced by students in understanding force diagrams at horizontal and inclined surfaces. A physics student at Tanjung Pura University (pre-service physics teacher) who completed course in basic physics participated in a force concept test with six questions that include three concepts: fixed objects, moving objects at a constant speed, and the object moves with continuous acceleration in both the horizontal and oblique levels. The test is examined the students' ability to choose the appropriate force based on the context. Results showed that 44% of students had difficulty solving the test problems, in addition, the most difficult task is to map the force diagram representing, which represents the force affecting the object at the inclined plane.

Sağlam-Arslan and Devecioğlu (2010) studied the level of student teachers' understanding of NSLOM and linked these levels to determine the model of student teacher understanding. A two-part achievement test was employed, including 12 open questions, and tested for 45 pre-service classroom teachers. The results showed that student teachers' have obvious weaknesses in understanding basic knowledge of NSLOM. This may be due to a lack of student teachers' ability to link scientific knowledge to real life phenomena and experiences.

Another major study carried out by Bayraktar (2009) who analyzed teachers' difficulties of physics before using force and motion, and to determine whether these difficulties vary with gender, educational level, and culture. The study was conducted using 79 students-teachers at one of Turkey's largest education colleges. Force Concept Inventory (FCI) with 29 multiple choice items was used to analyze student's-teacher's difficulties. The results of the study showed that physics students-teachers have a robust difficulty about impetus and active force. The results also showed that over time, difficulties of force and motion had lessened.

To clarify and to teach NSLOM, researchers used a variety of methods. For example, Setyanto, Sudjito and Rondonuwu (2018) used an instructional strategy called Understanding by Design (UbD) to design physics lesson on Newton's second law. All data collected from the description table is analyzed based on qualitative methods to modify the initial design to a better final design. The design has been modified according to the auditor's suggestion. The results showed that UbD can be used as an alternative design for physics courses related to Newton's second law. The results also showed that over time, misunderstanding of force and motion decreased. Over the years, test scores have continued to improve, indicating that university teaching has a positive effect on overcoming misunderstanding, although it is still not adequate to help students reach the level of Newtonian thinkers.

Although students are familiar with Newton's Laws because they have studied them since Middle or High School (Coelho, 2018; Itza-Ortiz, Rebello, & Zollman, 2004; Sari & Madlazim, 2015), the most difficult task for students is to determine the force diagram when the object is moving at a constant speed and constant acceleration in a steady state (Coelho, 2018). According to Setyanto, Sudjito and Rondonuwu (2018) the kind of misconception students face in Newton's law lessons is that they are confused about comprehension, velocity, force, and energy. Some students clearly do not understand the true definition of these concepts and the difference between these three terms. Therefore, visualization tools such as CSs should be used and using to facilitate students understanding, and to provide students the opportunity to create or draw their own representations (Coelho, 2018).

In general, previous studies have used CSs programs, especially in the study of physics and Newton's laws, to enhance attitudes toward physics, improve students' understanding, and eliminate misunderstandings at the university level. However, far too little attention has been paid to the difficulties that students face in learning NSLOM in high school level.

2.4.2 Computer Simulations and Newton's Second Law of Motion

Research studies suggests that when CSs are used as part of an instructional strategy to explore abstract concepts of physics, it can help students gain a deeper understanding of those concepts (Zacharia & Anderson, 2003). In order to eliminate the difficulties and misconceptions about students' learning outcomes when teaching NSLOM, additional use of simulations in science classrooms could potentially improve access to high-quality learning experiences for diverse students (Council, 2011, p.67). Several studies have highlighted the positive effect of using CSs and experiment animations in improving NSLOM learning. For example, Sari and Madlazim (2015) found that Newton's second law greatly improved the conceptual ability of students who used CSs to learn compared to students who did not study CSs. Using a sample from third semester of physics students in the Department of Mathematics and Natural Sciences at Surabaya State University. The sample size of the first group (experimental group) is N = 38, and the sample size of the second group (control group) is N = 38. The finding indicated that the CSs implementation in teaching and learning can improve the conceptual competence of NSLOM.

Couch (2014) examined the use of CSs, especially the effect of laboratory virtualization on students' understanding of mechanical concepts. In this study, experimental and controls groups received the same instructions in the form of lectures, exercises, homework, and tests. The difference between the two groups was that the experimental group uses a default lab activity, while the control group completes the paper worksheet. Analysis of the standard benefits of the force concept checklist and classroom tests showed that CSs appears to increase students' workload and participation.

2.5 Studies Related to the UAE Context

CSs is not common in the UAE context. However, virtual learning is one of the recent trends within the teaching schools of the UAE. This is important in the sense that Emirates will be looking forward to bringing in technologies in the form of e-learning and using other forms of technologies (Aoude, 2015). This is extremely important for the students to understand and develop mental models of physics (Aoude, 2015).

There is scarcity of studies related to the UAE. However, there are a number of studies related to the impact of technology in general. For example, Ismail, Almekhlafi and Almekhlafy (2010) scrutinized teachers' perceptions on technology integration in Arabic and English classes in K-12 schools in the UAE. Study results confirm the inevitable impact of technology on teaching practice, which in turn can enhance students learning in language lessons. In addition, teachers expressed their readiness to accelerate the pace of technology integration in teaching practice to improve teaching and learning effectiveness.

Awan (2012) carried out a study to examine the impact of computers / laptops on the dynamics of the teaching environment. Questionnaires were distributed to teachers who are currently pursuing master's degrees to collect teachers' opinions and experiences about using computers and laptops in the classroom. The results showed that teachers in the public and private sectors in the UAE are able to identify key issues related to the advantages and disadvantages of using technology. Regarding the problem of how to deal with the lack of adequate training from the perspective and lack of teaching, people raised great concerns and raised some teaching strategies, which would make the practice of managing technology-based classrooms possible.

Martin (2013), conducted a study to determine the level of participation of Emirati higher education students in digital technologies, including the Internet, and whether this level of participation is like an international model. The study used a mixed-method approach that included many higher education institutions in the UAE and included students from various geographical locations and disciplines in the country. Six main findings were extracted from the data. The overall results indicate that Emirati students in this study have better access to digital technologies than many other countries.

The research confirmed the importance of CSs in teaching and learning of physics concepts (Mengistu & Kahsay, 2015; Widiyatmoko, 2018; Obradović & Rančić, 2012, cited in Radulović, Stojanović and Županec, 2016; Smetana & Bell, 2012; D'Angelo et al., 2014). For example, Aoude (2015), focused on the impact of CSs on students' physics concepts related to uniform circular motion. The main purpose of the study was to examine the ability of CSs to help eleventh graders in the UAE learn facts, concepts, and procedures related to the uniform circular motion. It also aimed to study how CSs affects the achievements of students with different abilities in physics. Using the quasi experiment method, the students were divided into an experimental group and a control group. The experimental group is taught using CSs, and the control group is conducted with the help of video and animation in real time. The study showed that the experimental group had a statistically significant advantage over the control group, especially in terms of procedural knowledge. Additional results showed that students with middle and low education benefit more from CSs than students with higher education.

Almeqdadi and Halar (2017) carried out a study to investigate the effectiveness of TeachLive ™, one of the virtual learning simulations methods. TeachLivE ™ is a mixed reality learning environment that supports teacher practice in Florida, USA, and is currently implemented more than 40 campuses in the United States, involving multiple school districts and international partners. In addition, TeachLivE ™ has been implemented at the Emirates Institute for Higher Education in Abu Dhabi, United Arab Emirates and is used by some pre-service teachers (which is a classroom management activity), and to practice specific some teaching methods. Strategies that were taken before going to school without having to worry about the actual situation. Each student in this sample then practiced twice using TeachLivE ™, with each session lasting 10 minutes. The researchers analyzed these students' views on. The results showed that all students in this sample welcomed the use of simulations techniques and expressed a positive view of TeachLive ™ not only in classroom management, but also in education and content.

Alneyadi (2019) conducted a study in the UAE to explore the views of science teachers on the nature and frequency of implementation of Virtual Laboratory (VL) by students in the UAE and their contribution to the development of education. Samples of this study were randomly selected to include a comprehensive sample of science teachers in the second cycle of public schools. The randomly selected participants included 45 teachers from ten schools: Five schools for boys and five schools for girls. About 23 men and 22 women participated in the structured interviews. The main method used in this study is structured interview. Results showed that the VL has a reasonable impact on students' knowledge, skills, attitudes, achievements, and innovations, because teachers involved in the research believe that actual work activities carried out using VL have a positive impact on increasing students' scientific knowledge, scientific process, skills, intelligence, attitudes, and innovation. However, the VL is not used regularly, and it is only used on a small scale.

2.6 Demerits of Computer Simulations

Although most of the reviewed studies have shown that the use of CSs has been an effective way to improve students' learning about physics concepts, some studies did not find any statistically significant benefits of using CSs as part of a physics instruction. For example, Regan and Sheppard (1996) concluded that the use of CSs has no advantages over traditional methods. Steinberg (2000), on the other hand, compared air resistance simulations to paper and pencil activity, found that students' performance on common exam questions does not show much difference in scores. Similar findings were found by Stern, Barnea and Shauli (2008), who compared two groups of students, who both taught curriculum on the kinetic molecular theory. The experimental group then used CSs to spend extra class time on using the computerized simulations called "A Journey to the World of Particles". In the test to measure their understanding of the theory, students scored significantly higher in the experimental group than in the control group. However, overall achievement is very low and there are no differences in long-term learning.

Çetin (2018) examined the effects of simulations based cooperative learning on students' physics achievements, science process skills, attitudes towards physics, and interactive whiteboards. In the experimental group (N = 24), students taught with Student Teams Achievement Division (STAD) method with the integration of simulations in electricity topic, in the control group (N = 25), traditional learning supported by simulations. Results showed that the effect of cooperative simulation-based learning is not much difference from students' skills in the science process skills.

The controversy over scientific evidence for the use of CSs in practical laboratory methods has raged unabated for over a decades ago. For example, McKagan, Handley, Perkins and Wieman (2009) examined the effects of reforming the physics curriculum among other changes in the process, CSs of the photoelectric effect were performed in the course. The results showed that students' ability to communicate logically through observation and thinking did not improved. The researchers believe this may be a sign of a general inability on the part of students to reason in order to infer reasoning from observation. In the absence of a separate study of the teaching methods implemented, it is difficult to make allegations about the effectiveness of CSs on the basis of this study.

Podolefsky, Perkins and Adams (2009) suggested that CSs can't or should not replace real laboratory equipment. They placed PhET (simulations) in a social, cultural, and historical context, and they focused on the interaction of three metrics for tools: representations, materials, and environment. They used data from simulations research in the physics primer lab to examine the main features of these three ranges of tools that support student learning through participatory exploration. To explore why there were controversial findings regarding the efficacy of CSs on practical experiments methods. First, data were collected from two sources in the second semester: 1) students' laboratory activities with and without simulations feedback, and 2) classroom observations of students using simulations. Researchers derive useful information from student feedback, but further results can be obtained by incorporating experimental elements of the study, as shown in other studies. In addition, this long period may affect students' response and change their minds about the efficacy of CSs. Second, the notion that researchers couldn't have included a pretest and posttest to measure content knowledge about current and voltage, as well as the sample size was very small, it will be difficult to generalize the results. Finally, the researchers used the same sample as students completed the activity using the circuit construction kit and PhET sim. Then the following week, students completed an activity using real equipment, and after that students asked to complete an online survey to compare the simulations with the real equipment labs in an open response question.

Kelly, Bradley and Gratch (2008) compared simulations with equipment-based laboratory investigations. Students participated in this study in twelve laboratory experiments, six of which included simulations tests or equipment. The data used for comparison is a classification of pre- and post-laboratory reports, and the results indicated that there was no significant difference in the achievements of these reports between simulations or equipment investigations reports.

Despite the benefits of CSs over students' attitudes, there is debate as to whether such technology is effective (Abou Faour & Ayoubi, 2017; Regan &

Sheppard, 1996; Steinberg, 2000; Kelly, Bradley & Gratch, 2008; Stern, Barnea & Shauli, 2008). Research studies have also shown that there is no significant difference between CSs and attitudes regarding their effectiveness on students' learning. For instance, Abou Faour and Ayoubi (2017), investigated the impact of the use of CSs on the conceptual understanding of 10^{th} graders from DC circuit and their attitudes towards physics. The sample for this consisted of 50 students from 10^{th} grade at an official secondary school in Mount Lebanon. Participants were randomly divided into two groups, CSs experimental group was used for teaching, and experimental activities were performed using a circuit construction kit developed by the PhET simulation. However, the control group was taught using real laboratory equipment. Both groups underwent pre-test and post-test. Data analysis showed that there was no significant difference in the attitudes of the students in the two groups toward physics.

Researchers also mentioned several reasons that hamper teacher from using CSs: First, the training that teachers receive is not sufficient to implement CSs. Second, teachers have not changed their teaching behaviors; However, they continued to use older teaching methods. Third, teachers believe that using CSs is a means of engaging students in learning, not an instructional tool (Ertmer & Ottenbreit- Leftwich, 2010; Levin & Wadmany, 2008).

Despite these arguments supporting CSs, previous comments on research on CSs use did not show that CSs had distinct advantages (Regan & Sheppard, 1996; Steinberg, 2000; Kelly, Bradley & Gratch, 2008; Stern, Barnea & Shauli, 2008). This discrepancy may be due to some factors. For example, improper use of the CSs, as well as inappropriate analysis and explanation of research data (i.e., researchers ask wrong questions, or because of inappropriate education design and unrealistic simulations). Another example, most studies compared CSs, and classroom instructions. This comparative study will not achieve any meaningful results. Moreover, researchers have not focused on the key question of the conditions under which CSs is most effective or not effective.

2.7 Chapter Summary

This chapter outlines the theoretical and research efforts that tackled CSs as a technology integration tool, and its impact on physics education, especially performance and student attitudes in NSLOM. Based on the discussion above, there are three groups of thought that play a role in how to construct knowledge, there are theoretical framework sections tackled: constructivism, conceptual change, and information process approaches. CSs contributes to these approaches, as CSs improves students' active and meaningful learning, and CSs are powerful tools that allows students to connect new knowledge to their current knowledge building. This helps students understand common errors when they encounter specific problems, and students use these CSs to combine new information with existing knowledge structures.

The literature suggests that CSs can be effective learning tools when used as part of an instructional strategy in order to help students gain a deeper understanding of abstract physics concepts. The research also suggests that there is a positive correlation between CSs and student achievement (Çetin, 2018; Dilshad, Malik, Tabassum & Latif, 2016; Srisawasdi & Panjaburee, 2015; Riaz & Morote, 2015; Sari, Hassan, Güven & Şen, 2017).

Inquiry-based science teaching and learning in collaboration with CSs improve student's learning; like critical thinking and achievement, and it gives students the opportunity to learn freely and immersed in learning, each according to their academic level (Widiyatmoko, 2018; Hannel & Cuevas, 2018; Pedaste et al., 2015; Fan, Geelan, & Gillies, 2018; Hartoyo, Batlolona & Nilasari, 2019; Yuksel, Rebello & Bryan, 2017; Cairns & Areepattamannil, 2019). CSs can be effectively used to examine phenomena that are difficult to try in the classroom or laboratory environment because these phenomena are often complex, difficult, or technically unsafe, expensive, time consuming, or too fast (Jimoyiannis & Komis, 2001; Hannel & Cuevas, 2018; Sari, Pektaş, Çelik & Kirindi, 2019; Zacharia, 2007; Oymak & Ogan-Bekiroglu, 2017).

NSLOM is one of the most difficult subjects for students, however, CSs can be used to facilitate learning and understanding NSLOM (Sirait & Mursyid, 2018; Coelho, 2018; Setyanto, Sudjito & Rondonuwu, 2018; Sari & Madlazim, 2015).

Research has also suggested that CSs have a positive effect on students' attitudes toward physics (Abou Faour & Ayoubi, 2017; Oymak & Ogan-Bekiroglu, 2017; Almeqdadi & Halar, 2017; Alneyadi, 2019). There are a lot of inconsistencies between the results of the relationship between CSs and the attitudes towards physics. These differences are mainly due to the context of the studies and other unrelated variables related to the participants, the nature of the treatments, and even the studies design themselves. In addition, some students in the physics classes already struggle with content, and that struggle can lead to a negative attitude in the classroom, as well as a variety of simulations being studied in the physics class.

With all the benefits of CSs, however, limitations remain: (1) no physical manipulation of variables; (2) no measurement errors; (3) potential problems for students with poor computer literacy skills; And (4) scientific concepts may be lost if not properly directed by a teacher (Kelly et al., 2007 cited in Hannel & Cuevas, 2018, p. 42; Couch, 2014). Moreover, other studies have found that the use of CSs are ineffective (Choi & Gennaro, 1987). Some found that the use of CSs outperforms traditional methods without advantages (Winn et al., 2006).

The review of previous research findings revealed that very little research carried out on the impact of CSs on student learning in the UAE, specifically, on NSLOM and on attitudes toward physics. Furthermore, previous research did not examine the effect of CSs on students' performance and attitudes within inquiry-based context. Besides, previous research studies in the context of the UAE have not been significantly represented about the role of student performance and attitudes. Only few studies such as Aoude (2015) investigated the role of CSs and the performance of physics. Therefore, this study will help to better understand how CSs impact students learn physics within an inquiry-based learning environment. Thus, there is a critical need for the current study.

Chapter 3: Methodology

3.1 Chapter Overview

This chapter comprehensively introduces how this research is carried out. It begins with seven research questions and then describes the background, context, and settings of the study. Then describes the materials that were used for this research. Next, the research design is shown. It also describes the population, participants, and sampling procedures. Besides. The validity and reliability of the tools used to collect the data for this study; NSLMAT and TOSRA were also presented. Next, the procedures for collecting and analysing data for the study will be described. Ethical considerations have also been wholly resolved. Finally, this chapter summarizes the materials and methods used to conduct the research.

3.2 Research Background and Setting

3.2.1 The Emirati Context

In 2014, the UAE launched the National Agenda for 2021, with a significant focus on education (Haddad, 2020). The focus is on the shift in education from mere regurgitation of information to students' acquisition of knowledge (Sahoo, 2016, cited in Ridge, Kippels, & El Asad, 2015). The overall objective of this agenda is to provide all schools, universities, and students with smart systems and equipment as a basis for all teaching project and research methods (Haddad, 2020). Other goals mentioned in the same agenda included two main objectives to make the UAE one of the leading countries in providing world-class education. The national agenda identified areas that contribute to student development. To achieve these agenda (i.e., by 2021 the UAE is expected to rank among the best countries in international comparative studies such as TIMSS and PISA), it requires a new approach to the way student learn and adopted the international test to monitor student development (Haddad, 2020; Galil, 2014).

To achieve these goals, the UAE Ministry of Education has introduced a series of changes to the national curriculum over the past decade to shift from a content-based curriculum to a competency-based one, and from a teacher-centered learning approach to a student-centered approach.

Schools in the UAE follow the national curriculum, teaching physics begins in grade ten (before 2015) as separate subjects, and students must choose either a science or arts stream (Balfakih, 2003). However, the MOE revised this system and instead introduced new streams and curriculum (Ridge, Kippels & Farah, 2017). Four streams were adopted: the general stream, the professional stream, the advanced stream, and the elite stream. All students will begin from grade one in the general stream of learning (UAEG, 2019). After completing the ninth year, students can choose to remain in the general stream or join the advanced stream according to their performance. Students in the general and advanced stream will continue to study in grades 10, 11, and 12. The main difference between general and advanced streams lies in the range of science majors. Compared to the general stream, students in the advanced stream will have more instruction in mathematics and science (UAEG, 2019).

After completing the eighth grade, student can choose to join the group of "professional" (Vocational stream), where he continues to study in grades 9, 10, 11, and 12, and obtain a high school certificate equivalent to a technical high school certificate. Specialization (Vocational stream) follows a practical educational curriculum. Learning is based on applying knowledge and developing practical skills for students (UAEG, 2019).

Elite Stream on the other hand, was developed for academically outstanding students. This stream enrolls students from the sixth grade until the end of the twelfth grade. Elite stream focus on mathematics and science in a way to improve the ability to analyze, thinking, and problem-solving skills (UAEG, 2019).

3.2.2 Research Setting

This study was conducted in two schools that implement the curriculum of MOE; One for boys (taught by male teachers) and the other for girls (taught by female teachers). Both schools are located in one emirate in the UAE; The two schools implemented the curriculum provided by MOE. The socioeconomic status of students mostly of middle class.

In the girls' school, there are 760 students in grades 9-12. This school has three eleventh grade classes; One of them was chosen randomly to be a control group, while another class was chosen as an experimental group. The second school for boys has about 870 students in grades 9-12. It has four eleventh grade classes; One was randomly chosen to be a control group, while another class was chosen to be an experimental group. All classes at both schools use digital books and hard copies for teaching, as all students are equipped with personal laptops. All the classes in the study have similar demographic characteristics and similar school hours. Physics lessons are taught by qualified teachers who are fluent in English. Furthermore, both groups were in the advanced stream in the 2019-2020 academic year.

3.3 Materials

In this study, the students were given step by step instructions on how to use the PhET simulations of NSLOM. Students then performed a set of experiments using the predefined instructions provided in the NSLOM worksheet. The students were expected to discover mathematical relationships of NSLOM in order to improve their conceptual and procedural understanding of NSLOM. The following is a description of the materials used in this study; the unit used, the NSLOM PhET simulations, and the activities guide that was used to guide students in the experimental and control groups through 5E inquiry instruction.

3.3.1 Justifications for Choosing the Unit

NSLOM has been chosen because of its wide range of applications and is an interesting piece of content that must be handled by CSs. If a student fails to learn classical mechanics, it is because of a misunderstanding of the NSLOM. The content was also linked to previous conceptual and procedural knowledge that the students learned in science books at the basic stage. The general focuses of the unit were as follows:

- What the concept of a force means in physics, and why forces are vectors (the force is a vector quantity that is a measure of how an object interacts with other objects).

- The relationship among the net force on an object, the object’s mass, and its acceleration.
- Newton’s three laws of motion govern the motion of objects under the influence of forces.

  a) The first law deals with objects for which external forces are balanced.

  b) The second law describes those cases for which external forces are not balanced.

  c) The third law addresses equal (in magnitude) and opposite (in direction) forces that two bodies exert on each other.
- Fundamental forces include gravitational attraction and electromagnetic attraction and repulsion. In daily experience, important forces have tension and normal and friction.
- Free-body diagrams are valuable aids in working problems.
- The significance of the net force on an object, and what happens when the net force is zero.
- Multiple forces are acting on an object sum to a net force.
- Kinetic friction opposes the motion of moving objects; static friction opposes the impending motion of objects at rest.
- Applications of Newton's laws of motion involve multiple objects, multiple forces, and friction; applying the laws to analyze a situation is among the essential problem-solving techniques in physics.

3.3.2 Newton's Second Law of Motion Lab Simulation

NSLOM is a fundamental and useful equation in mechanics. The law addresses the relationship between force and motion (Mico, Mandili, Tahiri & Muco, 2010). NGSS (2013) describes the NSLOM as the following "The movement of an object depends on the sum of the forces acting on it". If the total force affecting an object is not zero, then its movement will change. The greater the mass of an object, the more force is needed to achieve the same change of motion. For any given object, greater forces cause greater movement changes" (NGSS, 2013, p. 59).

Consequently, by analyzing the NSLOM, it can be summarized as the acceleration of the object is directly proportional to the force and inversely proportional to the mass of the object. The equation of this law is $F = ma$ [Net force = (mass)(acceleration)] (NGSS, 2013; Serwey & Jewett, 2014; Itza-Ortiz, Rebello & Zollman, 2004).

According to Mico, Mandili, Tahiri and Muco (2010), Newton's second law of motion in many textbooks often presented so abstractly that students cannot see the relationship between force and motion. It is vital to allow students to know the relationship between force and motion (Mico, Mandili, Tahiri & Muco, 2010). Figure 4 represents the types of forces and how they relate it to motion. To enhance the theoretical understanding of how objects move and how they accelerate, interactive simulations of the forces and computational motions obtained from PhET are used as inquiry tools for students (Adams et al., 2008), because PhET simulations provide a high degree of interaction between user control, dynamic feedback, and multiple representations (Adams et al., 2008).

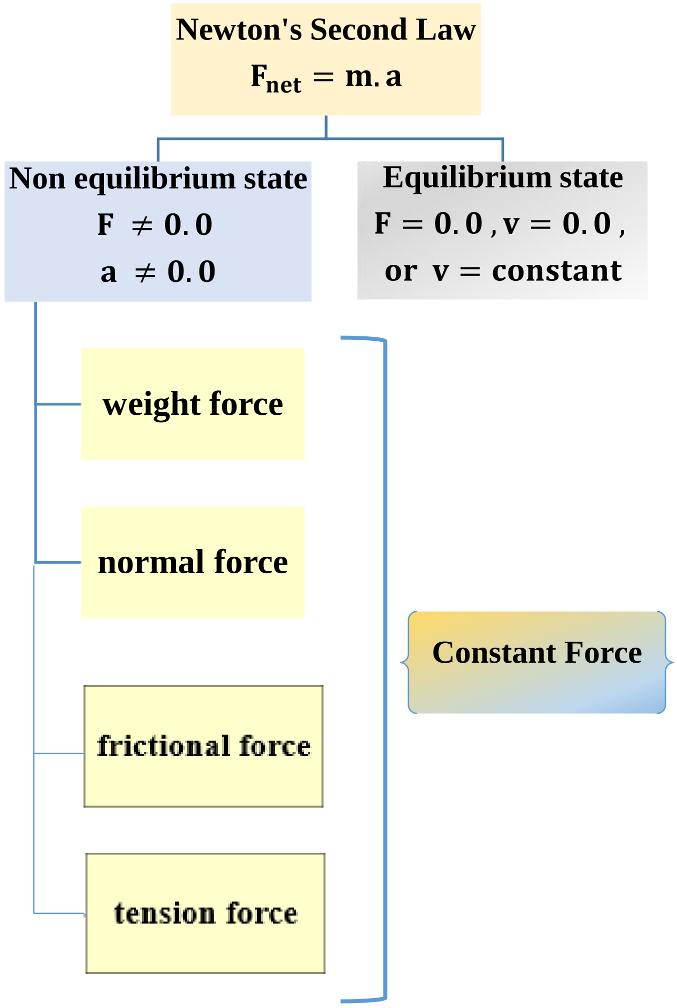

Figure 4: Concept Map that Analyze the Types of Forces

The NSLOM simulations that was used in the current study was a java-based program that is downloaded and installed on student's computers from the site http://phet.colorado.edu. Which is free to use (see Appendix H). Students were given step-by-step instructions on how to use the NSLOM simulations and were asked to explore the different parts of the simulations. A series of controls in the control bar area allow students to change analogue input parameters. Before running the simulations and making the necessary observations, students need to determine which variables need to be changed and which should not. Each student then performed a series of experiments using the pre-explanation provided in the NSLOM worksheet. Finally, students are asked to determine the mathematical relationships of NSLOM from graphs and visual representations. The simulations of Newton's second law of motion are composed of six different simulations related to NSLOM. Figures 5-11 show screenshots of each of the six simulations. PhET allows students to interact with Newtonian representations of force and motion and lets students create their own experiments.

The simulation of force and motion was designed and developed to allow students to visualize the forces and phenomena induced by motion, so that they can get a more scientific view of the concept of force and motion, as shown in Figure 5. In the simulation, Java applet calculates force, friction, position, speed, and acceleration. These analytic tools and graphical representations can help students grasp motion-related math.

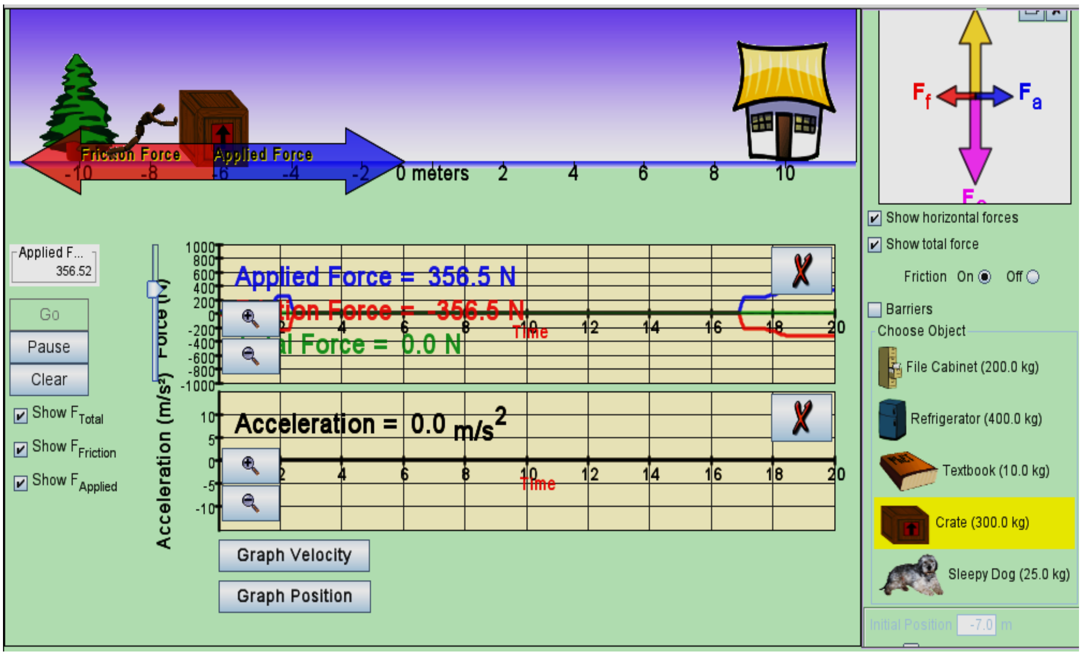

Figure 5: Screenshot of CSs with a Visual Representation of Forces

For example, by simulating part of a force and movement (see Figures 6 and 7), students can interact with it to understand how mass affects the acceleration of a force-carrying body, balanced and unbalanced forces - causes of acceleration, force, and frictional movement.

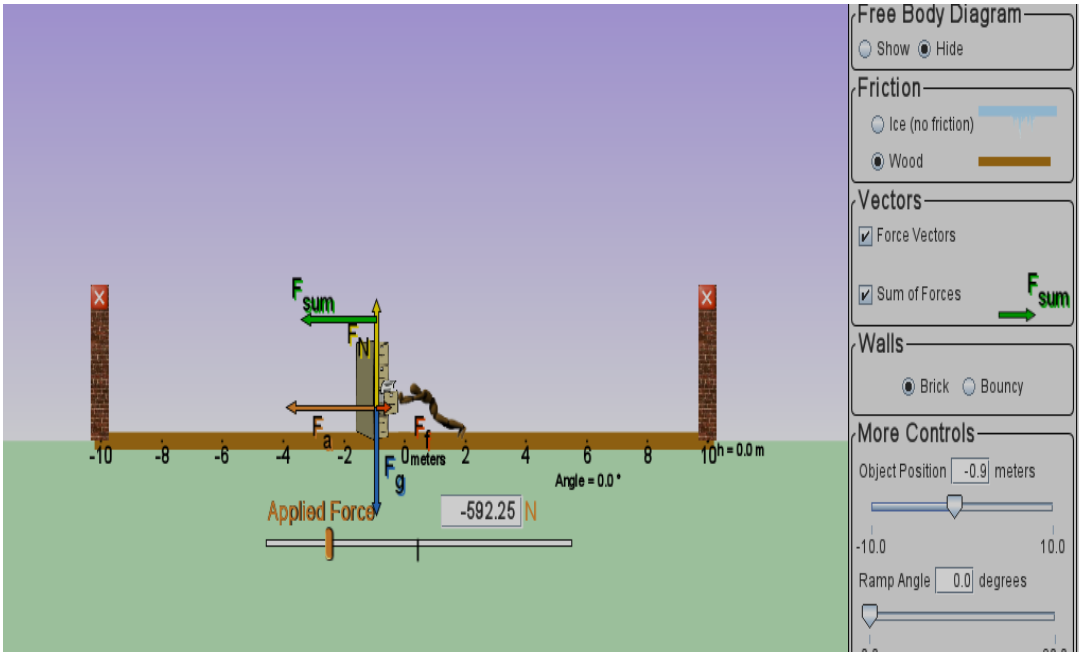

Figure 6: Screenshot of CSs with a Visual Representation of Forces in a Horizontal Surface

According to NSLOM, the movement of the container depends on the friction (friction force) generated by the load and the tensile force (applied force) exerted by the person. These two forces have opposite directions and act on the container. Its relative size determines the movement of the container. The arrows indicate the forces applied, and students can change the attributes of the objects (such as box, refrigerator, girl, and man), and the friction force as displayed in Figure 7.

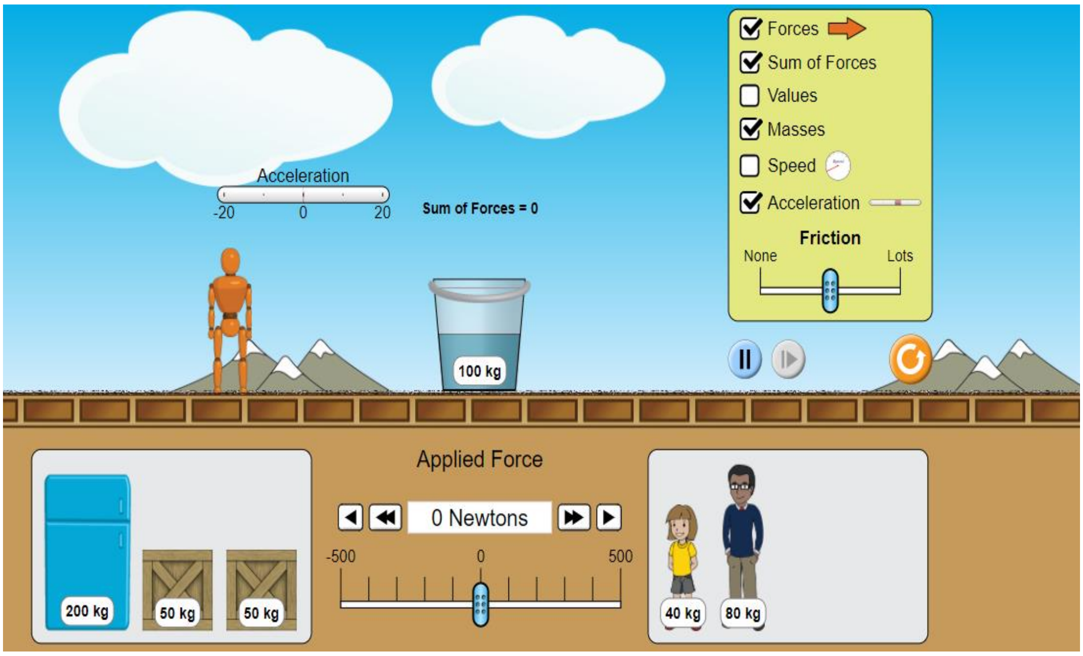

Figure 7: Screenshot of CSs with a Visual Representation of Horizontal Forces in Different Objects

The PhET simulation of the movement shown in Figure 8 shows the effect of increasing or decreasing the angle of the inclined surface, so that students can easily manipulate the angle to accurately measure the force and other factors such as friction, normal force, gravity, and objects acceleration, which are difficult to achieve in the opposite real world.

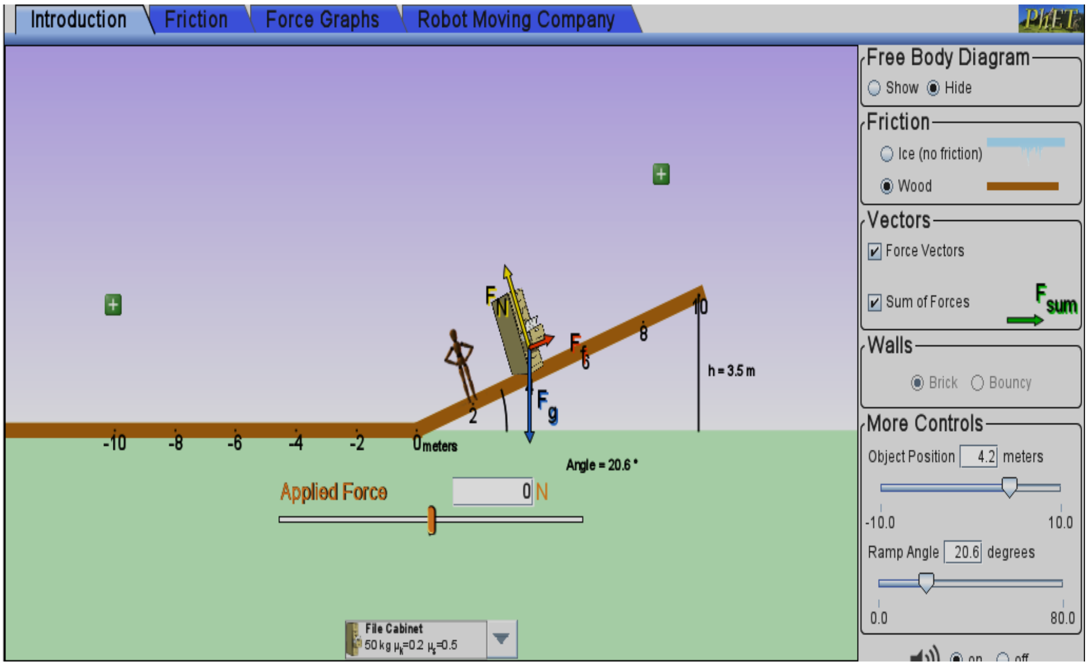

Figure 8: Screenshot of CSs with a Visual Representation of Forces in the Inclined Surface

In Figure 9, the students can create this experiment in ideal condition (non-frictional surfaces and the absence of air resistance) that are difficult to generate in the real world, by eliminating the friction and other resistive force. In addition to studying the influence of the amount and the shape of the masses on motion, as well as learners can turn friction and choose different values of the coefficient of friction. They can also change the amount of applied force and the objects (masses) to see what happens.

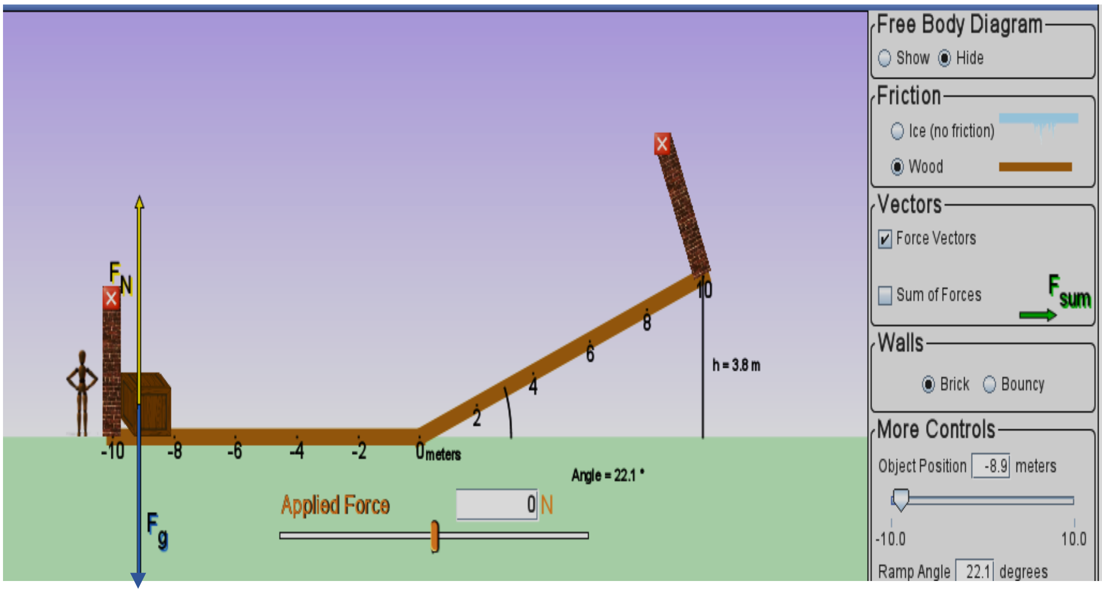

Figure 9: Screenshot of CSs with a Visual Representation of Forces in the Horizontal and Inclined Surface

A game of Robot is used to demonstrate the principles of NSLOM in the simulation: Robot moving company. The students can play by placing the file cabinet on the horizontal ground and then using the arrows, so that the Robot "start" to try to push the file cabinet instantly from the company to the house without letting the cabinet to slide down. They can see the force diagram during the motion (see Figure 10).

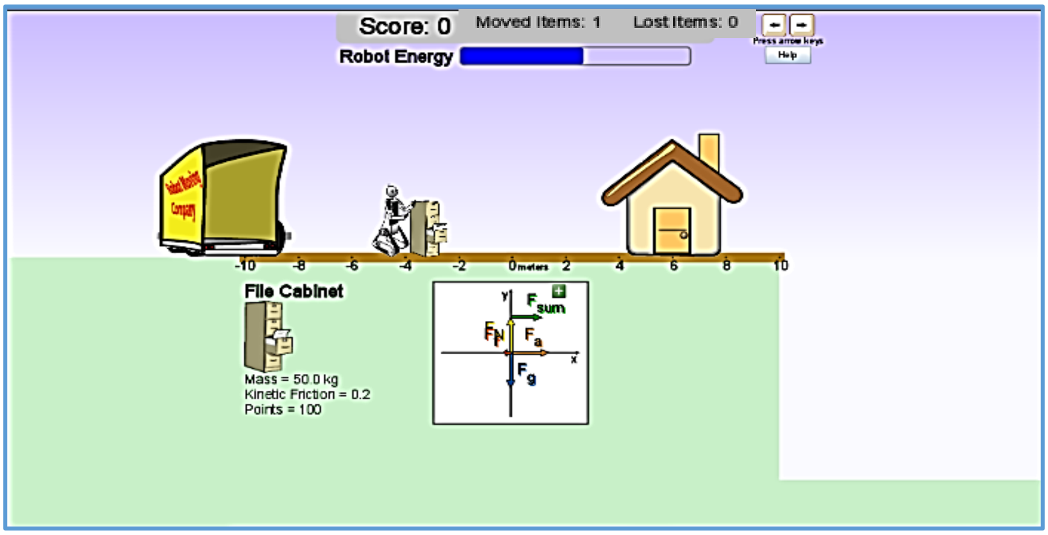

Figure 10: Screenshot of CSs with Robot Applying Forces in a Horizontal Surface

Students can make the game more challenging by placing an inclined surface. Figure 11 shows how students would be able to move a small crate from the company to the house, by using the corrective force associated with the angle to prevent the crate from falling.

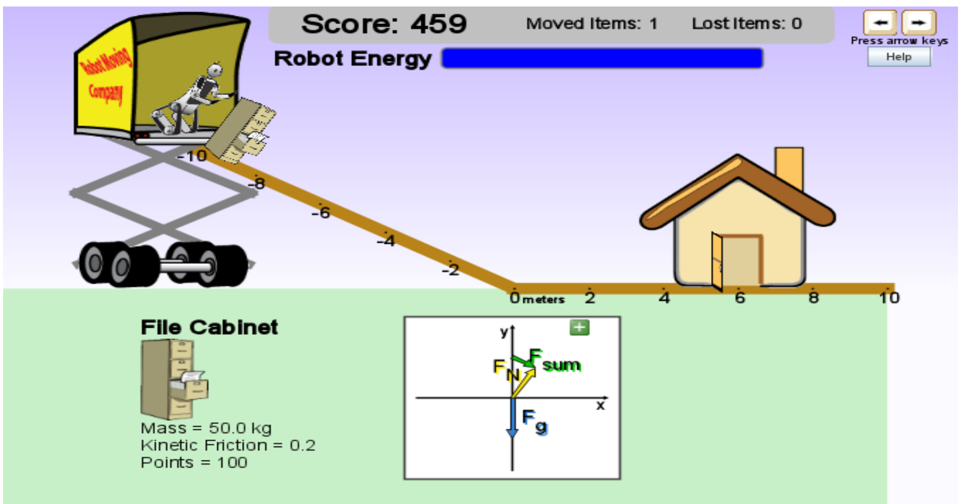

Figure 11: Screenshot of CSs with Robot Applying Forces in an Inclined Surface

3.3.3 Inquiry Context

Secondary school students often think that there is a scientific method. This idea reinforced in traditional laboratory courses in which students engage in things such as observing, measuring, identifying the variables, defining measurement uncertainty, calculating the error distribution, make assumptions, perform calculations, draw graphs, find relationships between variables, and make suggestions (Stern, Echeverría & Porta, 2017). To make the process easier, they are often provided with a list of instructions. Even if the experience is fun, students will find the process boring because they do not have enough freedom to think and make suggestions (Stern, Echeverría & Porta, 2017).

Constructivist oriented learning approaches are based on the belief that learning occurs when students actively participate in the process of creating meaning and knowledge rather than passively receiving information (INACSLSC, 2016). Therefore, any simulation-based expertise requires targeted, systematic and flexible regular schedules. To achieve optimal results, simulations design and development must take into account criteria that can improve the effectiveness of simulation-based experiments (INACSLSC, 2016).

The 5E learning cycle is a model designed to promote scientific inquiry. Each "E" is part of the process that helps students arrange learning experiences to create a link between previous knowledge and new concepts (Mirana, 2016; Sarı, Hassan, Güven & Şen, 2017).

According to the 5E strategy, the researcher uses a variety of reference materials and incorporate other worksheets into the educational context to integrate activities with concepts of active learning and scientific inquiry while adhering to the scientific topics mentioned in the students' books.

These worksheets were presented to a group of experts, including professors from the college of science and education (see Appendix C), and some teachers teaching physics to 11th grade students during the 2019/2020 school year. They were asked to express their opinion on the following points:

- The suitability of the activities for the students' level
- How appropriate are the activities for the learning strategy used 5E?
- The suitability of the instructional objectives for the content of the material

Finally, a printed NSLOM worksheet (see Appendix C) was provided to guide students in their use of the simulations, students went through the simulations with an activity that covered NSLOM topics.

3.3.4 5E's Model

The model focuses on students' discovery and deeper understanding of direct teaching (Duran & Duran, 2004). This model has proved to be effective in students' mastery of topics, scientific reasoning, interest, and attitude (Lo, 2017, p. 39). 5E's consists of five stages (see Figure 12). These are: Engage, Explore, Explain, Elaborate, and Evaluate.

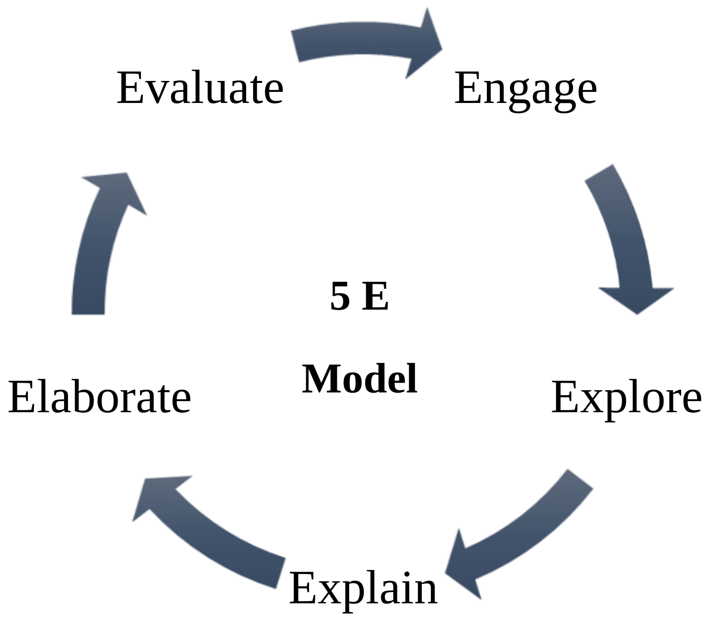

Figure 12: 5E Model Steps

During the “engagement” phase, students will be attracted, and their preconceptions will be revealed. Activities at this stage should link past and current learning experiences, reveal previous concepts, and organize student thinking about learning outcomes for recent activities. Teachers can gain access to students’ prior knowledge and help them integrate new concepts using short activities to stimulate their curiosity and prior knowledge goals (August et al., 2014; Sarı, Hassan, Güven & Şen, 2017; Duran & Duran, 2004; Bybee, 2009; Bybee, 2014). For example, the teacher can ask his students questions like; (List all the things you know about force? Names the different types of forces? and Distinguish between mass and force?).

In the next phase of 5 E's, “exploration”, students are provided with a joint base of experience. Defines and develops concepts, processes, and skills. In this phase, students have time to think, plan, investigate, and organize the information gathered to explore their environment actively. Furthermore, manipulate these materials, so that students can define their ideal goals (August et al., 2014; Sarı, Hassan, Güven & Şen, 2017; Duran & Duran, 2004; Bybee, 2009; Bybee, 2014). For example, during working on simulations, teacher can ask students to reflect on questions such as; (a) What could have happened to the box, if the friction force stronger? b) If you were in the simulations, and the box was coming towards you, how could you respond to stop it? c) In contrast, what would be the scenario, if the same events have happened on a plane snow ground?).

During the “explanation”, students clarify the concepts they were exploring. They could express their conceptual understanding or establish new skills, or the teachers help student’s emphasis on their past experiences in engagement and exploration and provide opportunities to explain their understanding goals (August et al., 2014; Sarı, Hassan, Güven & Şen, 2017; Duran & Duran, 2004; Bybee, 2009; Bybee, 2014). For example, students can use the simulations to conduct an experiment to find the relationships between force, mass, and acceleration, or think of procedures to investigate how different applied forces affect the acceleration of an object.

In phase 4 of 5E “elaboration”, students have the opportunity to expand and improve their understanding of the concept and apply it to practical situations. Students can gain a more profound and comprehensive understanding of key concepts, learn more about areas of interest, and improve their skills. For example, after analyzing the data obtained from the simulations, the students can answer the following: (1) What do you notice about the motion when there is no force added? 2) How did the motion of the object change when more force was added? 3) How did the motion of the object change when more mass was added?).

Finally, in the last stage of the 5E “evaluation”, students are encouraged to assess their understanding and teachers assess their progress in achieving educational goals (August et al., 2014; Sarı, Hassan, Güven & Şen, 2017; Duran & Duran, 2004; Bybee, 2009; Bybee, 2014). Table 1 summarizes these stages (Lo, 2017). For example, students can use essential vocabulary, group discussion notes, data table, and graph data as textual evidence to answer the following questions: (1) How do mass and force affect the motion of an object? 2) Design your own inquiry, demonstrating the effect of mass on forces? 3) write a general statement relating the acceleration and mass, when the force acting is constant).

Table 1: Summary of the 5E Instructional Model, Adapted from Lo (2017)

Phase	Description
Engagement	Teachers use learning activities to promote students' curiosity and activate their prior knowledge required for learning the new topic.
Exploration	Students gain experiences related to the learning items through activities such as preliminary investigations. Based on students' experiences in the engagement.
Explanation	Teachers introduce the new knowledge and skills to their students.
Elaboration	Teachers reinforce students' understanding and improve their skills by offering additional activities. Students have to apply what they learned to solve novel problems.
Evaluation	Students assess their understanding and ability. Meanwhile, teachers evaluate students' learning progress and their learning outcomes.

3.3.5 PhET Simulation

Psycharis (2011) believes that interactive simulations are a powerful learning tool that enables teachers to develop and deliver these high-quality lessons to engage students and make learning enjoyable and relevant. In fact, CSs can make visual content invisible and create multiple representations (Wieman, Adams & Perkins, 2008). According to Wieman, Adams, Loeblein and Perkins (2010), CSs can be used in a variety of learning settings, including presentations, individual or group activities, and laboratories. CSs are a tool designed to improve the workload of the well-designed curriculum and excellent instructors, but it cannot be replaced.

Many researchers have argued that there is ample evidence that PhET interactive simulations can be a powerful tool for students to learn science, as their design has an intuitive interface for students with minimal text (Keller, Finkelstein, Perkins & Pollock, 2007; Batuyong & Antonio, 2018; Adams, 2009). When using PhET in teaching, students gain essential learning experiences, which are summarized in three main axes: Learning physics is fun, learning real physics, and learning physics is simple and easy (Batuyong & Antonio, 2018).

Keller, Finkelstein, Perkins and Pollock (2007) documented the effectiveness of using of PhET program. The Development Kit Circuit Construction Kit (CCK) is conducted in two environments: interactive university lectures and an inquiry-based laboratory. Compared to conventional demos, the relative gain in understanding concepts for students viewing CCK is greater. Furthermore, students who use CCK without a clear current paradigm prefer simulations over other groups. This view is supported by Vic (2010), who described physics students in grades 11 and 12 using the PhET CCK to identify circuit experiments through a virtual laboratory and states that a PhET simulations can help students envision the intangible world of electronics and electronic solutions. The PhET simulations provide a way to collect virtual data. The study also suggested that teachers should use this simulation as a tool for exploration and discussion.

Activities based on PhET interactive simulations can be a way to enhance students' perceptions, thereby enabling people to gain a deeper understanding of the concepts of physics (Podolefsky, Perkins & Adams, 2010). For example, according to Wieman, Adams, Loeblein and Perkins (2010), PhET simulations are useful in laboratory activities, making it impractical to explore working on real equipment. For example, students explore acceleration using multiple different variables (force, mass, and friction). Students can repeat experiments and quickly explore the effects of many different parameters.

The great advantage of PhET is that it can model inaccessible conditions in a real laboratory so that the process can be explored under various conditions, such as no air resistance, no friction, and no risk (Batuyong & Antonio, 2018; Lamina, 2019; D'Angelo et al., 2014; Quellmalz & Pellegrino, 2009; Finkelstein et al., 2005b). Interactive PhET simulation is now widely used in the teaching of physics (Wieman, Adams, Loeblein & Perkins, 2010). Many simulations were issued per year to support universities and K12 students (Perkins, Moore & Chasteen, 2014). Adams et al. (2008) claimed that there are several ways to use the PhET simulator in teaching, for example, the PhET simulations can help: present new topics, build concepts or skills, and provide final review and reflection. It also provides a common visualization between students and teachers to facilitate all communication (Perkins, Moore & Chasteen, 2014). Finally, the PhET simulation can be played online or downloaded for free, very research-based, interactive animation and ease of use, and it allows actions that are difficult or not to take in the real world (Batuyong & Antonio, 2018; Perkins, 2012).

3.4 Research Design

The study employed a quasi-experimental pretest-posttest design/control group design, see Table 2. Creswell (2013) suggested that in quasi-experiment design causation is determined by applying a treatment or condition to one group and using the results compared to a control group. This design is used to show the differences in the physics performance and attitudes of the UAE eleventh graders students in learning NSLOM within the context of scientific inquiry instruction by using CSs as compared to eleventh grade students who learn Newton's second law of motion by the use face-to-face instruction. This design is an appropriate one as it provides an environment for comparison of the two groups based on the intervention; CSs within an inquiry-based learning environment.

Table 2: The Experiment Design Pattern

Groups	Pretest	treatment	Post-test
Experimental group	Applied	Receiving treatment CSs instruction	Applied
Control group	Applied	**No treatment** Face-to-face instruction	Applied

The main Independent Variables (IV) is the instructional method, which had two levels: (1) CSs within an inquiry-based learning environment (experimental group) (2) learning through traditional face-to-face instructions (control group). The Dependent Variable (DV) in this design was students' performance on two levels, namely, conceptual and procedural understanding. A NSLMAT pretest was used to assess the UAE eleventh graders students when learning NSLOM within the context of scientific inquiry instruction before the implementation of the intervention. Then the same test was administered after the intervention as a posttest to compare differences in performance mean scores between students in the treatment group, who learned by CSs within an inquiry-based learning environment, and their counterparts in the control group, who learned NSLOM by the use of face-to-face instruction.

The same pretest post-test intervention quasi-experiment also used to assess the effects of using CSs within an inquiry-based learning environment on students' attitudes towards physics. This survey design meant to determine the effects of the teaching and learning medium as the primary independent variable on the dependent variables, attitudes towards physics.

3.5 Population and Sampling

In this study, the target population consisted of secondary school students aged 16-18 years (grade 11) in a major city in the UAE. All schools are using the same curriculum in teaching physics. In this study, two schools were selected as purposeful convenience sampling (Etikan, Musa & Alkassim, 2016), one for boys (taught by male teachers) and the other for girls (taught by female teachers). The criteria used to select these schools included: The grade 11 students in these schools were familiar with the content of the PhET simulation, the students shared similar demographic characteristics such as age, gender, and ethnicity, and both schools are located in one emirate in the UAE; Almost 90% of students are Emirati; 10% of the students are Arab students. The socio-economic status of mostly from middle class. All classes have one lesson time and one number of physics lessons. Both schools equipped each student with an individual laptop, as well as print text in the teaching of physics. Physics lessons are taught by qualified teachers who are fluent in English. Also, the two groups are in the advanced stream in the academic year of 2019-2020.

90 students participated in this study: 50 males and 40 females. Table 3 summarizes the characteristics of the study groups participants.

Table 3: Study Groups

Groups	Gender	Number (N)	Total
CGs	Female	20	45
	Male	25	
EGs	Female	20	45
	Male	25	

The sample of classes was obtained by means of the random sampling technique. The study included four classes of students; In the girl school, there were three grade 11 classes; one of these three classes have been randomly allocated to face to face instruction (Control Group [CG]), while another class was assigned to the CSs within an inquiry-based learning environment treatment (Experimental Group [EG]). The second school for boys has four grade 11 classes; one was chosen randomly to be a CG, whereas another class chosen to be the EG. Pre-treatment testing of both instruments (NSLMAT and TOSRA subscales) were performed before treatment to determine a student’s prior knowledge of NSLOM and their level of attitudes toward physics. The EGs were treated with the PhET simulations. After treatment, all students receive the same test and survey as a posttest.

3.6 Research Instruments

The effect of experimental treatment is evaluated using two instruments: NSLMAT was developed to assess a student's understanding of conceptual and procedural knowledge. The second instrument focuses on assessing students' attitudes toward science based on three scales of TOSRA, in particular, attitudes to scientific inquiry, enjoyment of science lessons, and a career interest in science. In this study, two instruments were used to answer the research questions.

3.6.1 Newton's Second Law of Motion Achievement Test (NSLMAT)

The test included two-tire multiple choice questions that assess students' performance in NSLOM at both conceptual and procedural levels. A test was developed in such a way to be suitable and comprehensible for the students.

According to Biggs (1996), multiple-choice test critics claim that it only tests factual knowledge, and not conceptual understanding. As, it focuses on low order thinking skills. One possible solution is to use a two-tier Multiple Choice Question (MCQ). According to Mann and Treagust (2000), this question aims to help students and teachers understand students' struggles so that they can correct any misunderstandings or difficult areas and deepen their understanding of the topic.

The two-tier MCQ format is similar to the traditional MCQ format, but as the name suggests, it contains a second tier of questions related to the main question. The first tier of the question usually relates to a statement of knowledge. However, the second level of the question is suitable for testing students' ability to learn and not only remember, but also requires a higher level of thinking (Williams, 2006).

The two-tier MCQs was developed following the procedure used by previous researchers in this field, namely, Treagust (1985, 1998). The development process was divided into three stages and ten steps, see Figure 13. In the first stage, the scope of the research content is defined. The second stage involves identifying student ideas when using multi-level notation (based on the responses of a group of 60 students) to describe and explain NSLOM. Stage 3 includes several steps in designing the test project and reviewing the final version of the two- tier MCQs diagnostic tool.

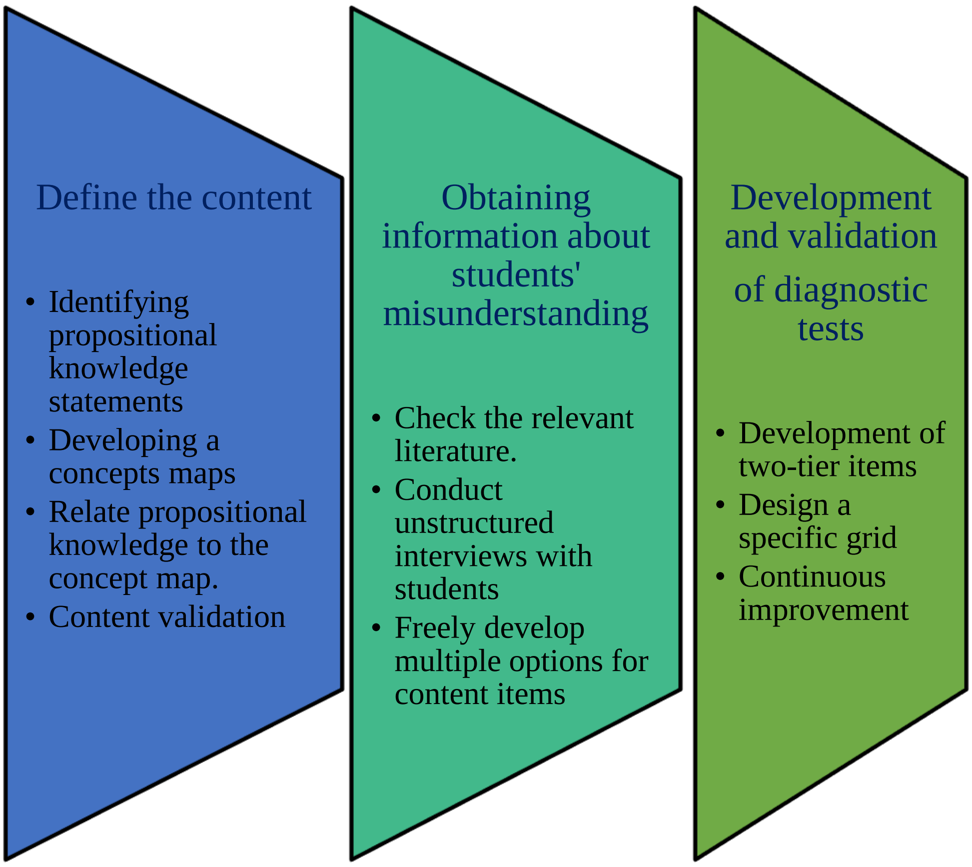

Figure 13: Scheme of the Development Process of a Two-Tier Diagnostic Test Based on Treagust (1988)

3.6.1.1 Phase One: Define the Content Area of NSLOM

The first stage of MCQ development involves the design and development of a two- tier MCQ. These questions were specially developed for 11th- grade students at NSLOM in the UAE. NSLOM was chosen after an extensive literature review, reporting that both local and international students have learning difficulties and misunderstandings on these specific topics (Antwi, 2013). In this stage, first, the content boundaries and learning goals were determined according to the purpose of the study. The following educational objectives related to the field of study are recorded:

- Students can explain the types of Forces.
- Students can distinguish between Weight and Mass.
- Students can calculate net force.
- Students can determine and calculate the Normal Force.
- Students can explain Free-Body Diagrams.
- Students can explain Newton's First Law.
- Students can explain Newton's Second Law.
- Students can explain Newton's Third Law.
- Students can interpret useful ropes and Pulleys.
- Students can determine and calculate problems related to Two Books Connected on a Table.
- Students can interpret effective Kinetic Friction.
- Students can interpret effective Static Friction.
- Students can determine and calculate problems related to Two Blocks Connected by a Rope—with Friction.

Then ten concept maps were drawn for each topic, and one for each concept included in this study. It also examines the relationship between theoretical knowledge and concept maps. All concept maps were validated by six physics teachers who also participated in teaching physics for the 11th grade. Test development is based on the final version of the proposed knowledge statement and concept map.

3.6.1.2 Phase Two: Identifying Students' Conceptions when Describing and Explaining NSLOM

A significant feature of this stage involved defining student conceptions when describing and explaining NSLOM. In addition to a review of the research literature (Antwi, 2013), written answers (including semi-structured and freely answered questions) were used in 17 exercises to identify students' ideas (see Appendix A). The researcher conducted these exercises with 60 students in grade 11 and designed responses for grade 11 physics students' distracters factors based on literature reviews and the reasons presented in the interviews. Distracters factors include alternative conceptions, and they were created from this list. These alternative conceptions were then used to create a two-tier MCQs diagnostic test, where the questions included an introduction and four alternatives, one of which is correct answer. These questions were then evaluated by a group of physics teachers and supervisors of the physics department at a major district (zone) in Abu Dhabi.

The test was then prepared in its preliminary form, as it included 30 items. It was presented to a group of physics teachers and supervisors. The appropriate adjustments were made based on their opinions and observations. The following observations listed incorporate:

1. Reduce the number of test items to be less than 30.

2. Delete some items which required a long time to answer, as well as exclude items which their level exceeded the UAE 11th grade students.

3. Delete some items that require advanced mathematical skills.

4. Some educators also referred to the amendment of the wording of some paragraphs and alternatives to make them clearer.

Following this initial evaluation, questions were asked and considered appropriate for the study. The revised version of the test is shown in Appendix (B).

3.6.1.3 Phase 3: Development and Validation of NSLMAT

In this stage, and based on literature review and interviews, the two-tier diagnostic tests have been developed, where the first tier is a traditional multiple-choice step, and the second tier is a possible reason to give a specific answer to the first tier (Haladyna & Rodriguez, 2013). The second level contains four answers, one of which is the expected answer. Distractors included high frequencies of wrong reasons and scientifically unacceptable conceptions held by grade 11 physics students.

3.6.1.4 NSLMAT Validation

With regard to the validity of the content, the test was presented to a group of educators, consisting of 10 experts specialized in physics and physics education, consisting of inspectors and high school teachers, as well as to a group of university professors, (see Appendix C). The experts were asked to ensure that the test was content valid in terms of formulation of phrases and its language, scientific accuracy, comprehensiveness of the measuring tool, and its suitability for the goal for which it was developed. Additionally, the experts were asked to judge the clarity of the paragraphs, and their suitability for the participants of the study, see Appendix (B). The researcher obtained some opinions and suggestions from the judges, see Appendix (E).

In the light of these observation received, the researcher modified the initial form by rewriting some of the phrases, other phrases were excluded. Besides, the symbols rewritten in ways that are similar to one presented in the book published in the UAE for advanced 11th graders in 2019, and after all the changes made, the final image of the scale consisting of 16 questions can be found in Appendix (D). The questions include an introduction and four alternatives, one of which is correct. Therefore, students must choose an answer from symbolic options A, B, C, and D. While the justification for the answer choices from one of the options numbers 1, 2, 3, and 4. The focus of the test items was on: (1) conceptual understanding, (2) and procedural understanding. Table 4 shows the distributions of items on both conceptual and procedural domains.

Table 4: Distribution of Items in the Final Version of NSLMAT

Knowledge domains	Items
Procedural knowledge	Q2, Q4, Q6, Q7, Q9, Q10, Q11, and Q13
Conceptual Knowledge	Q1, Q3, Q5, Q8, Q12, Q14, Q15, and Q16

3.6.1.5 NSLMAT Reliability

Split-half reliability was calculated to assess the internal consistency of this NSLMAT by comparing the results of the odd numbers with the results from the even numbers as illustrated in Tables 5 and 6, respectively.

Table 5: Reliability Statistics for NSLMAT Exam

Cronbach's Alpha	Part 1	Value	0.741
		N of Items	16[a]
	Part 2	Value	0.844
		N of Items	16[b]
	Total N of Items		32
Correlation Between Forms			0.611
Spearman-Brown Coefficient	Equal Length		0.759
	Unequal Length		0.759
Guttman Split-Half Coefficient			0.758

Table 6: Scale Statistics of NALMAT

	Mean	Variance	Std. Deviation	N of Items
Part 1	13.73	3.857	1.964	15[a]
Part 2	12.03	4.309	2.076	13[b]
Both Parts	25.77	13.151	3.626	28

Because the reliability and the variance of the two parts were not equals, the researcher was adopted Guttman split-half reliability coefficient, and it was found 0.758. This means that the scores are acceptable in terms of reliability since it was between -1 and 1.

The internal consistency validity of the test for conceptual and procedural domains, as well as the test items, were also calculated as shown in the Tables 7, 8, and 9.

It is evident from Table 7 and Table 8 that most of the test items in its conceptual and procedural dimensions are associated with the overall score, with a statistically significant correlation at the level of significance 0.01, except for questions 4 and 12, and this indicates that the internal consistency characterizes the test.

Table 7: Correlation Coefficients Between Each Domain with Overall Score of Test

Knowledge domain	Coefficient of correlation with the total score		Significance level
Conceptual	Question	0.759**	0.01
	Answer	0.561**	0.01
	Total	0.796**	0.01
Procedural	Question	0.952**	0.01
	Answer	0.896**	0.01
	Total	0.944**	0.01

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8: Correlation Coefficients Between Questions and Overall Score of the Conceptual Domain

Question number		Coefficient of correlation	Significance level
2	Question	0.829**	0.01
	Answer	0.788	
4	Question	0.103	Not significant
	Answer	0.463	
6	Question	0.793**	0.01
	Answer	0.703	
7	Question	0.829**	0.01
	Answer	0.834	
9	Question	0.712**	0.01
	Answer	0.827	
10	Question	0.671**	0.01
	Answer	0.745	
11	Question	0.955**	0.01
	Answer	0.885	
13	Question	0.612**	0.01
	Answer	0.755	

Table 9: Correlation Coefficients Between Questions and Overall Score of the Procedural Domain

Question number		Coefficient of correlation	Significance level
1	Question	0.840**	0.01
	Answer	0.787	
3	Question	0.694**	0.01
	Answer	0.592	
5	Question	0.885**	0.01
	Answer	0.649	
8	Question	0.961**	0.01
	Answer	0.880	
12	Question	0.252	Not significant
	Answer	0.212	
14	Question	0.813**	0.01
	Answer	0.787	
15	Question	0.759**	0.01
	Answer	0.659	
16	Question	0.955**	0.01
	Answer	0.788	

**. Correlation is significant at the 0.01 level (2-tailed).

3.6.2 Survey of Physics Attitudes (TOSRA)

Test of Science Related Attitudes (TOSRA) was selected for use in this study because of its proven validity and reliability, TOSRA does not combine conceptually-different constructs to form one scale, and its scales has demonstrated unidimensional and independence in past studies through factor analysis (Fraser & Lee, 2015). One of the advantages of TOSRA is that it provides a profile of scores for many conceptually different attitudes, and although the results are difficult to interpret on an absolute scale, they can offer a comparative interpretation (Fraser & Lee, 2015). TOSRA was chosen for this study because it was shown to be valid and reliable in different contexts (Smist, Archambault & Owens, 1994; Fraser & Lee, 2015).

As Fraser stated that, “TORSA is likely to be most useful for examining the performance of groups or classes of students” (Frasier, 1981, p. 1). Moreover, Fraser (1981) designed TOSRA and subdivided into component subscales to measure seven different science related attitudes among secondary school students. These subscales include: (1) Leisure Interest in Science, (2) Attitude toward Scientific Inquiry, (3) Adoption of Scientific Attitudes, (4) Normality of Scientists, (5) Enjoyment of Science Lessons, (6) Social Implications of Science and (7) Career Interest in Science. Each subscale contains ten items, while the total instrument contains 70 items. Each subscale comprises 10 statements to which students must react using a 5-point Likert-type scale that ranges from Strongly agree (5) to Strongly disagree (1). Five of these items are worded positively and five negatively to avoid stereotyped responses. According to Unfried, Faber, Stanhope and Wiebe (2015) TOSRA has internal consistency ranging from 0.64 to 0.93 for its subscales, and acceptable test–retest reliability.

The researcher was granted the permission by the authors of TOSRA to use the survey on May 24th, 2020, as shown Appendix F.

Three scales that relevance to the purpose of the study were chosen from TOSRA and adopted under the supervision of the researcher’s advisor: Attitude toward Scientific Inquiry (ASI) (10 items), Enjoyment of Science Lessons (ESL) (10 items) and Career Interest in Science (CIS) (10items) (see Appendix G). Table 10 represents the distribution of items for the three subscales. The TOSRA items involve coordinating a response that requires students to express their level of agreement with each statement on a 5-point scale, including a Strongly (high) degree of Agreement (SA), Agree (A), Not sure (N), Disagree (D), and Strongly Disagree (SD), to assess students' retrospective pretest levels of attitudes toward physics, as well as to assess their posttest levels of attitudes toward physics. Within each scale, five are positive items and five are negative, with respect to their position on science and science related issues. Scoring includes response to SA, A, N, D and SD designation 5, 4, 3, 2, 1, the items that have been identified as Positive (+) 1, 2, 3, 4 and 5 in response to SA, A, N, D, SD. As shown in Table 10 (Fraser, 1981), the items marked as negative (-) scores 1, 2, 3, 4 and 5 for SA, A, and N answers and D and SD, respectively. Record missing or invalid answers 3. The questionnaire used in this study is found in Appendix G. The results of the pretest and posttest scores are the mean of the elements that make up the scale.

Table 10: Distribution and Scoring of Items According to TOSRA Subscale

Subscale	Distribution of Items
ASI	1, 4(-), 7, 10(-), 13, 16(-), 19, 22(-), 25, 28(-)
ESL	2, 5(-), 8, 11(-), 14, 17(-), 20, 23(-), 26, 29(-)
CIS	3(-), 6, 9(-), 12, 15(-), 18, 21(-), 24, 27(-), 30

For negative items (-), SA, A, NS, D, and SD are scored 1, 2, 3, 4, 5, respectively.

After preparing the scale, it was reviewed and verified by a jury specialized in the fields of education, physics, and research. The experts provided comments and suggestions to the researcher. For example, some teachers recommended reducing the textual density because they believed that they needed a long time to answer, and their level exceeded the UAE 11th grade students. Another example, some educators also referred to the amendment of the wording of some paragraphs and alternatives to make them clearer. The researcher also asked some students in the test sample to read the scale to make sure they fully understood all the meanings. In the preparation of the final version of the scale, most of the suggestions of experts and students were taken into consideration (see Appendix G). After validating the scale, the researcher assessed the reliability of the constructs of the scale using Cronbach's Alpha coefficient, and the results are presented in Table 11.

Table 11: Reliability Coefficients for Survey of TOSRA Subscale

Scale	N of Items	Mean	Std. Deviation	Cronbach's Alpha (α)
ASI	10	22.12	5.992	0.720
ESL	10	22.93	6.647	0.724
CIS	10	23.60	6.777	0.759
All the Three Scales	30			0.90

As illustrated in Table 11, carrying out Cronbach's alpha coefficient test showed the scale reached acceptable reliability, $\alpha = 0.90$. The reliabilities that obtained was associated with Fraser's (1981). Cronbach's alpha coefficient value for "ASI" was the lowest, $\alpha = 0.720$. On the other hand, Cronbach's alpha coefficient value for "CIS" was the highest, $\alpha = 0.759$. Therefore, the scores of the three subscales were found reliable as their mean scores ranged between 0 and 1. In fact, the coefficient alpha of 0.90 suggests that this TOSRA subscales as standalone instrument was reasonably reliable for respondents in this study and its internal consistency could be trusted.

3.7 Pilot Study

A pilot study was included in the research design prior to data collection to determine the feasibility and application of the research instruments (In, 2017). The pilot study focused on the wording used in pre- and posttests to ensure those study participants correctly understood and responded the test items, as well as the relevance of the questions and applicability of the content (In, 2017). The pilot study did not include any treatment or control group. Instead, the pilot study focuses on determining the effectiveness of test instruments (In, 2017).

NSLMAT was given to eleventh graders from the same schools. They were randomly assigned as pilot samples, and did not participate in the experiment, and provided feedback on their understanding of questions related to NSLOM. Their responses indicate that they understand these questions. However, four items of the NSLMAT were rewritten to simplifies their content. Additionally, the results of the collected data were found to be reliable in the Alpha Cronbach coefficient ($\alpha = 0.84$).

Likewise, the TOSRA subscale used the same procedure. Chose the same students as the test sample. Next, use the students' comments to review the questionnaire to ensure that all items are clear and correct. In the TOSRA subscale survey, the reliability of the pilot sample was found, Cronbach's alpha coefficient ($\alpha = 0.94$) for the subscale survey of TOSRA.

3.8 Data Collection Procedures

After the official approval from ADEK in the UAE obtained, the study took place on October 30, 2019 as shown in Appendix I. Two eleventh grade classes were chosen in each school to participate in the study. Then the classes are randomly assigned to the EG or the CG. The simulations used in this study were a PhET simulations developed by the University of Colorado. NSLOM simulations include the forces exerted on objects, acceleration, distances and masses, and friction that is invisible to the naked eye. However, the relationship between these variables can be seen in the PhET simulations. Since the student controls these variables, the simulation is interactive, and the resulting effects can then be recorded. The existing worksheets from the PhET website were adapted and used to test the students' knowledge and understanding of the NSLOM, see Appendix J. These worksheets describe how to use and access the PhET simulations and are prepared to answer questions while running the simulations. The worksheets depend mainly on the content, and the student must fill in the values that change as the student deals with various variables in the simulations. The worksheets are identified by the students themselves and discussed by the teacher and students. Additionally, the worksheets were also used to find out if students can use their knowledge of NSLOM, as well as they contained summarized types of questions where the student had to calculate certain values by applying their knowledge.

Schools sent permission forms on October 30th, 2019 with all students in these classes to approve and allow their participation in the study in the same day (see Appendixes K). The consent form that was sent to parents (see Appendixes L) provided them about the purpose of the research and some details that the students will study, and they will be targeted to respond to pretest and posttest to measure the NSLMAT, and a survey to measure students' attitudes toward physics. The letter included that participating in this study is voluntarily, and the data will be confidential and anonymous, and used only for research purposes. Then, a meeting was held with participating teachers to train for the experiment. The researcher asked their permission to participate and informed them that their participation is voluntary, and they have the right to withdraw at any time. They showed enthusiasm and support. The researcher conducted the training, including instructions for conducting the pretest and posttest, as well as how to teach this topic through CSs within an inquiry-based learning environment. Provide detailed lesson plans (Appendix M) for teachers from all instructional groups to carry out learning activities.

Data collection takes about one month, and the data was collected in different stages, as shown in Figure 14. Firstly, on November 3, 2019, all students of the EGs and the CGs took part in a pretest and survey, it takes about 45 minutes and 20 minutes respectively.

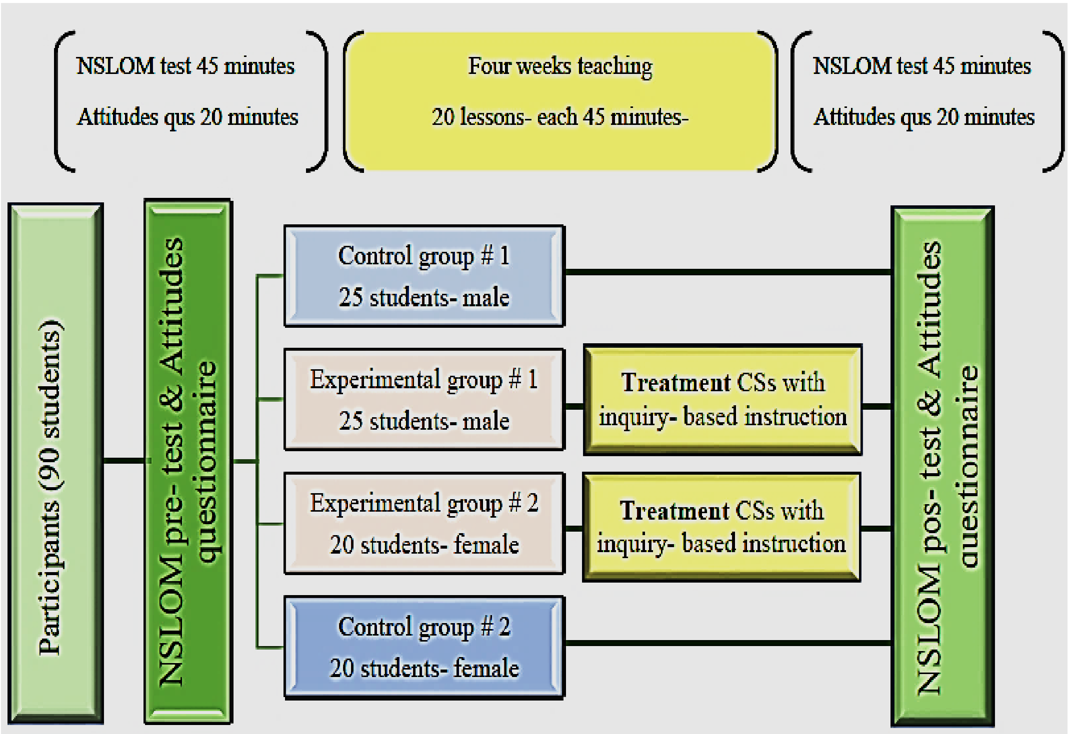

Figure14: Experimental Procedure of the Study

The purpose of the survey was explained to the students, they were informed that there was no right or wrong answer, and they were assured that the results would be kept confidential, and their participation is as voluntarily basis. Additionally, their participation in the test is voluntarily and the result will not affect their grades. Secondly, teachers started teaching the unit from November 4 to December 4, 2019. The students participating in this study had already received approximately 20 lessons of instruction and had also completed 3-lessons labs covering various physics concepts in NSLOM. The NSLOM activities sessions were administered in three separate sessions in different week, with 45-60 minutes for each session. The control group conducted experiments on NSLOM in a traditional lab experiments, and the experimental group conducted similar experiments using CSs within an inquiry-based learning environment. In traditional and CGs the students engaged in a hands-on activity on 'NSLOM'. However, the students in EGs were expected to discover mathematical relationships of NSLOM and explain phenomena in the NSLOM simulation. Thirdly, the students took the same test that was conducted on December 5, 2019 and received the same survey. The answers to the exam and the survey took approximately 45 minutes and 20 minutes, respectively. The NSLMAT test and the TOSRA subscale survey were conducted in an environment of integrity to prevent any cheating or support (Meyers, Gamst & Guarino, 2016; Creswell & Creswell, 2017), and the researcher explained to the students to work independently. Finally, after the process was completed, a feedback report on the results for the entire groups were submitted to each school, without comparing schools or identifying students in order to maintain confidentiality.

3.9 Research Questions

The main objective of the study is to examine the impact of CSs within an inquiry-based learning environment on grade 11 UAE students' learning of Newton's second law of motion and attitude toward physics. To achieve this goal, seven research questions were proposed.

1- What impact does CSs have on student performance in Newton's second law of motion within an inquiry context?

2- Are there any statistically significant differences in performance in Newton's second law of motion between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions?

3- Is there any statistically significant difference in performance regarding conceptual understanding in Newton's second law of motion, between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions?

4- Is there any statistically significant difference in learning achievement regarding procedural understanding in Newton's second law of motion, between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions?

5- What impact do computer simulations have on student attitudes towards physics when taught within an inquiry context?

6- Is there any statistically significant difference in attitudes towards physics between students who studied through using CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions?

7- What is the interaction, if any, between students' gender and the use of CSs in teaching NSLOM within the context of scientific inquiry on performance and attitudes toward physics?

To answer these seven research questions, two instruments were used: (1) Newton's Second Law of Motion Achievement Test (NSLMAT) was administered twice to the students to assess physics performance in conceptual and procedural domains before and after the experiment, and (2) TOSRA subscale was administered twice to determine whether students' attitudes toward physics were developed/changed.

For the first research question, which focused on determining the impact of CSs on student performance at NSLOM within an inquiry context, data was collected using a NSLMAT pre-test-post-test quasi-experimental instrument. Similarly, an analysis of students' responses to items associated with NSLMAT was conducted to collect data on students' performance reported in both groups. To study the second, third, and fourth research questions (i.e., for the second research question, which focused on determining if there was a difference in students' performance in NSLMAT between, students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions. For the third and fourth research question, which focused on comparing student performance regarding conceptual and procedural understanding in NSLOM, between students who studied through CSs within an inquiry-based learning environment and students who studied through traditional face-to-face instructions). The results obtained from NSLMAT were also used to compare between the two groups.

For the fifth and sixth research questions, which focused on determining the impact of CSs on student attitudes towards physics when taught within an inquiry context, and comparing students' attitudes towards physics, between students who studied through CSs within an inquiry based learning environment and students who studied through traditional face-to-face instructions, data were explored utilizing the survey of TOSRA subscale to collect data about student attitudes towards physics and were also used to compare between the two groups.

Finally, in the seventh research question, which focused on determining whether there is an interaction between gender and the use of CSs that affected students' performance and attitudes toward physics, data obtained from analysis of the results of the NSLMAT and the TOSRA subscale questionnaire were used.

3.10 Data Analysis

Data analysis is one of the most important elements in the quantitative method; Therefore, the researcher reviewed previous studies that used similar instruments, and consulted an expert in the field of statistics to select the most appropriate analysis statistics to analyze the data.

Data from NSLMAT and TOSRA were analyzed using the Statistical Package for the Social Sciences (SPSS 25). Means (M) and Standard Deviations (SD) were calculated. The mean gain score and standard deviation were used to calculate Cohen's d effect sizes. According to Cohen (1992), independent means and standard deviations can be used to calculate effect sizes, d = 0.20 is a small effect size, d = 0.50 is medium effect size, and d = 0.80 is a large effect size.

In this study, the main assumptions were tested to ensure the accuracy and correct interpretation of the results. Since the number of cases is less than 100 (N = 90), the Shapiro-Wilk statistic results should be considered to test the normal distribution of the data, and for testing the homogeneity of variances, Leven’s test was calculated for the assumptions that the variances of the two groups are equal. It was found that the assumptions have not been violated. Similarly, it was found that the assumptions have not been violated for the two genders.

To answer research question one, three kinds of analysis were used. Firstly, mean scores and standard deviations were used to compare the differences between conceptual and procedural understanding scores of the EGs and CGs before and after the treatment. Secondly, the independent sample t-test was used to determine the initial comparison of the two groups before the intervention. Finally, the pre and posttest results for the two-tier test were analyzed, and the Percentage (%) of correct answers that students get through this test is compared.

To evaluate the effectiveness of the intervention, Hake’s normalized gain was calculated. Hake’s (1998) introduced the normalized gain <g> was used to measure the effectiveness of CSs within an inquiry-based learning environment in promoting conceptual and procedural understanding. According to Hake’s (1998) defined the “average normalized gain <g> for CSs within an inquiry-based learning environment as the ratio of the actual average gain to the maximum possible average gain”.

$$g = \frac{Post\ test\ \% - Pre\ test\%}{100\% - Pre\ test}$$

To answer research question two, descriptive statistics of mean scores and standard deviation were used to compare NSLMAT scores differences for both the EGs and the CGs and the two genders. Mean gain scores and standard deviations were also used to calculate Cohen's *d* effect sizes. One-way Analysis of Variance (ANOVA) was used to determine whether there were any statistically significant differences between the two groups before the intervention. It was found that pretest scores at $p < 0.05$ were not significantly. Similarly, an independent-samples t-test was conducted to check whether there was a significant difference between the mean of male and female students. A paired t-test was done to determine whether there was any statistically significant difference between the pre- and posttest scores in NSLMAT for each of the two groups.

To answer research question three, conceptual understanding scores were stratified by gender. Mean scores and standard deviations were used to compare conceptual understanding differences for both the EGs and CGs. Mean gain scores and standard deviations were also used to calculate Cohen's d effect sizes. One-way ANOVA is used to determine whether there were any statistically significant differences between the two groups and genders before the intervention. A paired t-test was done to determine whether there was any statistically significant difference between the pre- and posttest scores in NSLMAT for each of the two groups and genders. A similar analysis was conducted for the treatment group in the fourth research question.

To answer research question five, mean scores and standard deviations were used to compare ASI, ESL, CIS scores differences between the EGs and CGs before and after the treatment. An independent-samples t-test was conducted to check whether there was a significant difference between the two groups, as well as genders.

To answer research question six, Multivariate Analysis of Variance (MANOVA) was undertaken using three credit evaluation orientations; ASI, ESL, and CIS as dependent variables and instruction method as an independent variable with two multiple levels: CSs within an inquiry-based learning environment and face-to-face instruction. Before starting the analysis, it was essential to check the data for the MANOVA assumptions. Meyers, Gamst and Guarino (2016) identified several assumptions to use MANOVA. First, the design of this study ensures that the participants are independent of one another. Moreover, the ASI, ESL, and CIS measurement types are continuous. Additionally, the data are consistent with the assumption of an appropriate sample size.

As for normality condition, two tests of normality were done, and since the number of cases is above 50, the result of Shapiro-Wilk was to be considered for testing the normal distribution of data. This test showed that the data is distributed normally since the value of the test is more significant than 0.05 for each variable.

To check whether the homogeneity of variance and covariance assumption was met, Box's Test of Equality of Covariance Matrices test was run. The analysis did not yield significant results at $p > 0.05$ (Box's M = 40.542, $p = 0.004 < 0.05$), indicating that the variance-covariance matrices of the dependent variable between treatment level and gender are not equal and the homogeneity assumption was tenable.

Therefore, there was no reason to believe that any variances between the three subscales groups differed significantly.

Bartlett's Test of Sphericity is statistically significant (approximate chi-square $\chi^2 = 219.784$, $p = 0.000 < 0.001$). Indicating sufficient correlation between the dependent measures to proceed with the analysis.

Finally, concerning checking for outliers, data were split into two halves, and the linear regression Mahalanobis distance test was done to find out the critical values of the data. Mahalanobis critical value was less than the critical value identified by χ^2. Thus, there were no extreme or outliers in the data. Thus, data met the assumptions of having no outliers.

3.11 Ethical Considerations

Once the official approval from the College of Education at United Arab Emirates University (UAEU) obtained on October 6, 2019, as shown in Appendix N, permission was granted to conduct the research by ADEK in the UAE who is the employer of the researcher (see Appendix I). Additionally, the researcher applied for ethical clearance to the Ethics Review Committee of the UAEU. The Research Ethics Sub-Committee for Social Sciences granted permission in writing, and this can be found in Appendix O.

Contact the school’s principals and obtain permission. The teachers involved in the study were very energetic and willing to participate in the study from the beginning. A brief account of the study was given to them and discussed their role in research, and the different activities were discussed. The process was explained by indicating that this research could be valuable not only to the students at the school but also to the students and teachers in the province, the data was used only for the research purposes and has been kept secret, and the collected data in this study would not be revealed to anybody that might cause any physical, social or psychological harm to the students.

Organized a meeting with students to explain the basic principles of this study. This was scheduled as students in the study have the right to be informed about the aims, purposes and the consequences, and the likely publication of the findings. Additionally, the students reported that the school's names, the students' names, nationalities, ethnicity, religions, and backgrounds would not be revealed to the public, to prevent any threat that may cause any harm. Moreover, all students informed that their participation was voluntary, and no one would be harmed by participation in this study. They were notified that they could withdraw from the study at any time, as shown in the various consent forms (see Appendixes K and L). These forms have been completed, signed, and collected by the parties concerned.

3.12 Conclusion

This chapter was intended to provide detailed description and explanations of the research methods adopted in the light of its objectives. It started with stating that the main purpose of the study to verify whether the purposeful use of CSs within an inquiry-based learning environment may influence the learning of NSLOM and the attitudes towards physics of eleventh- grade students. The design of the study was explained followed by the research settings and context. A detailed information about the materials, resources, and test were provided. Additionally, this chapter described the population, sampling, and participants. The instruments used and its validity and reliability, the research questions of the study, and how the data was collected and analyzed, was discussed. This chapter also outlined in detail the ethical and legal procedures followed in this research to prevent any privacy invasion and any type of harm to participants. Finally, the next chapter would display the results and findings of the study.

Chapter 4: Findings

4.1 Chapter Overview

The purpose of this study was to investigate the impact of CSs on the UAE eleventh grade students' learning of Newton's second law of motion within the context of scientific inquiry instruction. It also aimed at assessing the impact of CSs on students' attitudes level towards physics while learning NSLOM under CSs within an inquiry-based learning environment. The outcomes of using CSs within an inquiry-based learning environment were compared to a face-to-face instruction. This study also explored whether or not will be a gender differences when learning about NSLOM using CSs within an inquiry-based learning environment.

To answer the research questions, two instruments were used: (1) NSLMAT test with 16 items was used to measure students' conceptual and procedural understanding of NSLOM topics. Both groups took a pretest before teaching the NSLOM topic, and after completing 20 lessons using CSs within an inquiry-based learning environment or face-to-face instruction, the same test was given as posttest. (2) The TOSRA scale attitude survey towards physics, to compare the attitudes levels of the two groups on three scales namely, Attitudes to Scientific Inquiry (ASI), Attitudes to Career Interest in Science (CIS) and Enjoyment of Science Lessons (ESL).

The study used various statistical analyses to find out the answers for each research question. Descriptive statistics (Mean and Standard Deviation) were used to analyze the data used in each group. An independent sample t-test was used to compare the NSLMAT mean between the two groups. One-way ANOVA is used to determine if there were statistically significant differences between the groups before the intervention. Additionally, a paired sample t-test was used to compare the NSLMAT mean and students' attitudes in each group.

Moreover, MANOVA analysis was performed to identify any significant differences in the TOSRA scale in (1) ASI; (2) ESL; and (3) CIS among male and female students to different groups; EGs and CGs. Univariate analysis of variance (ANOVA) was used to study further the significant results obtained from the MANOVA analysis to check whether there were differences between the different response categories, and whether they were significant. Finally, a post-hoc test was then employed to examine paired mean comparisons resulting from the variance analysis. Below are the results organized by research question.

4.2 Results of Research Question One

What impact do computer simulations have on student performance in Newton's second law of motion within an inquiry context?

The NSLMAT includes two types of assessment questions, namely conceptual and procedural questions, that are designed to assess students' learning outcomes. Conceptual questions were used to assess students' understanding of NSLOM (i.e., concepts and principles), and procedural questions were used to assess students' performance at procedural level skills.

NSLMAT mean scores and standard deviations for the participant were calculated using SPSS 25. In this regard, an independent sample t-test was used to determine whether the two groups were initially comparable before the intervention.

The results of an independent sample t-test reveal that pretest scores at the $p < 0.05$ level of the two groups were not significantly statistically different. For the EGs (M = 18.00, SD = 3.24) and the CGs (M = 17.51, SD = 2.84) conditions; t (88) = 0.093, p = 0.927. This means that students in the two groups are comparable, as illustrated in Table 12.

Table 12: An Independent-Samples t-Test of NSLMAT of the Two Groups

Groups	N	Mean	SD	t	df	Sig.
Pre- CGs	45	17.51	2.84			
Pre- EGs	45	18.00	3.24	0.093	88	0.927

Table 13 shows the results of the students' performance scores before and after the treatment (simulations) for each group independently. Mean differences suggest that the EGs performed higher in all the tests, including before receiving any type of treatment. The EGs scored 0.48 points higher than the CGs on the pretest and 5.20 points higher on posttest (see Table 13).

Table 13: Performance Results of NSLMAT Stratified by Group

	EGs (*N* = 45)			CGs (*N* = 45)		
	Mean	Std. Deviation	Std. Error of Mean	Mean	Std. Deviation	Std. Error of Mean
Pretest	18.00	3.24	0.48	17.51	2.84	0.42
Posttest	25.51	3.62	0.54	20.31	4.09	0.61

The normalized gain factor from the posttest to that of the pretest was computed using the formula:

$$g = \frac{Post\ test\ \% - Pre\ test\%}{100\% - Pre\ test}$$

Where posttest percentage is the students' score after the posttest out of 100%, and pretest percentage is the students score after the pretest out of 100%. Hake (1998) divided the average gain values as; high gain scores if ($g \geq 0.7$) medium gain scores if ($0.3 \leq g < 0.7$) and low gain if ($g < 0.3$).

As can be seen from Table 14, the results show that, EGs which used the CSs within an inquiry-based learning environment to learn the concepts of NSLOM had medium gain scores, while the CGs who was treated the same topic by a face-to-face as an instructional strategy had scored low gain score ranges.

Table 14: Mean Gain of the Two Groups

Groups	N	Mean Pretest (%)	Mean Post-test (%)	Mean difference (%)	Gain (g)
CGs	45	56	63	7	0.16
EGs	45	56	80	24	0.55

The pre and posttest results were analyzed for the first tier (the questions). Figure 15 shows the percentage of students' correct answers obtained from this test. The values varied between 40% and 73% for the pretest and varied between 56% and 88% for the post test.

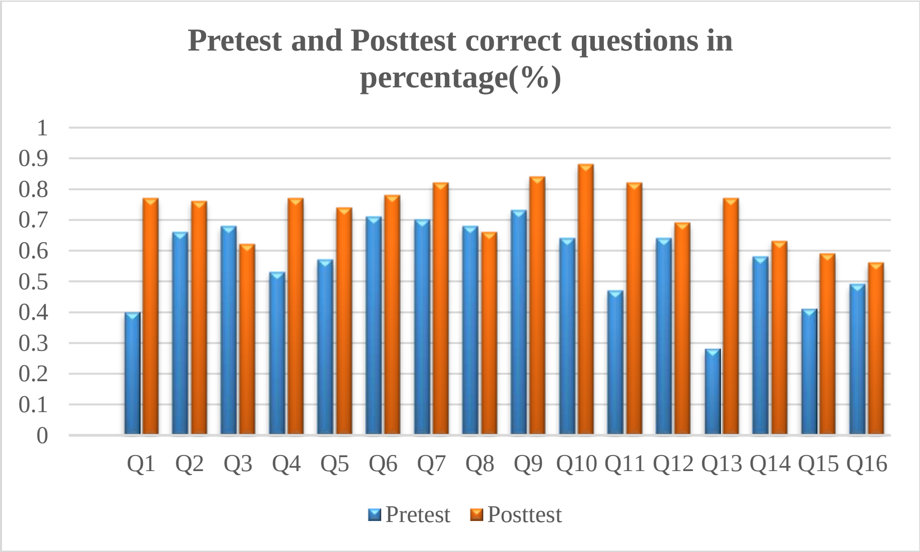

Figure 15: Results of the Pretest and Posttest for the First Tier

Likewise, the results of the pretest and posttest were analyzed for the second tier (answers). Figure 16 shows the percentage of students' correct answers obtained from this test. The values varied between 20% and 69% for the pretest and varied between 52% and 84% for the posttest.

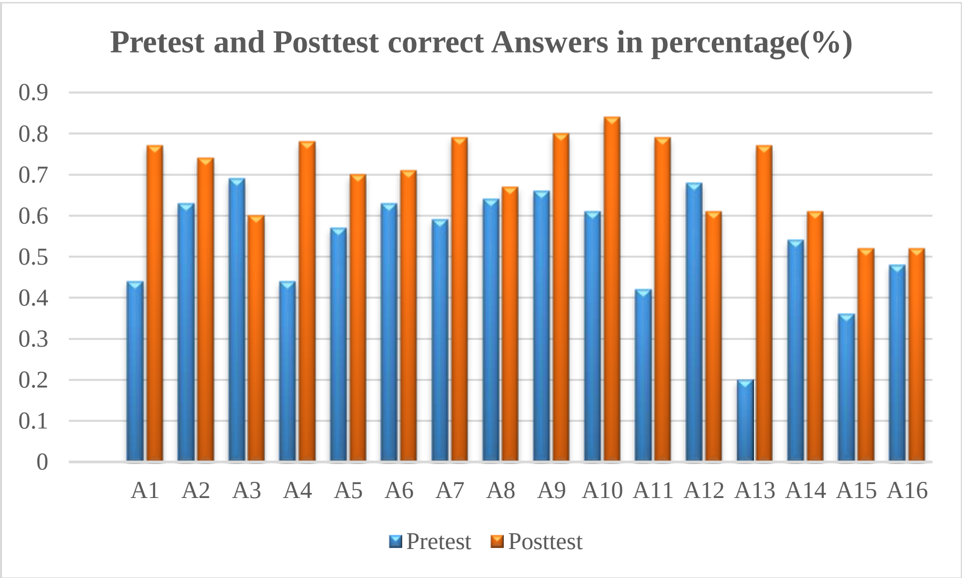

Figure 16: Results of the Pretest and Posttest for the Second Tier

Table 15 represent the results from the two-tire test. This analysis revealed that for the pretest, 57% of the students who had chosen the correct answer gave a false or no explanation for their choice, in this case, only 54% of the students showed a correct understanding of NSLOM by choosing the correct answers. In contrast to the results from the pretest, 73% of the students who answered NSLMAT correctly were also showed an improvement in understanding with 70% correct answers.

Table 15: Results of the Two-tier Test

The two-tires	N	Pretest (%)	Posttest (%)	Difference (%)
First-tier (Questions)	90	57	73	16
Second-tier (Answers)	90	54	70	16

4.3 Results of Research Two

Are there any statistically significant differences in performance in Newton's second law of motion between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face teachings?

To identify the means of NSLMAT of the eleventh-grade students using CSs within an inquiry-based learning environment and those using face-to-face instruction, means and standard deviations were calculated for the CGs and EGs. Table 16 shows the NSLMAT score results for each group before and after treatment independently. Table 16 shows that the students in the CGs (M =17.51, SD = 2.84) and in the EGs (M = 18.00, SD = 3.24) have the same performance in the pre-test. There was a higher mean in the posttest of the CGs and EGs with (M = 20.31, SD = 4.09) and (M = 25.51, SD = 3.62) respectively. The means of pretest of the EGs and CGs are graphically shown in Figure 17.

Compared to the moderating effect of face-to-face instruction on students' understanding (d = 0.73), the CSs within an inquiry-based learning environment had a large impact on enhancing students' knowledge of NSLOM topics (d = 2.56) (Table 16).

Table 16: Performance in NSLOM Gains Stratified by Group

	Pretest			Posttest			
Group	Mean	Std. Deviation	Variance	Mean	Std. Deviation	Variance	Cohen's d*
EGs	18.00	3.24	10.500	25.51	3.62	13.119	2.56
CGs	17.51	2.84	8.074	20.31	4.09	16.765	0.73

*: d = effect size

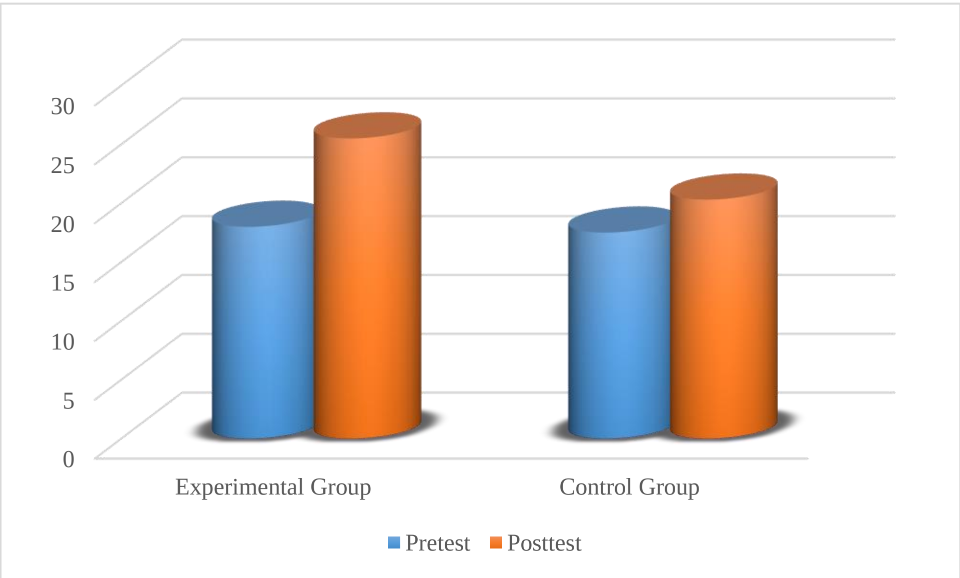

Figure 17: Means of Pretest for the Two Groups

To evaluate the impact of the intervention on the EGs achievement in NSLOM, descriptive statistics were calculated for their pretest and posttest scores on the NSLMAT. The EGs has a higher mean score ($M = 25.51$, $SD = 3.62$) than the CGs ($M = 20.31$, $SD = 4.09$). Furthermore, the Variance (VAR) of scores around the mean value in CGs ($VAR = 16.76$) is slightly higher than in EGs ($VAR = 13.11$). The means of posttest of the EGs and CGs are graphically shown in Figure 17.

Effect sizes were calculated on knowledge gains (Table 16) to compare the effect of the CSs within an inquiry-based learning environment on NSLMAT comprehension performance in each group. Cohen (1992) described the degree of these effects. where $d = 0.20$ is a small effect size, $d = 0.50$ is a medium effect size, and $d = 0.80$ is a large effect size.

Overall, the CSs-based instruction had the greatest effect on changing students' understanding of NSLOM topics in comparison to face-to-face instruction.

Given the sample size, the normal distribution of the data, and the insignificance of the homogeneity of variance, the data was analyzed using the one-way ANOVA to determine whether the two groups were comparable initially before the intervention.

A one- way ANOVA was used to determine whether the two groups were initially comparable before the intervention. It was found that there was no significant difference on pre-test scores at the $p < 0.05$ level for the two groups [$F(1, 89) = 0.579$, $p = 0.449$] as described in Table 17.

Table 17: One-Way ANOVA of the Pretest Scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.378	1	5.378	0.579	0.449
Within Groups	817.244	88	9.287		
Total	822.622	89			

Table 18 shows the means of pretest of the two genders. It's clear that there were no statistically significant differences between male students in the CGs (M = 17.76, SD = 3.03) and in the EGs (M = 18.04, SD = 3.43). they had the same performance in the pre-test. This was also found for female students in the CG (M = 17.20, SD = 2.62) and in the EG (M = 17.95, SD = 3.06). There was a higher mean in the pre-test for the EGs which as indicated did not differ significantly from the CGs mean. The means of pretest of the two genders are graphically shown in Figure 18.

Table 18: Descriptive Statistics for the Pre-Test Based on Gender

Gender	Condition	N	Mean	Std. Deviation
CGs	Male	25	17.76	3.0315
	Female	20	17.20	2.6278
EGs	Male	25	18.04	3.4337
	Female	20	17.95	3.0689

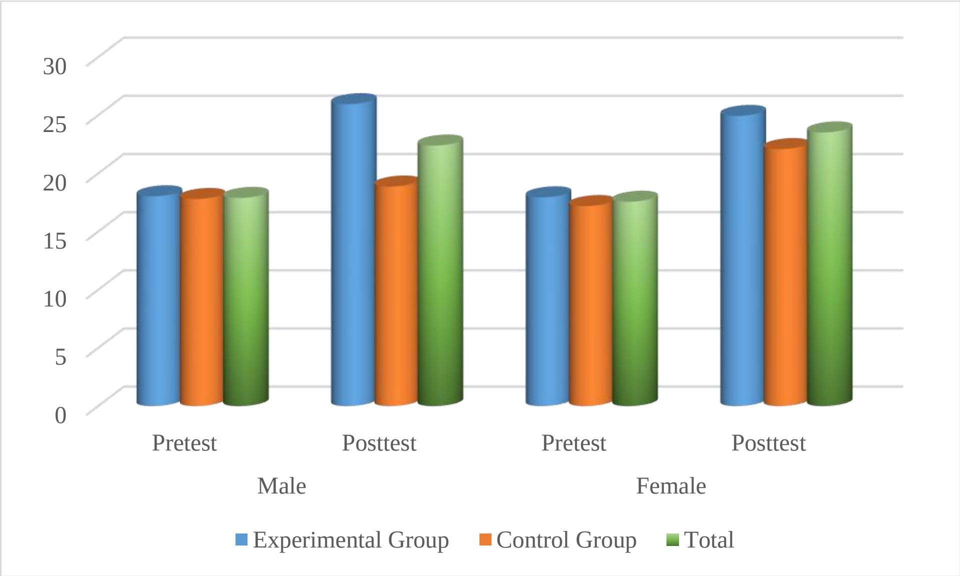

Figure 18: Graphical Comparison of the Mean Scores of the Two Groups Stratified by Gender

An independent-samples t-test was conducted to examine whether there was a significant difference between the mean of the male and female students. Table 19 shows the independent-samples t-test results from the SPSS 25. The subsequent test assuming equality of variances indicated that there was no significant difference in the means t (88) = 0.502 and p = 0.617.

The independent t-test for the equality of means indicated that the difference in the means was not significant, so there was no difference in the two groups of male and female students before teaching started in the section of NSLOM.

Table 19: An Independent-Samples t-test of NSLMAT of the Two Gender

	Groups	N	Mean	SD	t	df	Sig.
Pretest	Male	50	17.90	3.20			
	Female	40	17.57	2.84	0.502	88	0.617

A one- way ANOVA was used to determine whether the EGs to that of the CGs in the posttest were significantly different after the intervention. As shown in Table 20, it was found that the post-test scores at $p < 0.05$ for the two groups were significantly different [F (1,89) = 40.718, p = 0.000].

Table 20: One-Way ANOVA of the Posttest Scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	608.40	1	608.40	40.718	0.000
Within Groups	1314.88	88	14.94		
Total	1923.28	89			

A paired-sample t- test was conducted to check whether there was a significant difference between the mean pretest and posttest scores for the EGs. Since the p values of the Kolmogorov-Smirnov test were larger than 0.05, the data sets were normally distributed.

Table 21 shows the paired-sample t-test results from the SPSS. It shows that there is a significant difference between the pre-test and post-test scores in the EGs, which can be reported as, t (44) = 11.133, p < 0.05.

Table 21: Paired-Sample t- test of Pre and Post-test of EGs

Pretest		Posttest				
Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
18.0000	3.24037	25.51	3.62	11.133	44	0.000

As shown in Table 22, the pretest results of the male students in the EG (M = 17.90, SD = 3.20) and in the posttest (M = 22.42, SD = 4.68) were significantly different. The same significantly different results were found for the female students in the pretest results (M = 17.57, SD = 2.84) and in the posttest (M = 23.52, SD = 4.59). Mean differences for the EGs suggest that the male students scored 4.52 points lower than the female students 5.95 after receiving CSs within an inquiry-based learning environment. The above results suggest that CSs within an inquiry-based learning environment had a large effect on both female students (d = 1.49) and male students (d = 2.44). These results suggest that CSs within an inquiry-based learning environment also helped female and male students gain a better understanding of NSLOM topics. The graphical comparison of the CGs and the EGs is shown above in Figure 18.

Table 22: Performance in NSLOM Gains Stratified by Gender

	Pretest		Posttest			
Gender	Mean	Std. Deviation	Mean	Std. Deviation	Mean Difference	Cohen's d*
Male	17.90	3.21	22.42	4.68	4.52	1.13
Female	17.57	2.85	23.53	4.59	5.95	1.56

*: d = effect size

4.4 Results of Research Question Three

Is there any statistically significant difference in performance regarding conceptual understanding in Newton's second law of motion, between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face teachings?

The conceptual questions of the test were designed in such a way to verify students' understanding of the concept. Conceptual questions require students to think conceptually about the behavior of variables under specific circumstances, and how changes in one parameter will affect other parameters or how a concept relates to specific conditions. If students evoke a concept without really understanding its meaning, they will have difficulty finding the right solution. The conceptual test consisted of 8 MCQs.

The conceptual pretest and post test scores mean, and the standard deviations of the two groups are shown in Table 23. Table 23 shows that the students in the CGs (M = 8.93, SD = 2.31) and in the EG (M =8.88, SD = 2.40) have the same performance in the conceptual pretest. There was a higher mean in the conceptual posttest of the CGs and EGs with (M = 10.86, SD = 2.94) and (M = 14.44, SD = 2.00), respectively. Overall results indicate that the CSs within an inquiry-based learning environment had the greatest effect on enhancing students' conceptual understanding of NSLOM topics in comparison to face-to-face instruction. The means test of the EGs and CGs are graphically shown in Figure 19.

Effect sizes were calculated on conceptual knowledge gains (Table 23) to compare the effect of CSs within an inquiry-based learning environment within each group on performance on conceptual understanding. With a Cohen's d effect size calculation, it indicates that compared to the medium effect of face-to-face instruction (d = 0.73), the CSs within an inquiry-based learning environment had the most considerable effect in enhancing students' understanding of concepts (d = 2.51) (Table 23).

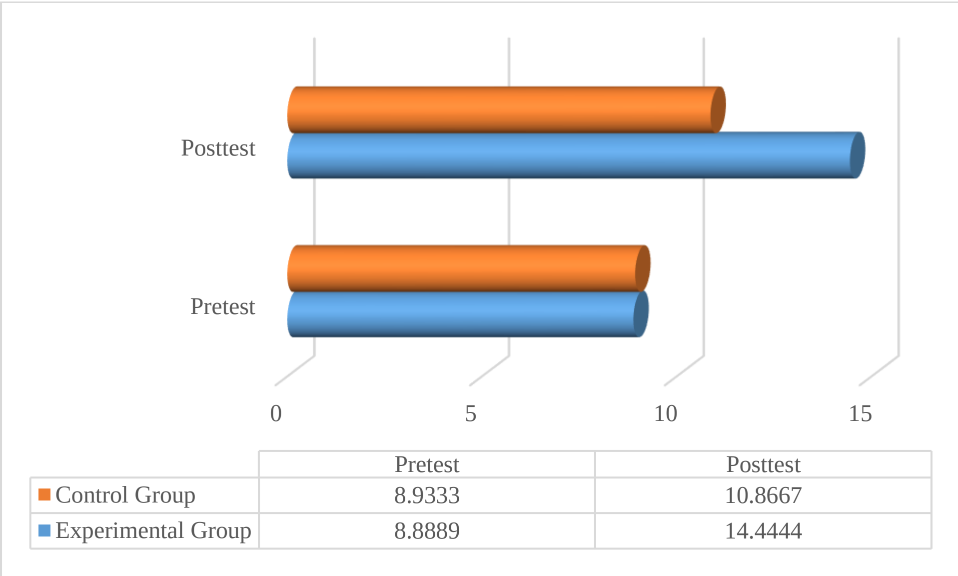

Figure 19: Means of Pre and Post Conceptual Test of the Two Groups

To evaluate the impact of the gender on the conceptual performance in the NSLMAT, descriptive statistics were calculated for their pretest and posttest scores on the conceptual NSLMAT. Table 23 presents the pretest and posttest means and standard deviation for the two gender. Table 23 shows that the male students in the CG (M = 9.08, SD = 2.27) and in the EG (M = 8.96, SD = 2.45) have the same performance in the pretest. This was also found among the female students in the CG (M = 8.75, SD = 2.40) and in the EG (M = 8.80, SD = 2.39). Results suggest that CSs within an inquiry-based learning environment had a large effect (d = 2.94) and (d = 2.10) for both male and female, respectively.

Table 23: Performance in Conceptual Gains Stratified by Group and Gender

			Pretest		Posttest		
Groups	N	Gender	Mean	Std. Deviation	Mean	Std. Deviation	Cohen's d*
EG	25	Male	8.96	2.45	14.96	1.51	2.94
	20	Female	8.80	2.39	13.80	2.37	2.10
	45	Total	8.88	2.40	14.44	2.00	2.51
CG	25	Male	9.08	2.27	10.24	2.74	0.46
	20	Female	8.75	2.40	11.65	3.06	1.05
	45	Total	8.93	2.31	10.86	2.94	0.73

*: d = effect size

A normality test was performed to see if the conceptual data were normally distributed. Since the *p* value of the Kolmogorov-Smirnov test is greater than 0.05, then the dataset is normally distributed. Moreover, the Levene test for equality of variances was used to assess the homogeneity of the variance, and the result was not significant $p > 0.05$. Levene's test was upheld for the students in pretest.

A one-way ANOVA was used to determine whether the two groups were initially comparable before the intervention. As shown in Table 24, it was found that there was no significant difference in pretest scores at $p < 0.05$ level between the two groups [F (1,89) = 0. 008, p = 0.929)]. This means that the students in the two groups were comparable.

Table 24: One-Way ANOVA of the Conceptual Pretest Scores of the Two Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.044	1	.044	0.008	0.929
Within Groups	489.24	88	5.56		
Total	489.28	89			

A normality test was performed to see if the conceptual data were normally distributed, and since the *p* value of the Kolmogorov-Smirnov test is greater than 0.05, then the dataset is normally distributed. Moreover, the Levene test for equality of variances was used to assess the homogeneity of the variance, and the result was not significant $p > 0.05$. Levene's test was upheld for the students in pretest.

A one-way ANOVA was used to determine whether the two gender were initially comparable before the intervention. As shown in Table 25, there was no significant difference in pretest scores for both gender at $p < 0.05$ level, [$F(1,89) = 0.241$, $p = 0.625$]. This means that the two gender were comparable, so there was no difference in the two groups of male and female students before teaching started in the conceptual section.

Table 25: One-Way ANOVA of the Conceptual Pretest of the Two Gender

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.334	1	1.334	0.241	0.625
Within Groups	487.955	88	5.545		
Total	489.289	89			

A paired-sample t- test was conducted to check whether there was a significant difference between the mean pretest and posttest scores for the CGs in the conceptual domain. Table 26 shows the paired sample t-test results from the SPSS. Table 26 shows that there is a significant difference between the pretest and posttest scores in the CGs, which can be reported as, t (44) = -3.83, p < 0.05. In the CGs the findings indicate that not using CSs improved female performance on NSLMAT conceptual domain t (19) = -3.39, p = 0.003 (p < 0.05) and d = 1.05, i.e., a large effect. However, the findings of the male group indicate that not using CSs had not improved male performance on NSLMAT conceptual domain t (24) = -2.05, p = 0.051($p > 0.01$), $d = 0.46$ (small effect) see Table 26. These results suggest that face-to-face instruction also helped female students gain a better understanding of NSLOM concept topics relative to the male students.

Table 26: Paired-Sample t- Test of Conceptual Items Based on CGs and Gender

Pretest- Posttest for CGs							
	Pretest		Posttest				
	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
CGs	8.9333	2.31	10.86	2.94	-3.83	44	0.000
Pretest-Posttest for two Gender of CGs							
	Pretest		Posttest				
Pretest-Posttest	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
Male	9.0800	2.27	10.24	2.74	-2.05	24	0.051
Female	8.75	2.40	11.65	3.06	-3.39	19	0.003

A paired-sample t- test was conducted to check whether there was a significant difference between the mean pre-test and post-test scores for the EGs in conceptual domain. Table 27 shows the paired sample t- test results from the SPSS 25.

Table 27 shows that there is a significant difference between the pretest and posttest scores in the EGs, which can be reported as, t (44) = -12.4, p < 0.05. In the EGs the findings indicate that using CSs within an inquiry-based learning environment improved female performance on NSLOM conceptual domain t (19) = -6.31, p = 0.000 (p < 0.05) and d = 2.10, i.e., a large effect. Additionally, the findings of the male group indicate that using CSs improved male performance on NSLOM conceptual domain t (24) = -12.0, p = 0.000 (p < 0.05), d = 2.94 (large effect) see Table 27. These results suggest that CSs within an inquiry-based learning environment helped female and male students gain a better understanding of NSLOM conceptual topics.

Table 27: Paired-Sample t- Test of Conceptual Items Based on EGs and Gender

Pretest- Posttest for the EGs							
	Pretest		Posttest				
	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
EGs	8.88	2.40	14.44	2.00	-12.4	44	0.000
Pretest-Posttest for two Gender of EGs							
	Pretest		Posttest				
Pretest-Posttest	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
Male	8.96	2.45	14.96	1.51	-12.0	24	0.000
Female	8.8000	2.39737	13.800	2.00630	-6.31	19	0.000

In summary, for the female students these findings indicate that, not using CSs within an inquiry-based learning environment significantly improve their performance on the conceptual knowledge items. Although there was no significant difference in the scores, the means did increase. Therefore, these results indicate that for female students both use and lack of use of CSs within an inquiry-based learning environment leads to a large effect size and improved their performance. For the male students, these findings indicate that, not using CSs within an inquiry-based learning environment their performance did not significantly improve on the conceptual knowledge items, this led to a small effect size which also was not significant. When CSs within an inquiry-based learning environment was used, the effect size was large. Therefore, these results indicate that for male students the use of CSs within an inquiry-based learning environment had a large effect size and the lack of use of CSs within an inquiry-based learning environment leads to a small effect size in their performance, although this decrease is not significant. Had also a large effect size. Moreover, when using CSs within an inquiry-based learning environment, the difference in the conceptual performance of male students is higher than that of female students, and the change is more significant when using CSs compared to not using the CSs. The graphical comparison of the conceptual mean scores of the CGs and the EGs is shown below in Figure 20.

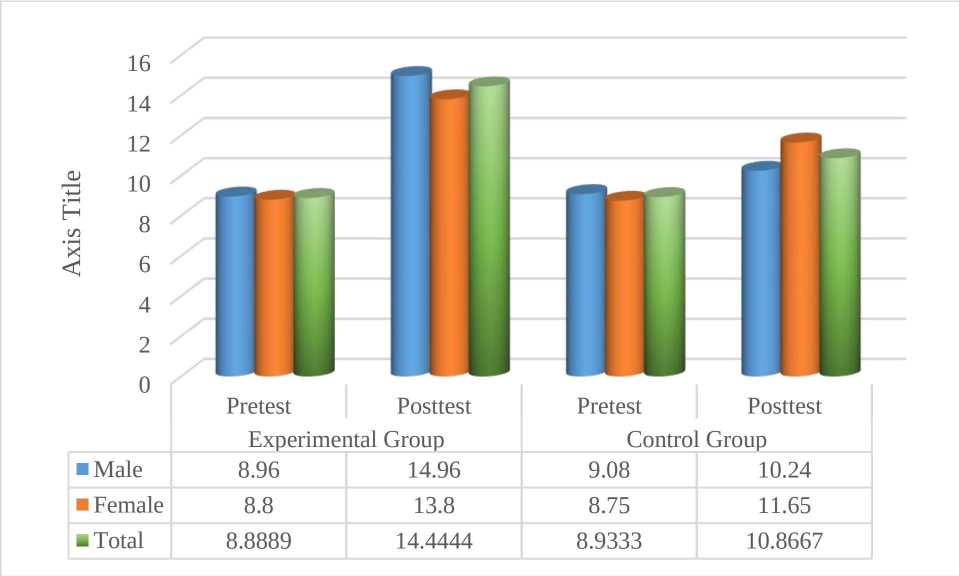

Figure 20: Graphical Comparison of the Conceptual Mean Scores of the Two Groups Stratified by Gender

4.5 Results of Research Question Four

Is there any statistically significant difference in learning achievement regarding procedural understanding in Newton's second law of motion, between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face teachings?

Procedural questions of the test were designed to focus on procedural knowledge. Students were asked to think clearly about the constraints and the structure of the question and explain how to obtain answers from the constraints through various steps. The complexity of procedural problems varies considerably. For example, some problems require only one or two steps to solve, while some problems require different procedures. Procedural questions focus on assessing students' deep understanding of the procedures and their application. The procedural test consists of 8 MCQs.

The procedural pretest and post test scores mean, and standard deviations of both groups are shown in Table 28.

Table 28: Performance in Procedural Gains Stratified by Group and Gender

			Pretest		Posttest		
Groups	N	Gender	Mean	Std. Deviation	Mean	Std. Deviation	Cohen's d*
EGs	25	Male	9.08	2.08	11.00	2.27	0.88
	20	Female	9.15	2.87	11.15	2.70	0.72
	45	Total	9.11	2.43	11.06	2.44	0.80
CGs	25	Male	8.68	2.30	8.64	2.44	0.02
	20	Female	8.45	2.21	10.45	2.87	0.78
	45	Total	8.57	2.24	9.44	2.76	0.34

*: d = effect size

Table 28 shows that the students in the CGs (M = 8.58, SD = 2.24) and in the EGs (M = 9.11, SD = 2.43) have the same performance in the procedural pretest. There was a higher mean in the procedural posttest of the CGs and EGs with (M = 9.44, SD = 2.77) and (M = 11.07, SD = 2.44), respectively. Overall results indicate that the CSs within an inquiry-based learning environment had the greatest effect on changing students' procedural understanding of NSLOM in comparison to face-to-face instruction. The means test of the EGs and CGs are graphically shown in Figure 21.

Effect sizes were calculated on procedural knowledge gains (Table 28) to compare the effect of CSs within an inquiry-based learning environment in each group on performance on procedural understanding. With a Cohen's d effect size calculation, it indicates that, compared to the small effect of face-to-face instruction (d = 0.34), acceptance of the simulation has the most significant effect on enhancing students' understanding of the procedural concepts (d = 0.80) (Table 28).

Descriptive statistics of pre- and post-test results for the procedural NSLMAT were calculated to assess the effect of gender on procedural performance in NSLOM. Table 28 describes the pretest and posttest means and standard deviations for both genders. Table 28 shows that the male students in CG (M = 8.68, SD = 2.30) and EG (M = 9.08, SD = 2.08) have the same performance in the pretest. It was also found among the female students of CG (M = 8.45, SD = 2.21) and EG (M = 9.15, SD = 2.87).

The results show that the CSs within an inquiry-based learning environment had a large effect on male (d = 0.88) and female (d = 0.72). Face-to-face instruction had a small effect on students' understanding of procedural NSLOM (d = 0.34). However, face-to-face instruction had a moderate effect on female students (d = 0.78), and a minimal effect on male students (d = 0.02). These results indicate that, compared to the male students, the CSs within an inquiry-based learning environment also helped the female students to understand the NSLOM subjects better.

A normality test was performed to see if the procedural data were normally distributed, and since the *p* value of the Kolmogorov-Smirnov test is greater than 0.05, then the dataset is normally distributed. Moreover, the Levene test for equality of variances was used to assess the homogeneity of the variance, and the result was not significant p > 0.05. Levene's test was upheld for the students in pretest.

A one-way ANOVA was used to determine whether the two groups were comparable initially before the intervention. As shown in Table 29, there was no significant difference in pretest scores at p < 0.05 between the two groups [F (1,89) = 766, p = 0.384]. This means that the students in the two groups are comparable, so there was no difference in the EGs and in the CGs before teaching started in the procedural section.

Table 29: One-Way ANOVA of the Procedural Pretest Scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.34	1	1.34	0.766	0.384
Within Groups	154.44	88	1.75		
Total	155.78	89			

A normality test was performed to see if the procedural data were normally distributed, and since the p value of the Kolmogorov-Smirnov test is greater than 0.05, then the dataset is normally distributed. Moreover, the Levene test for equality of variances was used to assess the homogeneity of the variance, and the result was not significant p > 0.05. Levene's test was upheld for the students in pretest.

A one-way ANOVA was used to determine whether the two genders were initially comparable before the intervention. As shown in Table 30, it was found that there was no significant difference on pretest scores at the p < 0.05 level for the two genders [F (1, 89) = 0.008, p = 0.930]. This means that the two genders were comparable, so there was no difference in the two groups of male and female students before teaching started in the procedural section.

Table 30: One-Way ANOVA of the Procedural Pretest Scores of the Two Gender

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.014	1	0.014	0.008	0.930
Within Groups	155.77	88	1.770		
Total	155.78	89			

Paired-samples t-test was used to determine if there was a specific change in the performance from pretest to posttest in the procedural domain. Homogeneity of variance was assessed using Levene's test for equality of variances, and the result was not significant $p > 0.05$. Levene's test was upheld for the learners in posttest. Since the p values of the Kolmogorov-Smirnov test were larger than 0.05, the data sets were normally distributed.

A paired-sample t-test was conducted to check whether there was a significant difference between the mean pretest and posttest scores for the CGs in the procedural domain. Table 31 gives the paired-sample t-test results from the SPSS 25.

Table 31 shows that there is no significant difference between the pre and posttest scores for the CGs, which can be reported as $t(44) = -1.533$, $p > 0.05$. In the CGs, study results showed that not using CSs within an inquiry-based learning environment did not improve female's performance in the NSLOM procedural domain $t(19) = -2.57$, $p = 0.091$ ($p > 0.05$). Likewise, findings in the male group showed that not using CSs within an inquiry-based learning environment did not improve male's performance in the NSLOM procedural domain t (24) = 0.052, p = 0.959 ($p > 0.05$). These results indicate that face-to-face instruction did not help female or male students to understand the topic of the NSLOM procedural better.

Table 31: Paired-Sample t- Test of Procedural Items Based on CGs and Gender

	Pretest- Posttest for CGs						
	Pretest		Posttest				
	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
CGs	8.57	2.24	9.444	2.76	-1.53	44	0.133
	Pretest-Posttest for two Gender of CGs						
	Pretest		Posttest				
Pretest-Posttest	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
Male	8.68	2.30	8.64	2.44	.052	24	0.959
Female	8.45	2.21	10.45	2.87	-2.57	19	0.091

A paired-sample t-test was conducted to check if there was a significant difference between the mean of the pretest and posttest scores for EGs in the procedural domain. Table 32 shows the results of the paired sample t-test results from the SPSS.

Table 32 shows that there is a significant difference between the pretest and posttest scores of the EGs, which can be reported as, t (44) = -3.86, $p < 0.05$. In EGs, the study results showed that the use of CSs within an inquiry-based learning environment could improve female performance in the NSLOM procedural domain t (19) = -2.35, p = 0.029 ($p < 0.05$) and d = 0.72, which is a Moderate effect. Besides, the results of the male group showed that the use of CSs within an inquiry-based learning environment improved the performance of male students in the NSLOM procedural domain t (24) = -3.07, p = 0.005 (p < 0.05), d = 0.88 (large effect), see Table 32. These results suggest that CSs within an inquiry-based learning environment also helped male and female students gain a better understanding of NSLOM procedural topics.

Table 32: Paired-Sample t- Test of Procedural Items Based on EGs and Gender

Pretest- Posttest for Simulation Group							
	Pretest		Posttest				
	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
EGs	9.1111	2.43	11.06	2.44	-3.86	44	0.000
Pretest-Posttest for two Gender of EGs							
	Pretest		Posttest				
Pretest-Posttest	Mean	Std. Deviation	Mean	Std. Deviation	t	df	Sig.
Male	9.08	2.08	11.00	2.27	-3.07	24	0.005
Female	9.15	2.87	11.15	2.70	-2.35	19	0.029

Overall, for the female students, these findings indicate that not using CSs within an inquiry-based learning environment did not improve female’s performance in the NSLOM procedural domain leading to medium effect size which also was not significant, while the use of CSs within an inquiry based learning environment could improve female performance in the NSLOM procedural domain. For the male students, these findings suggest that the performance of not using CSs within an inquiry-based learning environment did not improve significantly on the elements of procedural knowledge, leading to small effect size which also was not significant. When using CSs within an inquiry-based learning environment, the effect size was large. Additionally, when using CSs within an inquiry-based learning environment, the difference in the performance of the male students' procedural knowledge is greater than the difference between the female students and compared to the non-use of CSs within an inquiry based learning environment, the changes when using CSs within an inquiry based learning environment are more considerable. When using CSs within an inquiry-based learning environment, the difference in procedural performance among male students is greater than that of female students and compared to not using CSs; the performance difference is more significant when using CSs within an inquiry based learning environment. A graphical comparison between the mean procedural scores for the CGs and the EGs is shown in Figure 21.

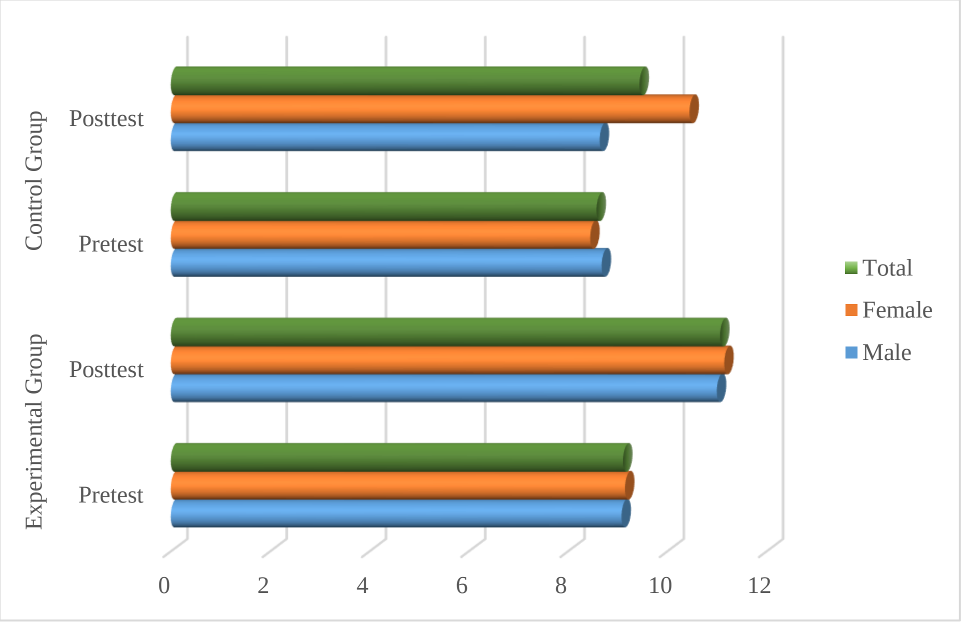

Figure 21: Graphical Comparison of the Procedural Mean Scores of the EGs and CGs Stratified by Gender

4.6 Results of Research Question Five

What impact do computer simulations have on student attitudes towards physics when taught within an inquiry context?

TOSRA was designed to measure seven distinct science-related attitudes among secondary school students. In this study, as described in chapter three, three of the seven science-related attitudes were studied: (1) attitude of science inquiry, (2) enjoyment of science lessons and (3) career interest in science (Fraser, 1981).

Prior to the experimental process, it was examined whether students in the experimental and control groups had comparable levels of attitude toward physics. For this purpose, three scales of TOSRA were given as a pretest for both groups. The mean score of the pretest was compared using the independent sample t-test. Table 33 illustrates the mean scores of the experimental and control groups and the t-test results.

The results of an independent sample t-test revealed that the two groups were statistically not significantly different on pretest scores at the $p < 0.05$. For the EGs ($M = 2.16$, $SD = 0.72$) and CGs ($M = 2.14$, $SD = 0.591$); $t(88) = 0.122$, $p = 0.904$. As described in Table 33, it can be said that prior to the experimental procedure the level of attitudes towards physics of experimental and control groups' physics attitudes are comparable.

Table 33: Independent Samples t-Test Results of Pretest Attitudes for the Two Groups

Groups	N	Mean	SD	t	df	Sig.
CGs	45	2.14	0.59	0.122	88	0.904
EGs	45	2.16	0.72			

Both groups were preserved with the TOSRA scale. As shown in Table 34, the TOSRA scales scores for the CGs and the EGs were not statistically different in the pretest scores (p > 0.05).

Table 34: TOSRA Pretest Sub-scale Results of the Two Groups

	Groups	N	Mean	SD	t	df	Sig.
ASI	Experimental	45	2.07	0.722	-0.235	88	0.815
	Control	45	2.10	0.61			
ESL	Experimental	45	2.22	0.74	0.182	88	0.856
	Control	45	2.20	0.63			
CIS	Experimental	45	2.19	0.77	0.382	88	0.703
	Control	45	2.13	0.65			

An independent sample t-test was performed to check if there was a significant difference between the mean of the male and female students. Table 35 shows the independent sample t-test results from the SPSS.

The subsequent test assuming equality of variances indicated that there was no significant difference in the means t (88) = 0.189 and p = 0.850. As described in Table 35, the independent t-test for the equality of means indicated that the difference in the means was not significant, so there was no difference in the male and female students' attitudes before the start of teaching the NSLOM section. It can be said that the physics attitudes of the male and female students were similar before the experiment.

Table 35: An Independent-Samples t-Test of Attitudes of the Two Gender

Groups	N	Mean	SD	t	df	Sig.
Pre-Male	50	2.17	0.69	0.189	88	0.850
Pre-female	40	2.14	0.61			

At the end of the intervention (4 weeks later), to determine if there was a meaningful significant difference between the attitudes scores as measured by the three scales TOSRA of the EGs and the CGs in the posttest scores, the independent t-test were used. The analysis findings obtained are presented in Table 36.

Table 36 shows that there is a meaningful statistical difference between the two groups' combined physics attitude scale means on posttest scores at the $p < .05$ level for the two groups. For the EGs (M = 4.17, SD = 0.18) and the CGs (M = 2.68, SD = 0.39) conditions; t (88) = 22.76, p = 0.000. As shown in Table 36. It can be said that after the experiment, the experimental and control groups' physics attitudes are not equivalent.

Table 36: Independent Samples t-Test Results of Posttest Attitudes for the Two Groups

Groups	N	Mean	SD	t	df	Sig.
CGs	45	2.68	0.39	22.76	88	0.000
EGs	45	4.17	0.18			

Table 37 shows results for each scale independently. The results showed that there were statistically significant differences between the two groups on each scale. Significant differences (p = 0.000) were found in favor of the EGs in ASI, ESL and CIS. It can be considered that the attitudes towards ASI, ESL and CIS is very effective in the CSs within an inquiry-based learning environment. In this case, it can be said that CSs within an inquiry-based learning environment has a positive effect on the attitudes of students toward physics. Figures 22 and 23 show graphical comparisons of mean TOSRA scale scores for the EGs and gender, respectively.

Table 37: TOSRA Posttest Sub-scale Results of the Two Groups

	Groups	N	Mean	SD	t	df	Sig.
ASI	Experimental	45	4.01	.34	15.819	88	0.000
	Control	45	2.49	.54			
ESL	Experimental	45	4.24	.33	17.169	88	0.000
	Control	45	2.72	.48			
CIS	Experimental	45	4.26	.29	18.067	88	0.000
	Control	45	2.85	.43			

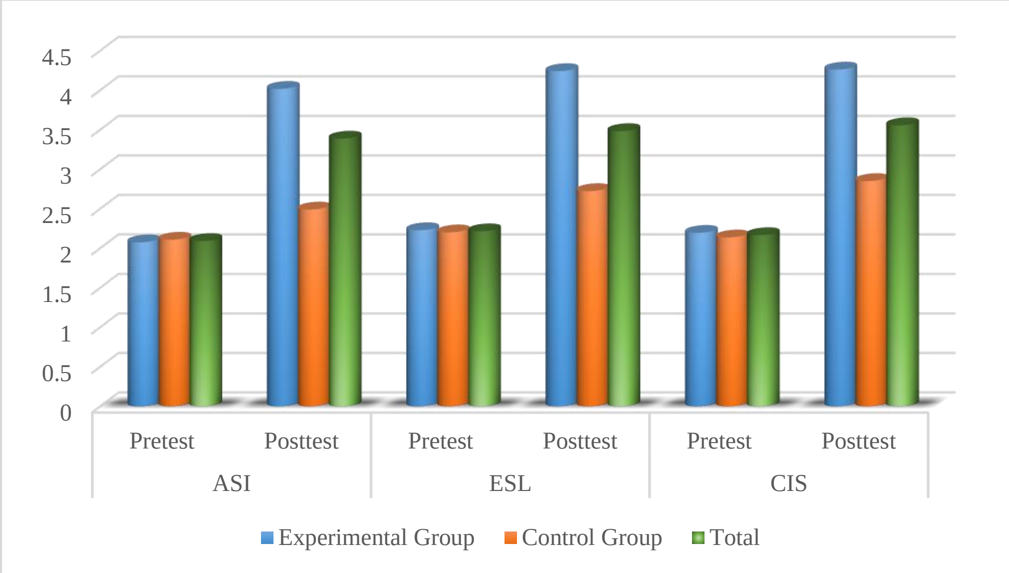

Figure 22: Graphical Comparison of TOSRA Subscale Mean Scores of the Experimental and Control Groups

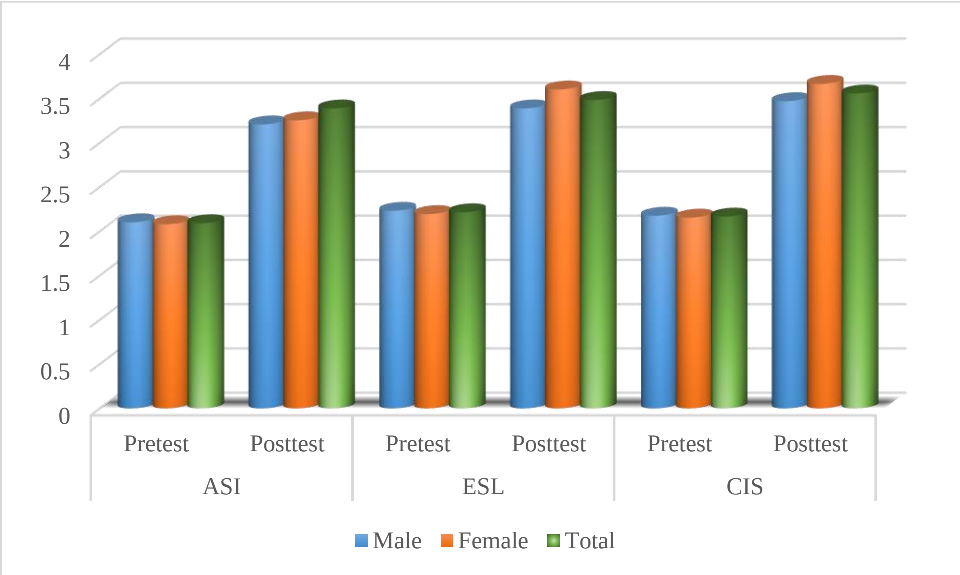

Figure 23: Graphical Comparison of TOSRA Subscale Mean Scores of the Two Gender

Table 38: Attitudes Gains for TOSRA Subscale Stratified by Gender for EGs

Scale		Pretest		Posttest		Cohen's d*
		Mean	Std. Deviation	Mean	Std. Deviation	
ASI	Male	2.10	0.72	3.20	0.99	1.27
	Female	2.08	0.59	3.31	0.75	1.81
	Total	2.09	0.66	3.25	0.89	1.47
ESL	Male	2.23	0.69	3.38	0.93	1.40
	Female	2.19	0.68	3.60	0.77	1.92
	Total	2.21	0.68	3.48	0.86	1.62
CIS	Male	2.17	0.75	3.47	0.81	1.64
	Female	2.15	0.66	3.66	0.77	2.10
	Total	2.16	0.71	3.55	0.79	1.83

*: d = effect size

Effect sizes were calculated to compare the effect of the CSs in each gender on their attitudes toward physics (see Table 38 above). EG Received the CSs within an inquiry based learning environment had the greatest effecting on enhancing both male and female students' attitudes towards physics (d > 0.8).

4.7 Results of Research Question Six

Is there any statistically significant difference in attitudes towards physics between students who studied through using CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions?

To answer this question and to compare the groups and identifies the mean differences between the groups, MANOVA was undertaken using the three scales (ASI, ESL and CIS) as dependent variables and instruction method as an independent variable with two multiple levels: CSs within an inquiry-based learning environment and face-to-face instruction. Table 38 above provides each dependent variable sample size, means, and standard deviations for each level of the independent variable.

No extreme scores, outlier, or statistical assumption violations were observed in the present data. Evaluation of the properties of the data set (such as normality, equality of variance-covariance matrices) showed that these data met the necessary statistical assumptions required to perform the analyses. A statistically significant Box's M test at the $p > 0.05$ level, showed unequal variance-covariance matrices of the dependent variables across levels of treatment and gender. Thus, it is necessitated the use of Pillai's trace to assess multivariate effects. Bartlett's Test of Sphericity is statistically significant, and these indicated sufficient correlation between the dependent measures to proceed with the analysis.

The MANOVA results (see Table 39) indicated that *group* had a significant impact on attitudes at the three levels at the $p < 0.05$ level (Pillai's Trace = 0.871, $F(3, 84) = 188.776$, $p = 0.000 < 0.05$). The effect size for this relationship partial $\eta^2 = 0.871$ for tests. Thus, suggesting that there were significant differences in attitudes among the three subscales to different students' groups. Similarly, the MANOVA results showed that Gender had a significant influence on attitudes at the three levels at the $p < 0.05$ level (Pillai' s Trace = 0.102, $F (3, 84) = 3.197$, $p = 0.028 < 0.05$). The effect size for this partial relationship η^2 was 0.102 for tests. Therefore, suggesting that there was a significant difference in attitudes as perceived among the three subscales based on students' gender. The multivariate interaction effect of *group X Gender* was also statistically significant, Pillai's trace = 0.107, $F (3,84) = 3.357$, $p = 0.023 < 0.05$, partial $\eta^2 = 0.107$.

In order to investigate in which types of attitudes (ASI, ESL and CIS), that were significant differences among student groups (EG and CG) and students' gender (male and female). Two-way MANOVA test was used to determine the effects of any interaction between the two levels of the first independent variable, "groups"; (1) CSs within an inquiry-based learning environment (2) and face-to-face instruction and the two levels of the second independent variable, "Gender"; (1) male and (2) female on the three dependent variables; (1) attitude to scientific inquiry, (2) enjoyment of science lessons and (3) career interest in science.

Table 39: Two- way MANOVA for Posttest based on Groups and Students' Gender

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared (η2)
Intercept	Pillai's Trace	0.993	4276.701[b]	3.000	84.00	0.000	0.993
	Wilks' Lambda	0.007	4276.701[b]	3.000	84.00	0.000	0.993
	Hotelling's Trace	152.739	4276.701[b]	3.000	84.00	0.000	0.993
	Roy's Largest Root	152.739	4276.701[b]	3.000	84.00	0.000	0.993
Groups	Pillai's Trace	0.871	188.776[b]	3.000	84.00	0.000	0.871
	Wilks' Lambda	0.129	188.776[b]	3.000	84.00	0.000	0.871
	Hotelling's Trace	6.742	188.776[b]	3.000	84.00	0.000	0.871
	Roy's Largest Root	6.742	188.776[b]	3.000	84.00	0.000	0.871
Gender	Pillai's Trace	0.102	3.197[b]	3.000	84.00	0.028	0.102
	Wilks' Lambda	0.898	3.197[b]	3.000	84.00	0.028	0.102
	Hotelling's Trace	0.114	3.197[b]	3.000	84.00	0.028	0.102
	Roy's Largest Root	0.114	3.197[b]	3.000	84.00	0.028	0.102
Groups * Gender	Pillai's Trace	0.107	3.357[b]	3.000	84.00	0.023	0.107
	Wilks' Lambda	0.893	3.357[b]	3.000	84.00	0.023	0.107
	Hotelling's Trace	0.120	3.357[b]	3.000	84.00	0.023	0.107
	Roy's Largest Root	0.120	3.357[b]	3.000	84.00	0.02	0.107

Table 40 shows a significant difference between students' groups (EGs and CGs) regarding their scores on attitude towards scientific inquiry, F (1, 49.900) = 49.900, p = 0.000, partial η^2 = 0.748, enjoyment of science lessons, F (1, 49.767) = 49.767, p = 0.000, partial η^2 = 0.785 and career interest in science, F (1, 43.992) = 43.992, p = 0.000, partial η^2 = 0.797. The significant differences and the post-Hoc comparison test presented in Tables 41 and 42, respectively.

On the other hand, Table 40 shows significant differences among students based on gender in their scores on enjoyment of science lessons, F (1, 1.022) = 1.022, p = 0.013, partial η^2 = 0.070 and career interest in science, F (1, .845) = 0.845, p = 0.013, partial η^2 = 0.070. However, no significant difference was observed in the scores of the two groups in the attitude to scientific inquiry, F (1, .243) = 0.243, p = 0.268, partial η^2 = 0.014. The significant differences and a post hoc Bonferroni comparison test are presented in Tables 43 and 44, respectively.

Significant MANOVA results were followed with univariate ANOVA on each dependent measure separately to determine the locus of the statistically significant multivariate main effect of groups and gender on differences in attitudes towards physics among ASI, ESL and CIS.

Table 40: Two- way MANOVA for TOSRA Subscale based on Groups and Gender

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared (η2)
Intercept	ASI	944.820	1	944.820	4844.800	0.000	0.983
	ESL	1085.935	1	1085.935	6849.066	0.000	0.988
	CIS	1131.294	1	1131.294	8684.550	0.000	0.990
Groups	ASI	49.900	1	49.900	255.875	0.000	0.748
	ESL	49.767	1	49.767	313.883	0.000	0.785
	CIS	43.992	1	43.992	337.713	0.000	0.797
Gender	ASI	0.243	1	0.243	1.244	0.268	0.014
	ESL	1.022	1	1.022	6.449	0.013	0.070
	CIS	0.845	1	0.845	6.487	0.013	0.070
Group * Gender	ASI	1.428	1	1.428	7.323	0.008	0.078
	ESL	0.815	1	0.815	5.140	0.026	0.056
	CIS	0.030	1	0.030	.234	0.630	0.003
Error	ASI	16.772	86	0.195			
	ESL	13.635	86	0.159			
	CIS	11.203	86	0.130			
Total	ASI	1024.110	90				
	ESL	1159.330	90				
	CIS	1195.370	90				
Corrected Total	ASI	70.883	89				
	ESL	67.305	89				
	CIS	56.881	89				

ANOVA results are displayed in Table 41, there were statistically significant differences in the attitude towards scientific inquiry (F (1, 52.441) = 250.231, p = 0.000 < 0.05), enjoyment of science lessons (F (1, 51.832) = 294.788, p = 0.000 < 0.05) and career interest in science (F (1, 44.803) = 326.426, p = 0.000 < 0.05) among students to different instructional method.

Table 41: ANOVA Results for TOSRA-Subscale Measure by Groups

		Sum of Squares	df	Mean Square	F	Sig.
ASI	Between Groups	52.441	1	52.441	250.231	0.000
	Within Groups	18.442	88	0.210		
	Total	70.883	89			
ESL	Between Groups	51.832	1	51.832	294.788	0.000
	Within Groups	15.473	88	0.176		
	Total	67.305	89			
CIS	Between Groups	44.803	1	44.803	326.426	0.000
	Within Groups	12.078	88	0.137		
	Total	56.881	89			

Since Levene's F test indicated that the error variances of the dependent variables were equal in the three groups, Bonferroni for multiple comparisons was employed to perform the post-hoc analysis (see Table 42). An inspection of the mean scores suggested that students in the EGs (M = 4.01, SD = 0.34) were significantly higher than students in the CGs (M = 2.49, SD = 0.54).

For the ASI, a significant difference was found between EGs and CGs ($p < 0.05$), students in the EGs rated it significantly higher (M = 4.24, SD = 0.33) than students in the CGs (M = 2.72, SD = 0.48) at p = 0.05. Regarding ESL, students in the EGs rated it significantly higher (M = 4.24, SD = 0.33) than students in the CGs (M = 2.72, SD = 0.48) at p = 0.05. Furthermore, regarding CIS, students in the EGs rated it significantly higher (M = 4.26, SD = 0.29) than students in the CGs (M = 2.85, SD = 0.43) at p = 0.05.

Additionally, an analysis of mean scores showed that CIS had the highest mean score (M = 4.26) followed by ESL (M = 4.24), and ASI had the lowest mean score (M = 4.01) (see Table 37 above).

Table 42: Post Hoc Tests for Posttest based on TOSRA Subscale and Students' Groups

						95% Confidence Interval for Difference[b]	
Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
ASI	EGs	CGs	1.499*	0.094	0.000	1.312	1.685
	CGs	EGs	-1.499*	0.094	0.000	-1.685	-1.312
ESL	EGs	CGs	1.497*	0.084	0.000	1.329	1.664
	CGs	EGs	-1.497*	0.084	0.000	-1.664	-1.329
CIS	EGs	CGs	1.407*	0.077	0.000	1.255	1.559
	CGs	EGs	-1.407*	0.077	0.000	-1.559	-1.255

The results of ANOVA are shown in Table 43 which indicated that, there were no statistically significant differences in ASI (F (1, .243) = 1.244, p = 0.268 > 0.05). However, there was statistically significant difference in ESL (F (1, 1.022) = 6.449, p = 0.013 < 0.05), and there were also statistically significant differences in CIS (F (1, 0.845) = 6.487, p = 0.0.13 < 0.05) among students to different instructional method.

Table 43: ANOVA Results for TOSRA-Subscale Measure by Gender

		Sum of Squares	df	Mean Square	F	Sig.
ASI	Between Groups	.243	1	0.243	1.244	0.268
	Within Groups	70.641	88	0.803		
	Total	70.883	89			
ESL	Between Groups	1.022	1	1.022	6.449	0.013
	Within Groups	66.283	88	0.753		
	Total	67.305	89			
CIS	Between Groups	0.845	1	0.845	6.487	0.013
	Within Groups	56.036	88	0.637		
	Total	56.881	89			

Since Levene's F test showed that the error variances of the dependent variables were equal in the three groups, Sidak for multiple comparisons was employed to perform the post-hoc analysis (see Table 44). For ASI, no significant difference was found between male and female students (p > 0.05). An inspection of the mean scores suggested that with regard of ASI, male students showed higher level of attitudes (M = 4.08, SD = 0.27) than female students (M = 3.93, SD = 0.42) at p = 0.05, but not significant. Regarding CIS, female showed significantly higher level of attitudes (M = 4.35, SD = 0.23) than male students (M = 4.19, SD = 0.32) at p = 0.05. Regarding ESL, female showed significantly higher level of attitudes (M = 4.25, SD = 0.38) than male students (M = 4.23, SD = 0.30) at p = 0.05. Besides, an analysis of mean scores showed that CIS had the highest mean scores (M = 4.26), followed by ESL (M = 4.24), and the ASI had the lowest mean score (M = 4.01).

Table 44: Post Hoc Tests for Posttest based on TOSRA Attitudes Subscale and Students' Gender

						95% Confidence Interval for Difference[b]	
Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
ASI	Male	Female	-0.105	0.094	0.268	-0.291	0.082
	Female	Male	0.105	0.094	0.268	-0.082	0.291
ESL	Male	Female	-0.214*	0.084	0.013	-0.382	-0.047
	Female	Male	0.214*	0.084	0.013	0.047	0.382
CIS	Male	Female	-0.195*	0.077	0.013	-0.347	-0.043
	Female	Male	0.195*	0.077	0.013	0.043	0.347

Finally, Table 45 shows statistically significant differences among multivariate interaction effect of Groups × Gender in their scores on ASI (F (1, 1.428) = 1.428, p = 0.008, partial η^2 = 0.078) and ESL (F (1, .815) = 0.815, *p* = 0.026, partial η^2 = 0.056). However, in terms of group and gender interactions, no significant differences were observed in their CIS scores (F (1, 0.030) = 0.030, p = 0.630, partial η^2 = 0.003). This means that any student either male or female used CSs within an inquiry-based learning environment their attitudes increased more relative to face-to-face instruction at both ASI and ESL. Meanwhiles that, CSs within an inquiry-based learning environment did not affect students' attitudes in both gender regarding CIS.

Table 45: Means Scores and Standard Deviations for Measures of TOSRA Subscales Stratified by Gender

			EGs		CGs	
	Gender	N	Mean	Std Deviation	Mean	Std Deviation
ASI	Male	25	4.08	0.27	2.33	0.59
	Female	20	3.93	0.42	2.69	0.40
	Total	45	4.01	0.34	2.49	0.54
ESL	Male	25	4.23	0.30	2.54	0.44
	Female	20	4.25	0.38	2.95	0.44
	Total	45	4.24	0.33	2.72	0.48
CIS	Male	25	4.19	0.32	2.74	0.42
	Female	20	4.35	0.23	2.98	0.41
	Total	45	4.26	0.29	2.8511	0.43

4.8 Summary

This chapter has presented the data analysis and findings, by describing how the different groups were taught and the outcomes of the instruction employed in this study. It focused first on data analysis and findings relating to NSLOM performance divided into conceptual and procedural knowledge. It then presented and examined students' attitudes to different TOSRA scale (ASI, ESL and CIS). Statistical analysis of the pretest and posttest scores were provided for both NSLMAT and attitudes towards physics "TOSRA subscale questionnaire" with students from all the two groups. The seven research questions that guided this study were also answered in this chapter. Overall results suggest that the CSs within an inquiry-based learning environment had a large effect on students' learning of NSLOM topics in comparison to the face-to-face instruction. Furthermore, compared to face-to-face instruction, CSs within an inquiry-based learning environment contributed positively more to attitudes of students toward physics.

Results also suggest that there were gender differences when learning with CSs within an inquiry-based learning environment. The CSs within an inquiry-based learning environment seemed to have had the greatest effect on conceptual knowledge for both male and female students. However, not using CSs significantly improve female performance on the conceptual knowledge items, as well as males' performance cannot be substantially improved in aspects of conceptual knowledge. Additionally, CSs within an inquiry-based learning environment seemed to have had the greatest effect on procedural knowledge for both male and female students.

However, not using CSs did not significantly improve male and female performance on the procedural knowledge items.

It can be said that the CSs within an inquiry-based learning environment has a positive effect on students' attitudes towards TOSRA subscales. It can be considered that the CSs within an inquiry-based learning environment had significantly impacted the level of ASI, ESL and CIS. This means that any student, whether male or female used CSs within an inquiry-based learning environment, their attitudes are likely increase more than those who do not use CSs within an inquiry-based learning environment in both ASI and ESL. However, CSs within an inquiry-based learning environment did not affect students' attitudes in both gender regarding CIS.

Chapter 5: Discussion and Conclusion

5.1 Chapter Overview

Newton's second law of motion may be a vital classical mechanical phenomenon that helps students understand the pattern of motion of objects. It is one among the historically important topics that the students must learn for the successful understanding of the fundamentals of Newtonian mechanics. But the topic of the NSLOM is extremely poorly understood by most students and therefore they often are unable to answer the questions thereon within the National Certificate physics examination. Research suggests that teaching using CSs within an inquiry-based learning environment can have benefits on the teaching and learning of NSLOM.

The aim of this study was to determine the impact of CSs on the UAE students' learning of NSLOM and attitudes toward physics within the context of scientific inquiry instruction in two schools in Al Ain city, UAE, and seven research questions guided the study.

To answer the seven questions that guided the study, two groups were compared. One, where the teachers were using the traditional face-to-face method of teaching as the CGs, and the second group, CSs within an inquiry-based learning environment were used, where the students were given the opportunity to manipulate the simulations and actively learning with a context of inquiry learning.

This chapter highlights and discusses the main results of the seven research questions in the study considering the results of past research studies, theoretical backgrounds, and other relevant research studies. First, the results of the research questions are discussed and presented separately and compared with the results of relevant studies in different contexts. Second, a conclusion of the entire research is drawn. Third, implementations and recommendations for the fields of physics education and research are provided. Finally, future research opportunities are offered to fill the research gap locally and beyond.

5.2 Discussion of Research Question One and Two

The first research question of this study was " What impact do CSs have on student performance in Newton's second law of motion within an inquiry context?". The analysis of the pre-and post-test data showed that there is an impact on the performance of the students when they were given the opportunity via manipulation of the CSs in the classroom (see section 4.2). The analysis showed that 73% of students who answered NSLMAT correctly, provided explanation to their responses with 70% of response were correct. This result indicates that CSs have contributed to improvement of their knowledge and understanding. When comparing the improvement in the mean post-test scores, the CGs showed the lowest improvement. The EGs students who were subjected to CSs within an inquiry-based learning environment, performed better than the CGs students. The Hake's normalized gain which is presented in section 4.2 also revealed the success of the CSs in teaching and learning of the NSLOM. The Hake's normalized score of 0.16 for the CGs suggests that the method employed in this group promoted a very little understanding in NSLOM or the learning was less effective. However, the Hake's normalized score of 0.55 for the EGs suggests that the method employed in this group promoted a significant understanding in NSLOM or the learning was more effective.

These results revealed that CSs through visualization help to establish connection and draw attention to the concepts and details of NSLOM, and therefore, students become active participants as they attempt to mimic the reality of the small world and include many topics and real relationships in a reference frame (Hirshman & Bjork, 1988; Stieff, Bateman & Uttal, 2005). Furthermore, Husain (2010) argues that CSs encourage independent, experiential and discovery learning, unlike, students interact with the system, change parameters and track their effects accordingly. Additionally, these results revealed that the use of CSs as an interactive demonstration tool in the classroom for teaching and learning of the NSLOM was effective. EGs student's performance improvement may be attributed to the role of teachers and students in this group. The result of the study is in line with the theoretical framework that is Constructivism. In the constructivist view, students, learn in accordance with their own potential, building knowledge through collaboration and social activities. CSs learning environment also gives students the opportunity to learn by building knowledge through activities. The constructive principle used by the teachers is responsible for the success of this group. In this group, the teacher was a facilitator that helped the students to develop their understanding and ability to perform difficult tasks in a meaningful environment. The teachers provided the environment and tools to help explain the various relationships at NSLOM and this helped the students gain their understanding. According to Philips (1997), constructive theory enables students to actively participate in the development of knowledge and to take an active part in the learning process. In the EGs, students were provided with and guided with more authoritative tasks. This allowed teachers to use more reflective methods in different lessons.

The results of this study are in line with previous studies of CSs effect based on a constructivist approach to alleviating confusion in physics learning/teaching, including those reported by Ghadiri, Norouzi and Fardanesh (2016), and Vick (2010). As CSs make visual modeling more realistic, abstract systems become more concrete, or graphic representations of abstract systems (Wibowo et al., 2016). It is well suited for reducing complexity through tools such as slow-motion experimental observations in the process of hypothesis formation, experimentation, and data interpretation (Chang et al., 2008; Posner, Strike, Hewson & Gertzog, 1982), as well as clarifying observations (Renken & Nunez, 2013; Coştu et al., 2017). The success students taught using CSs within an inquiry-based learning environment is also due to the conceptual change approach that was adopted by the teachers to help students sort the information based on the information previously gained for later retrieval. In the EGs, the teachers used CSs in the context of scientific inquiry, where students are liberated by creating ideas in their minds and finding solutions to problems. According to Chang et al. (2008), brief interactions such as CSs contribute to the acquisition of knowledge and the additional process of conceptual change.

The data showed that there was a performance gain for the first and second tier items. One possible explanation for this phenomenon lies in the procedures used during class. The 5E inquiry model that students used in the lesson should helped them organize and develop a good understanding. This is when the EGs first started using the CSs. Since students were still familiar with the simulator, less effort may have been expended in learning physics concepts, which could lead to the significant difference in their performance noted. The results of this study are similar to the study by Yuksel, Rebello and Bryan (2017), in which their research showed that students who received model-based inquiry instruction increased the complexity of their explanation compared to the traditional compute-based instruction group. The results of this study are also similar to the study by Sarı, Hassan, Güven and Şen (2017), in which their research showed that the 5E teaching model integrated in the CSs has the potential to help 11th grade students to improve their physics academic performance. The success of the use of CSs in this study confirms the findings of Bayrak (2008), Jimoyiannis and Komis, (2001), Holec, Spodniaková Pfefferová and Raganová. (2004), Adesina (2013), Bakaç, Kartal and Akbay (2011). The finding is also in line with those of Sreelekha (2018) findings that claim the effectiveness of CSs on senior secondary school students' achievements in practical physics in Educational district III, Lagos state, Nigeria. Ghadiri, Norouzi and Fardanesh (2016), and Eveline, Jumadi, Wilujeng and Kuswanto (2019) confirmed the impact of scaffolding learning through CSs on students' conceptual understanding and academic independence. This supports the role of teacher and student is central in the use of various simulations in the classroom, especially at the secondary school level.

In summary, the results of this study showed that CSs within an inquiry-based learning environment produced a better performance and retention in students than the conventional model of instruction (face-to-face), as a method to help understand conceptions that are held by students on NSLOM topics taught.

To respond to Research Question two, which focused on determining if there is a difference in students' performance in NSLOM between control and treatment groups (CSs within an inquiry-based learning environment and face-to-face instruction), the effect size of knowledge gaining was calculated to compare the effect of CSs within an inquiry based learning environment on the NSLMAT performance of each group. A significant effect was observed in the overall post-test between the EGs and CGs. The CSs were more influential in increasing the knowledge of the students' NSLOM contents than the face-to-face instruction. Post-test one-way ANOVA was used to determine whether the EGs of the post-test CGs differed significantly after the intervention. A significant effect was observed after the overall examination between the EGs and CGs. Paired-sample t-test was conducted to test whether there was a significant difference between each of EGs pretest mean, and posttest mean scores and CGs pretest mean, and posttest mean scores. It is interesting to note that the results showed that CGs instruction had a moderating effect on students' understanding of NSLOM compared with that of EGs. Furthermore, the results indicated that face-to-face instruction helped female students better understand NSLOM contents, compared to male students. The results also showed that CSs within an inquiry-based learning environment had a significant effect on female students and male students. These results suggested that CSs within an inquiry-based learning environment can help both female and male students gain a better understanding of NSLOM topics.

Results of this research show that students in the EGs performed better than students in the CGs. That is, students are doing better using CSs in the context of scientific inquiry. A possible explanation for these results is that the students may be motivated to better understand the concepts, which may have enabled the students to achieve better grades. In particular, CSs within an inquiry-based learning environment can produce more results than those taught in face-to-face instruction, which may make students more interested in extending the experiment. Through these experiments, students were able to gain a deeper understanding of the basic principles of each lesson (Mengistu & Kahsay, 2015; Podolefsky, Perkins & Adams, 2010). The positive impact of CSs on students' performance is likely to have a positive impact on students' attitudes toward physics. In this way, the CSs might have changed students' perceptions of physics, leading to better teaching in physics, which is reflected in their achievements. Compared to the CGs, EGs students were more interested in physics, enjoyed physics learning more, and more confident in their ability in mathematical physics (Bozkurt, & Ilik, 2010; Rutten, Van Joolingen & Van der Veen, 2012; Quellmalz, Timms, Silberglitt, & Buckley, 2012; UAEG, 2019). Therefore, CSs can be used as an alternative classroom learning tool. This conclusion is important and worth further discussion.

Another possibility is that the EGs showed significantly better performance than CGs due to increased student participation. CSs provided tools that make physics education more effective. Efficiency is reflected in two aspects. First, learning by CSs can save students time in performing complex calculations and manipulations (Widiyatmoko, 2018; Wilson, 2016). The students involved in the EGs were also able to create different examples in addition to the ones shown due to different graphing options that allow the student to retain the main plotting features (Husain, 2010; Stieff, Bateman & Uttal, 2005; Stern, Echeverría & Porta, 2017). In CGs, this feature was not available in the Graphing Calculator, so students cannot work with other examples. Second, CSs enable students to be more organized, store, and process data (Stern, Echeverría & Porta, 2017). This gives students more opportunities to communicate and interact with each other. For example, students can talk to each other and discuss possible solutions and methods. They can advance various assumptions, test these assumptions, and see the results of these tests instantly. In this way, CSs can allow students with opportunities to discuss and interact with each other and with content. This better interaction can lead to a better understanding of physics.

It should also be noted that students at CGs, did not have a time to perform a proper inquiry process to provide sufficient scaffold. An important principle of constructivism, identified by Papert (2020) and Stieff, Bateman and Uttal (2005) is to provide students with scaffold and the opportunity to construct, test, and evaluate their own learning, to foster meaningful learning and a deeper understanding of knowledge. This evaluation could be effectively performed by an EGs teachers who are considered to be familiar with inquiry instruction. Therefore, students have the opportunity to reflect the results obtained from PhET simulation as needed. However, in CGs, students did not have the opportunity to reflect the results they obtained from face-to-face learning as needed. Therefore, in all the physics classes, it is important for teachers to encourage this reflection so that students can develop and deepen their understanding.

The results of this study are in line with previous research on the effects of CSs, including those reported by Bayrak (2008), Holec, Spodniaková Pfefferová and Raganová (2004), Mengistu and Kahsay (2015), Çetin (2018), Sreelekha (2018), and Sarı, Hassan, Güven and Şen (2017). The findings of these research studies showed that the use of CSs in physics and science education can improve physics outcomes. Furthermore, the results of this study also support the results of two meta-analysis studies. In the first meta-analysis, 29 experimental studies concluded that CSs instruction was more effective than traditional classroom instruction on students’ achievement (Liao & Chen, 2007). In another meta-analysis, Rutten, Van Joolingen, and Van der Veen, (2012), who reviewed 510 experimental studies involving CSs, concluded that CSs improved learning outcomes and facilitate students' conceptual understanding, CSs can also have a positive effect on students' satisfaction, participation and initiative, and improve their perception of the classroom environment.

Finally, the results of this study showed that using CSs within an inquiry-based learning environment made notable contributions to students' conceptual and procedural learning of NSLOM. These results suggested that CSs within an inquiry-based learning environment can help male and female students better understand NSLOM topics. That is, students are doing better using CSs in the context of scientific inquiry (Smetana & Bell, 2012; D'Angelo et al., 2014; Srisawasdi & Panjaburee, 2015; Abou Faour & Ayoubi, 2017).

5.3 Discussion of Research Question Three and Four

To address research question three and four, which focused on comparing student performance regarding conceptual and procedural understanding in Newton's second law of motion, between students who studied through CSs within the context of scientific inquiry instruction and students who studied through traditional face-to-face instructions.

Paired-samples t-test and effect sizes were used to determine if there were any significant changes in the performance from pretest to posttest within the scope of the conceptual and procedural domains. The effect size indicated that the acquisition of

CSs within an inquiry-based learning environment made a significant difference on the conceptual understanding of the NSLOM compared to the students in face-to-face instruction. Moreover, there is a significant difference between the EG's pretest and posttest scores. Overall, the results showed that students who learned about NSLOM in CSs within an inquiry-based learning environment had a better conceptual understanding of NSLOM than students who used face-to-face instruction ($t(44) = -12.4$, $p < 0.05$). Paired sample t-test and the effect sizes also suggest that both male and female students benefited more from CSs within an inquiry-based learning environment in the NSLOM conceptual domain. This because CSs provide an engaging and interactive visual environment that enhances and supports conceptual and procedural understanding. Students can manipulate the parameters and use the results of the manipulation to construct new meanings in constructive ways. By enabling students to build relationships and connections between ideas and concepts, building this new knowledge can improve grades and strengthen understanding of concepts (Wieman, Adams, Loeblein & Perkins, 2010; Couch, 2014). According to Holec, Spodniaková Pfefferová & Raganová (2004), CSs can communicate dynamic information more accurately than diagrams and help students observe different phenomena. CSs allows students to see things that are usually too fast, too slow, or hidden.

Similarly, the effect size suggests that CSs within an inquiry-based learning environment made the biggest difference in NSLOM students' understanding of procedures compared to face-to-face instruction. Furthermore, there is a significant difference between the pre and post test scores for the EGs. Overall, the results indicated that students who learned NSLOM with CSs gained a better procedural understanding of NSLOM compared to students who used face-to-face instruction ($t(44) = -3.86$, $p < 0.05$). Paired sample t-test and effect sizes also suggest that both male and female students benefited more from CSs within an inquiry-based learning environment in the NSLOM procedural domain. This is because CSs provides learners with a realistic experience through which knowledge can be acquired and manipulated to better understand the relationship between the concepts studied. The results of the study are in line with the theoretical framework that is conceptual change approach. As, CSs provide a rich environment that eliminate distractors and constrain learning to relevant evidence through tools such as slow-motion experimental observations in the process of hypothesis formation, experimentation, and data interpretation. CSs can combine animation, visualization, and interactive laboratory experience (Widiyatmoko, 2018). Moreover, NGSS (2013) claimed that engaging in the scientific practice helps students understand the development of scientific knowledge. This direct participation provides them an understanding of the many methods used to explore, model, and interpret the world.

This study shows that male students improved more in their conceptual understanding than female students through the use of CSs. While female students were initially lagging in their conceptual understanding, the use of CSs helped them to catch up with their male counterparts. However, when it comes to procedural understanding, the support by CSs is less helpful. High effect sizes of improvements were reported for both gender in conceptual understanding. With procedural understanding, considerably lower and medium effect sizes were reported for female and male students, respectively. One reason might be biological differences such as quantitative skills and spatial visualization (Kahle,1994). This gender gap may be related to students' confidence (OECD, 2015b). When students are more confident, they give themselves the freedom to fail and engage in the trial and error that is fundamental to the acquisition of science / physics knowledge. A closer look at females' performance in science shows that females still lag behind males in their ability to "think like scientists" (OECD, 2015b). For example, females tend to lag behind males in academic performance when asked to mathematically formulate a situation and translate a word problem into a mathematical expression. According to the OECD (2015b), females are generally less self-efficacious in science than males. However, recent trends in international competition studies such as PISA and TIMSS showed different results and the gender gap depends greatly on the type of problem or situation males and females face. For example, males were more likely than females to feel confident that they would be able to discuss how new evidence can lead to a change of understanding about the possibility of life on Mars. However, females reported being more confident than males in describing the role of antibiotics in treating disease. Cultural beliefs can make females less confident than males because science is believed to be included in male-type tasks (Gokhale, Rabe-Hemp, Woeste & Machina, 2015). Finally, tackling underperformance among males requires first examining some of the differences in how males and females spend their time, both in school and after school, and in their behavior and attitudes towards their teachers (OECD, 2015b). For example, males are more likely than females to spend time on computers and the Internet, males are less likely than females to read outside of school for enjoyment, and males are more likely than females to play chess and program computers. Moreover, there are large differences in the extent to which males and females use a computer at school to play simulation games, according to the students' reports, this activity is not common for females (OECD, 2015b).

The results of this study are consistent with previous research on the effects of CSs on student performance in physics, including those reported by Finkelstein et al. (2005a), Zacharia and Anderson (2003), Hazelton, Shaffer and Heron (2013), Finkelstein, Perkins, Adams Kohl and Podolefsky (2005b), Abou Faour and Ayoubi, (2017), and Sreelekha (2018). Their research suggested that CSs can improve conceptual understanding and promote students' physics learning. The results of this study also support the findings of Adam, Lutfiyah, Mubarok and Suprapto (2020), Jimoyiannis and Komis (2001), and Nestel, Groom, Eikeland-Husebø and O'Donnell (2011), their research suggested that CSs can improve procedural understanding and help students overcome cognitive limitations. In a meta-analysis, 50 empirical studies and 61 consecutive primary studies have concluded that animation is generally beneficial for learning compared to static graphics displays (Berney & Bétrancourt, 2016). The results showed that the students in the EGs performed better than CGs students. In other words, the students performed better in using CSs; Therefore, CSs can be used as an alternative classroom teaching tool. This finding is important and deserves further examination. First, this study found that the CSs within an inquiry-based learning environment improved students' conceptual and procedural understanding of NSLOM. The results of this study are similar to those of Kollöffel and De Jong (2013), in which their research showed a significant gain in achievement scores in conceptual and procedural understanding involving 56 students in intermediate level vocational engineering training participated. Their results indicated that CSs may encourage students to perform well in conceptual and procedural domains and allow them to perform well in assessments. More specifically, the use of CSs allows students to be more interested in developing their experiences, as CSs can provide students with learning environments in which students search for meaning, appreciate uncertainty, and acquire responsibility (Akpan, 1998).

Second, another possibility is that the EGs had a significantly higher success proportion than CGs, which may be due to the increasing level of student engagement. CSs has provided tools to make NSLOM learning more engagement and effective. Engagement and efficiency are reflected in two aspects. First, as mentioned previously that learning with CSs saves students time in performing complex calculations and tasks. The students in the EGs were also able to demonstrate different examples. For example, students were requested to test their predictions using PhET interactive simulation. When students tested their hypotheses using PhET simulation, dynamic animations, images, charts, tables displayed in the computer interface, and printed words on textbooks helped to scaffold students' understanding. It is plausible that multiple representations in PhET simulations helped students understand concepts through the visual image channels. Second, CSs make it easier for students to organize, store, and manipulate their data. This has increased the opportunities for students to engage and interact with each other. For example, when students work in groups, they can talk to each other and discuss possible solutions and methods and they become engaged, they can make different hypotheses, test these hypotheses, and get the results of these tests immediately. Therefore, CSs can provide learning opportunities for students to communicate and interact more with each other and with the content. Such better interactions can lead to a better understanding of conceptual and procedural knowledge.

Third, another possibility of achieving significant performance in EGs compared to CGs may be attributed to the use of CSs within an inquiry-based learning environment, since teaching using inquiry instruction provided different activities to support students' acquisition and integration of NSLOM concepts.

Fourth, this study showed that CSs had a positive effect on student attitudes. The positive effect of CSs on students' conceptual and procedural performance can bring about a positive change in students' attitudes towards physics. That is, the CSs has changed students' attitudes toward physics as will be described later, which may lead to improved conceptual and procedural learning, which is reflected in their academic performance. Compared to CGs, students in EGs were more interested in physics, enjoyed more physics learning, were more confident in their physics with CSs, and appreciated physics more. These may have reduced phobias students may have about physics. Too often, these phobias leave students with the attitudes that they may not be able to succeed (Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). This lack of success in turn may lead to weak grades and a negative attitude. Through the positive experience of using CSs in this study, students' phobias can be reduced, and they can feel more confident, which can lead to improve their academic performance (Panoutsopoulos & Sampson, 2012).

Finally, CSs can provide meaningful and useful approaches to teachers. Teachers often express concern that they do not have time to find tools to help with learning (Swars, & Chestnutt, 2016). Lack of time often leads to boring and dual lessons. In this study, the remarkable results provide teachers with a teaching method that can improve academic performance, as well as promote a positive environment that allows students to develop a positive attitude towards physics. Physics teachers not only strive for excellence in physics, but they also want their students to adopt a more positive attitude that goes beyond the physics class. Therefore, CSs is important for physics teachers because it helps students to adopt a more positive attitude towards physics.

5.4 Discussion of Research Question Five and Six

In an attempt to answer the five and the six research questions focusing on attitudes toward physics, students completed the three scales adopted from TOSRA survey in this study. The survey measured attitudes in physics to determine if there is an increase in attitudes toward scientific inquiry, the enjoyment of science lessons, and a career interest in science. An independent sample t-test was conducted to determine if there was a significant difference between the mean of the two groups of students. The effect size was calculated to compare the effect of CSs on students' attitudes toward physics in each group. Significant MANOVA results were followed up with univariate ANOVA on each dependent measure separately to determine the locus of the statistically significant multivariate main effect of groups and gender on differences in attitude towards physics among attitude to scientific inquiry, enjoyment of science lessons, and career interest in science.

Students' attitudes play an important role in physics education. The development of students' negative attitude towards physics is one of the major reasons why students have difficulty in learning physics. Therefore, it is very important that the methods of physics teaching develop a positive attitude and encourage students to learn (Sarı, Hassan, Güven, & Şen, 2017; Oymak & Ogan-Bekiroglu, 2017).

According to the results of the TOSRA posttest scale, there are significant differences between the two groups in terms of scale factors. It was found that there were significant differences between the EGs and CGs in attitudes toward scientific inquiry, the enjoyment of science lessons, and a career interest in science. It can be noted that due to the personal interaction of the students, the attitude towards scientific inquiry, the enjoyment of science lessons, and a career interest in science in the EGs is noticeable. In this case, it can be said that CSs has a positive effect on students' attitudes towards learning physics. Similarly, the adoption of CSs has the most significant effect on improving the attitude of male and female students towards physics. This is because CSs can be performed by providing simplified models of phenomena and encouraging students to observe, discover, reconstruct, and receive immediate feedback about objects, events, and processes. Through CSs, students can change variables and track the results to produce scientific results. CSs can also provide capabilities to visualize hazardous, time-consuming or complex events for classroom or laboratory interactions (McDonald, 2016); Widiyatmoko, 2018; Blake & Scanlon 2007; Couch, 2014).

This study showed a higher gain in attitudes among students who use CSs than among students who do not use CSs. In this study, there was a significant increase in attitudes toward physics was found through the use of CSs. Research has shown that higher attitudes in physics can contribute to higher performance in physics (Kattayat, Josey & Asha, 2016; Sari, Pektaş, Çelik & Kirindi, 2019). Students with low attitudes may avoid physics-related situations. Those students with high levels of or positive attitudes may have a greater chance of overcoming negative situations in physics (Sari, Pektaş, Çelik & Kirindi, 2019; Sarı, Hassan, Güven & Şen, 2017; Oymak & Ogan-

Bekiroglu, 2017). In this study, CSs had a positive impact on students' attitudes, which may encourage students to have an additional desire to study more about physics.

On the other hand, methods such as face-to-face classroom instruction do not motivate the student to perform. In this study, the use of CSs showed that students are highly motivated to learn. Findings by Kattayat, Josey and Asha (2016), Sari, Pektaş, Çelik and Kirindi (2019), Sarı, Hassan, Güven and Şen (2017), Oymak and Ogan-Bekiroglu (2017), who found that when CSs approach was embedded in the instruction, the students became better learners and their attitudes increased towards physics. An increase in attitudes can lead to a more positive environment for students and teachers. This positive environment will enable students to pursue learning in a variety of fields. This current study also confirmed the results of Kattayat, Josey and Asha (2016), which showed that there is a positive and significant relationship between the physical achievement of adolescent students exposed to CSs assisted instruction and their attitude towards Physics. Through the use of CSs, students can design situations through their learning processes and speeds, which gives students greater success and accountability. This accountability and success provide teachers with resources to help motivate students.

The results of the study are in line with the theoretical framework that is information process theory, as learning takes place, information is entered from the environment, processed, stored in memory, and released in the form of educational capabilities. CSs provide an ideal environment to promote student's attention and awareness of the information received.

Researchers such as Finkelstein et al, (2005b) and Pyatt and Sims (2012) have suggested that the use of internet-based tools such as CSs may lead to a more successful learning environment that surpasses traditional approaches. Burton, Kijai and Sargeant (2005), suggested that it is imperative to provide students with more information about physics / science subjects and its future use, which will stimulate further interest in physics and science.

Attitude towards scientific inquiry

Vick (2010) mentioned that using PhET simulations in an inquiry-based context, helps students visualize the invisible world of electrons and dispel the misconception that electrons are used up in a circuit. In addition, Fan, Geelan, and Gillies (2018), have demonstrated that a combination of interactive simulations and inquiry-based learning can enhance the development of students' conceptual understanding, inquiry process skills, and confidence in learning. As a result, it can be said that the CSs within an inquiry-based learning environment has positively influenced the attitude of the students towards scientific inquiry. This finding is consistent with a study by Abdullah and Shariff (2008) who reported that inquiry-based CSs with heterogeneous-ability cooperative learning method is effective in enhancing scientific reasoning and conceptual understanding for students of all reasoning abilities. This finding is also consistent with the previous research by Sari, Pektaş, Çelik and Kirindi (2019), who concluded that computer-based laboratory and virtual laboratory applications have a positive effect on students' attitudes toward physics and motivations.

The current study showed that there was a significant difference between student groups in terms of (experimental and control) attitudes toward scientific inquiry, F (1, 49.900) = 49.900, p = 0.000, partial η^2 = 0.748. Students' attitudes increased due to the significant effect of CSs. Studies have shown that the use of CSs within an inquiry-based learning environment in comparison to face-to-face instruction yields incomparable results in improving students' attitudes, scientific knowledge, and performance (Kattayat, Josey & Asha, 2016; Bakaç, Kartal, & Akbay, 2011). The results showed that CSs within an inquiry-based learning environment has a positive effect on students' physics attitudes in a simulation-based inquiry-learning environment. The study has shown that CSs within an inquiry-based learning environment could provide benefits such as increasing interest in class and increasing self-confidence. Cairns and Areepattamannil (2019), conducted a study that used three-level Hierarchical Linear Modeling (HLM) as an analysis strategy to determine the relationship between inquiry-based science teaching, scientific achievement, and personality. Of the 170,474 15-year-old from 4,780 schools in 54 countries, all are interested in science. The results of the HLM analysis showed that inquiry-based science education is very important. It is highly positively related to interest and joy in learning science, effective scientific motives for the future, scientific self-esteem, and self-efficacy. This finding is in line with a study by Yuksel, Rebello and Bryan (2017), who reported that students' sophistication of their explanations was enhanced when students took model-based inquiry instruction compared to the traditional computer-based instruction.

In this study, CSs within an inquiry-based learning environment was carried out through the inquiry learning strategy. In inquiry learning, students often conduct processes such as making observations, creating research questions, designing hypotheses, designing and executing experiments to test hypotheses, creating and interpreting data, creating models, communicating, and prediction (Pedaste et al., 2015). CSs within an inquiry-based learning environment was carried out within the framework of the five-step inquiry cycle proposed by Hsiao, Hong, Chen, Lu & Chen (2017). During the engagement phase of this cycle, teachers use learning activities to foster student curiosity and activate the prior knowledge needed to learn new topics. During the exploration phase, students have done the necessary research to develop possible solutions based on students' experiences in the engagement. In this context, they have hypothesized to solve the problem and to test their hypotheses, they have designed and conducted a virtual experiment using CSs. Thus, CSs provided a link between the solution of the actual problem and the discovery. Students used CSs to develop models to solve problems and try to find the best solution. In other words, CSs have been used in the elaboration phase of scientific inquiry, in order to provide the necessary research and solution to solve new problems. In this study, the student's ability to design and perform virtual experiments using CSs shows that these simulations are effective in developing their scientific inquiry skills. For example, Huppert, Lomask and Lazarowitz (2002) found that CSs have a positive impact on the development of scientific process skills such as measurement, classification, graphical interpretation, data interpretation, variable control, and model design. Bell, Urhahne, Schanze and Ploetzner (2010) emphasize that students can make hypotheses and test using CSs more easily and quickly.

Nevertheless, the study showed that there was no significant difference among students' gender in their scores of the two groups on attitude to scientific inquiry, it was found that the students' personal interest and confidence in scientific inquiry was independent of their gender. All students, regardless of their gender, were equally receptive to gains in interest and confidence. The findings suggest that experiential learning in the form of CSs within an inquiry-based learning environment can contribute to increasing students' confidence and self-efficacy in scientific inquiry and can potentially increase students' interest in physics. Students with experience in scientific inquiry can add to the perception that they are qualified to do research (Robnett, Chemers & Zurbriggen, 2015).

Enjoyment of physics lessons

In the present study, the students' attitudes as measured by the level of enjoyment of physics lessons, was examined. The results indicated a significant effect in post-survey results between learning of CSs within an inquiry-based learning environment and face-to-face instruction environments. The study showed that there is a significant difference between student groups (experimental and control) regarding their scores on attitude to enjoyment of science lessons, $F (1, 49.767) = 49.767$, $p = 0.000$, partial $\eta^2 = 0.785$. The EGs had a greater increase in enjoyment in the classroom. Similar to the results in this study, Quinn and Lyons (2011) and Osborne and Collins (2001) found that students in Australia enjoying studying science. It seems that there is a considerable interest in shaping a student' s attitude towards science. These studies have found that enjoyment in science is highly correlated with continuation in physics and reveal large gender differences in such enjoyment. School enjoyment and interest in lessons is strongly enhanced by student sense of autonomy – including being able to work at their own pace, discussing issues with staff and other students, and encouraging them to make up their own minds about issues raised (Gorard & See, 2011). Gorard and See (2011) suggested that greater enjoyment of learning may be associated with greater student engagement and thus better education. Enjoyment could enhance attendance and inclusion at school, and lead to higher participation in education and training following school. It is part of building a student's lifelong identity, welcoming and finding opportunities for later learning. Students enjoy physics lessons because the delivery and activities of CSs approach are diverse (Gorard & See, 2011). CSs have great potential to improve students' learning as it can individualize learning to match student's pace, interests, and capabilities of each student and contextualize learning in engaging environments, as well as the increased use of CSs in science classrooms can potentially improve access to high-quality learning experiences for students in diverse context (Council, 2011, p.67). It was found that students in EGs found the physics lessons important and fun because it included examples of everyday life and that their knowledge about physics, they had learned in class was permanent. In the study of Gorard and See (2011), it was striking to find that a remarkable number of male and female students found the material included in science lessons interesting and fun.

In addition, this study investigated whether the male and female students enjoyed physics lessons. Results showed that the two groups had a significant difference between male and female students in their scores on enjoyment of science lessons, F (1, 1.022) = 1.022, p = 0.013, partial η^2 = 0.070. Female reported it to be significantly higher (M = 4.23, SD = 0.30) than male (M = 4.25, SD = 0.38). In support of Elwood and Carlisle (2003), the type of study has been shown to have significant effects on males' and females' enjoyment and motivation in learning physics. In this study, girls were significantly more positive in their perceptions about how CSs helped them learn physics; and in how much they expected and enjoyed in their physics lessons. Therefore, the findings underline how important it is for teachers to teach physics in a way that motivates boys and encourages their learning and development.

Parallel to the findings related to the enjoyment of studying physics, Stewart (1998) investigated the relationship between enjoyment and participation in physics and concluded that enjoyment of physics is more significant for girls than for boys as a reason for choosing it. Compared to 40% of girls taking Physics at A-Level made physics their favorite subject in GCSE, compared to 21% of boys. CSs within an inquiry-based learning environment improves the scientific discovery of students, which can be applied to the design of lessons materials, as students are committed to engaging in fun activities to explore and learn on their own.

As a part of their study of gender differences in examinations 18 year-old and above, Elwood and Carlisle (2003) surveyed 247 students from years 12 and 13 in England about their attitudes towards various aspects of the A-level physics syllabus. The study found that: Most of the students reported high levels of confidence and enjoyment; The female students' enjoyment of the subject was significantly higher than their male colleagues. In a study of 247 students aged 16 or 17 who chose A-level physics, girls had higher levels of physics enjoyment than boys, but all students had higher levels of confidence, motivation, and enjoyment, and They felt that the subject was socially relevant (Elwood and Comber, 1996). Because of CSs potential, students can understand abstract concepts in a more tangible way and interact with phenomena normally not accessible in a traditional classroom. CSs can provide students with the opportunity to practice decision-making in an environment that is both realistic and safe, and CSs can provide students with experience before actual activities.

Contrary to this result, the relevant literature found that there were differences between female and male students' perceptions of enjoyment in physics courses in favor of the male students (Kost, Pollock & Finkelstein, 2009). Reid (2003) showed that girls are much less likely to enjoy physical lessons than boys and are more likely to be bored, feeling unable to discuss or experiment with ideas. They do not pay attention in class and find the physics lessons less interesting and less confident. Seba, Ndunguru and Mkoma (2013) studied the attitudes of secondary school students towards physics and chemistry at selected schools in Tarimi-Mara, Tanzania. The study included 300 male and female students in private and public secondary schools. The data was collected using a reliable questionnaire. It was found that female students showed a negative attitude toward physics and chemistry compared to boys. Negative attitudes of female students are associated with lack of self-confidence, anxiety, and inadequate enjoyment of physics and chemistry.

Finally, students' attitudes toward physics lessons are more closely related to their intention to participate in discussing ideas, doing experiments, and knowing how well they are doing in physics. It is important to make physics an enjoyable subject for all students, whether or not they intend to pursue the subject after school.

Career interest in physics/science

With regard to career interest in physics/science, the current study showed that there is a significant difference between the student groups (experimental and control) in terms of their scores on career interest in physics/science, F (1, 43.99) = 43.99, p = 0.000, partial $\eta^2 = 0.797$. Students in the EGs scored significantly higher mean score (Mean = 4.26, SD = 0.29) than students in the CGs (M = 2.85, SD = 0.43). It was found that most of the students believed the CSs within an inquiry-based learning environment increased their interest in career related to physics/science. In this study, a positive attitude towards a career in science/physics may be due to their use of CSs when designing something and recognizing that the knowledge they possess are useful. As a result, it increases students' understanding and autonomy in society (Hidayati et al., 2017).

The importance of a career in physics/science is very valuable for students to participate in scientific improvements that will be useful to them and their country. Someone who has interests, skills, and confidence in a particular field will tend to have the desire to pursue a career in that field (Astalini, Kurniawan, Perdana & Kurniawan, 2019). The results suggested that CSs increase students' interest in career related to physics/science. CSs are a very suitable approach to physics as they help students develop skills and confidence to find solutions to real-life problems. CSs can be used effectively to study phenomena that are difficult to test in a classroom or laboratory environment because these phenomena are very complex, difficult, or technically dangerous, expensive, time-consuming, or very fast (Jimoyiannis & Komis, 2001; Hannel & Cuevas, 2018; Wieman, Adams, Loeblein & Perkins, 2010; Council, 2011). The students feel that CSs enables them to learn permanently, reify, and to relate to the daily life. In addition, students find CSs enjoyable, and they develop their attitudes towards physics by experimenting with physics to solve this problem. A large amount of research reporting that CSs within an inquiry-based learning environment enhances students' career interest in physics/science. Putra, Lumbantoruan and Samosir (2019) believe that if students spend time and are happy studying physics, they may decide to maintain their flexibility and pursue a career in physics. Although interest and enjoyment in physics are important constructs, they are not a sufficient reason for students to decide whether or not to continue studying physics (Elwood & Carlisle, 2003).

Interest in the profession of physics/science cannot be separated from an individual's determination to enter this field as a future career option. Students' interest in pursuing a career in physics/science is influenced by their learning outcomes and attitudes, as their interest and positive attitude in the field will stimulates their interest in physics as a future career consideration. Sadler, Sonnert, Hazari and Tai (2012) found that preschool activities are very important in increasing students' interest in science, technology, engineering, and mathematics careers, since students' interest in high school is stable. Students have a relatively high interest in physics / science related careers, possibly because they have considered family perspectives. According to a Turkish survey, one of the five parents expect their child to become a doctor in the future. Engaging in the life sciences, especially as a doctor in the medical field, is popular not only for students but also for families (Yerdelen, Kahraman & Taş, 2016). Elwood and Carlisle (2003) contended that girls value social programs more than boys and hope that they will have more social importance in physics lessons, which may be linked to higher employment rates for girls and retention in physics courses that focus on practical applications. In last five years in the United States, for example, the number of women representing science has also increased exponentially (Miller & Wai, 2015). For example, from 1960 to 2013, among scientists working in the United States, the percentage of women in the biological sciences increased from 28% to 49%, the percentage in chemistry increased from 8% to 35%, and the percentage in physics and astronomy increased from 3% to 11% (Hill, Corbett, & St. Rose, 2010).

Additionally, there is a significant difference between the gender of male and female in terms of professional interest in physics/science, F (1, .845) = .845, p = 0.013, partial η^2 = 0.070. Female's scores (M = 4.35, SD = 0.23) were significantly higher than male students (M = 4.19, SD = 0.32). The results of the study showed that compared to females, males are less interested in a physics/science related career, feel bored and lose attention in class, and find physics less interesting. This result concurs with the literature. For example, Miller and Wai (2015) found that high school students believe that scientists are isolated, have little time for social activities and that scientists' work has nothing to do with social problems. Although the students believe that physics is linked to their future profession, male students are not intended to continue their higher studies in the field (Elwood & Carlisle, 2003). There is evidence that girls are more likely to choose physics/science as a career option if they get to know others who promote them with regards to science, and girls themselves define that they are able to participate in scientific work because of their relationships with others (Baker & Leary, 1995). Miller, Blessing and Schwartz (2006) suggested that high school students are associated with positive attitudes while enjoying and taking an interest in science. In addition, the study also found that male students are not interested in a physics career and believe that physics subjects are difficult and need more time to study. Therefore, it is recommended that students be encouraged and motivated by providing them a supportive environment and learning materials. Aside from the fact that students dislike physics from the beginning, they also point out that a career in physics/science require a better understanding of career physics/science and being a scientist will be boring because they are often spending time in the laboratory (Sukarni, Jannah, Qoriyana & Zain, 2020).

The result of this study showed inconsistence with Seba, Ndunguru and Mkoma (2013) who indicated that the differences in the attitudes of boys and girls towards scientific subjects lead to the lowest number of women in the sciences profession compared to men. A meta-analysis study by Miller, Nolla, Eagly and Uttal (2018) found that children relate science to men. These results may indicate that although women's representation in science has increased over time, children notice men more than women in their environment. In his study of Scottish schools, Reid (2003) found that twice as many boys had a positive attitude toward physics as girls, and it was students who expressed an interest in studying physics after the age of 16 because of its usefulness for future careers and other aspects of their lives.

It is clear that the gender patterns taken up after the age of 16 are at least partly due to the different psychological characteristics of boys and girls (Sandika & Fitrihidajati, 2018). For example, boys were found to be more purposeful, dominant, independent, and competitive, while girls were more socially responsible, cooperative, and person orientated (Sandika & Fitrihidajati, 2018). Studies showed that early scientific experience will influence physics/science career choices and show that boys and girls have very different experiences, while boys prefer science-type outings, encouragement, and hands-on experiences (Baker & Leary, 1995; Miller, Blessing & Schwartz, 2006; Christidou, 2006). Numerous findings regarding gender differences in students' choices and perceptions of science subjects show that girls prefer and choose the biological sciences, whereas boys like and choose the physical sciences (Christidou, 2006; Miller, Blessing & Schwartz, 2006). Contrary to this view, Skryabina (2000) stated that if the content of physics lessons reflects the interests of girls, then physics may be more attractive to girls. Therefore, teachers need to know the attitudes of students during the learning process, because keeping this in mind, the teacher can improve design of learning in the classroom about the abilities the students have (Astalini, Kurniawan, Perdana & Phatoni, 2019).

The reason for less interest in pursuing a career in science or physics is usually the experience of failing to learn science in school. This is because, in most cases, science education does not attract students' interest by providing content that is irrelevant to their everyday context (Astalini, Kurniawan, Kurniawan & Anggraini, 2019). As such, CSs can combine animation, visualization, and interactive laboratory experiences that provide an engaging, interactive visual environment that enhances, and supports conceptual understanding. Students can manipulate the parameters and use the results in creative methods to construct new meanings (Wieman, Adams, Loeblein & Perkins, 2010; Couch, 2014). According to McDonald (2016) and Widiyatmoko (2018), CSs provide opportunities to imagine risky, time-consuming, or complicated events for interaction in the classroom or the laboratory. CSs can be achieved by providing dynamic theoretical models simplified models of events, or processes, and encouraging students to observe, discover, reconstruct, and quickly obtain feedback on objects, events, and processes.

At the context of the present study, the impact of the decrease in the number of boys studying science and physics could be attributed to the lack of scientifically educated men in the UAE. Reduction of scientifically trained employees has a negative impact on the national economy (Hill, Corbett & St Rose, 2010). Undoubtedly, this could lead to a shortage of key skills and knowledge, including a lack of skills and knowledge for future teachers who may not have the qualifications and background to nurture the next generation of students, particularly in the physics.

5.5 Conclusion

This study aimed at exploring the impact of CSs on grade 11 UAE students' learning of Newton's second law of motion and attitudes toward physics within the context of scientific inquiry instruction. To achieve the goal of the study, seven research questions were addressed to identify these effects. Mean scores and standard deviations were used to compare conceptual and procedural understanding scores differences between the EGs and CGs before and after the treatment. An independent sample t-test and ANOVA were used to determine the initial comparison of the two groups and genders before the intervention. The pre and post test results for the two-tier test were analyzed, and the percentage of correct answers that students get through this test is compared. Hake's normalized gain was calculated to measure the effectiveness of CSs within an inquiry-based learning environment in promoting conceptual and procedural understanding. The paired-samples t-test and effect sizes show that there is a significant difference in the pre and post test scores in the scope of conceptual and procedural domains. Additionally, paired sample t-test and effect sizes also suggest that both male and female students benefited more from CSs within an inquiry-based learning environment in the conceptual and procedural areas of NSLOM.

This research has shown that the use of CSs can improve the performance of physics students, particularly at conceptual and procedural levels. The MANOVA results showed that there were significant differences in attitudes as perceived among the three subscales for different treatment groups. Likewise, the MANOVA results showed that there was a significant difference in attitudes as perceived between the three subscales based on the gender of the students. Therefore, the use of CSs may likely lead to a positive change in students' attitudes towards Physics. In this study, a student's attitude towards scientific inquiry, enjoyment of science lessons, and career interest in physics/science increased. The results of this study suggest that CSs involvement in classrooms offers secondary schools' other opportunities to improve their performance in physics. In this context, the main results have been summarized as follows.

First, the results are generally expected and partially or fully supported by other research studies, and research results are highly relevant, nationally (Tairab & Al-Naqbi, 2017; Kassir, 2013; Aoude, 2015) and internationally (Mengistu & Kahsay, 2015; Sari, Pektaş, Çelik & Kirindi, 2019; Çetin, 2018; Batuyong & Antonio, 2018; Psycharis, 2011; Tawil & Dahlan, 2017; Abou Faour & Ayoubi, 2017; Martin, 2013; Almeqdadi & Halar, 2017; Alneyadi, 2019).

Second, this study found that the CSs within an inquiry-based learning environment improves students' conceptual and procedural understanding of NSLOM. CSs classes included a variety of activities to help students acquire and integrate physical concepts. In addition, this study has shown that face-to-face instruction improves students' conceptual and procedural understanding, but not as good as CSs within an inquiry-based learning environment. The difference between the two teaching methods was that the face-to-face instruction encouraged students to follow the teacher's instruction rather than developing the students' interests. As a result, the EGs identified more significant conceptual changes in understanding NSLOM than the CGs. In this study, inquiry-based learning with interactive PhET simulations successfully led to conceptual learning of students' in EGs than those in CGs. This result is consistent with an increasing number of studies that have shown the combination of CSs with the pedagogical framework works for students' learning (Finkelstein et al, 2005b; Zacharia & Anderson, 2003; Jimoyiannis & Komis, 2001; Hazelton, Shaffer & Heron, 2013; Bayrak, 2008; Abou Faour & Ayoubi, 2017; Mengistu & Kahsay, 2015; Çetin, 2018). The CSs within an inquiry-based learning environment provided students with more effective learning opportunities and their achievements outperformed face-to-face instruction (Podolefsky, Perkins, & Adams, 2009; Vick, 2010; Perkins, Moore & Chasteen, 2014; Sari, Pektaş, Çelik & Kirindi, 2019; Fan, Geelan, & Gillies, 2018). The results showed why the use of PhET simulations facilitated conceptual and procedural understanding (Batuyong & Antonio, 2018; Tawil & Dahlan, 2017), and that the PhET simulations provided an interactive virtual laboratory. The virtual lab supported implementation of experiments, particularly those that people cannot carry out in the real world. For example, NSLOM simulations created a frictionless setting where students modify parameters to test hypotheses.

Third, the result of this study challenges claims that gender differences are closely related to the science curriculum, favoring boys. In this study, female students performed as well as male counterparts. And the performance of female students was better than male students in the area of procedural understanding. The results of the current study support the assumption that when girls are engaged in the CSs environments, they can achieve the same success as boys (Abou Faour & Ayoubi, 2017; Chang, Chen, Lin, & Sung, 2008; Hazelton, Shaffer & Heron, 2013). Therefore, it will be safe to say that gender differences are on its way to decline in the UAE context, taking into account these findings and other finding such as TIMSS 2019.

Fourth, the 11^{th} grade students in EGs showed higher level of positive attitudes towards physics than their peers in CGs of the three TOSRA subscales. Since CSs within an inquiry based learning environment can effectively introduce young students to simple physical science concepts and provide them with opportunities to participate in higher-order thinking processes (Falloon, 2019), as well as provide an enjoyable learning environment, even on difficult physics topics like Newtonian mechanics; increased acceptance of tools and materials for experimentation, and increased attention that allows students to enjoy and learn a subject such as physics, which many students perceive as difficult (Ulukök, & Sari, 2016).

Fifth, the highest means of levels of attitudes were found in the average career interest in physics/science (M = 4.26) followed by enjoyment of science lessons (M = 4.24), and attitude to scientific inquiry had the lowest mean score (M = 4.01) in both EGs and CGs. However, in terms of group and gender interactions, no significant differences were observed in their career interest in science scores. This means that any student, whether male or female used CSs within an inquiry-based learning environment their attitudes increased in relation to that of the face-to-face attitude to scientific inquiry and enjoyment of science lessons groups. However, CSs within an inquiry based learning environment did not affect students' attitudes towards the career interest in science in terms of gender.

5.6 Implication and Recommendations

This study employed the NSLMAT and TOSRA survey to assess changes in NSLOM conceptual and procedural understanding of grade 11 students using two different teaching instruction approaches to determine which instruction would benefit students' learning; it confirmed the effectiveness of the CSs within an inquiry-based learning environment on improving students' conceptual and procedural understanding. The study also found that attitudes toward physics increased when students taught using CSs within an inquiry-based learning environment. Based on the described results of the research, the following are implementation and recommendations of the research.

First, this study has shown that CSs can improve student performance. CSs within an inquiry-based learning environment has more effect on physics performance than face-to-face instruction. As a result, decision makers and schools should gradually move towards CSs integration to improve students' understanding.

Second, this study shows how CSs can be useful for teachers. First, teachers have an alternative tool, CSs, that can be used to teach students physics. Teachers now have a tool to help students learn in the classroom. Second, teachers now have a tool that will enhance students' confidence in the classroom, boost their attitudes in physics, make physics more enjoyable for students, and can enrich students' knowledge, which in turn can be useful for more upper-level physics classes. Finally, teachers are challenged by unmotivated students in classrooms. These students are not only demotivated by their dislike of physics but also by their potentially poor skills (Asikhia, 2010). CSs provided teachers with the opportunity to provide students with a tool that not only allows them to enjoy physics, but also improves their physics skills. CSs allow teachers to use a tool in classrooms that can help transform a teacher-centered classroom into a student-centered classroom (Jacobs, Renandya, & Power, 2016). A student-centered classroom gives the lesson more task-oriented and makes the student the center of instruction. These instructional principles are principles that should be applied in every classroom today, so that students get the best opportunity to build their knowledge. Therefore, the CSs should always work to complement the student experience and expand it.

Third, NSLMAT and TOSRA surveys reported that students who were taught using CSs within an inquiry-based learning environment performed better than those who taught using face-to-face instruction. Thus, the implication of this is that CSs should be integrated in teaching physics to enhance students' attitudes and improve their physics performance. CSs provide students a tool that can take a theoretical principle such as NSLOM and apply the principle in different situations with ease. The student, in turn, can save the data and apply it to another case. CSs allow students to have a greater appreciation of physics through improving their attitudes toward physics.

Fourth, this study found that CSs achieve a conceptual change for grade 11 students, where CSs help students organize information based on information previously obtained for later retrieval, and through CSs students find topics of physics fun and relevant to their life or everyday experience (Wafer, 1996, cited in Lederman & Abell, 2014). The learning activity at each stage of 5E is based on the theory of conceptual change (Posner et al., 1982). Before a new concept can be adapted, there must be some dissatisfaction with the existing concept. The new concept should be tested through various training activities, and then be recognized as intelligible, plausible, and fruitful (Dole & Sinatra, 1998; Posner, Strike, Hewson & Gertzog, 1982). For example, during the evaluative forecasting phase, students use PhET simulations to test their hypotheses and record data. They have to pre-analyze the data and make claims. These instructional activities help students think of the new conceptions as intelligible. In the engagement, exploration, and explanation, more instructional activities, such as the teachers' explanation, aim to make students' conceptual understanding plausible. Finally, students' applications allow them to see that the conception as being fruitful. Therefore, it is recommended to teach and train students to apply these 5E strategies when learning physics; furthermore, these strategies should be integrated into the curriculum and teaching practices as well as, the assessment for learning and the assessment of learning.

Fifth, the results support the constructivist view that knowledge is constructed gradually by students and not directly transmitted by teachers. CSs provide an engaging and interactive visual environment that enhances and supports conceptual understanding. Students can manipulate parameters and use the results of these manipulations in constructive methods to build new meanings. By allowing students to form relationships between ideas and concepts, building this new knowledge can improve performance and deepen their understanding of concepts (Wieman, Adams, Loeblein & Perkins ,2010; Couch, 2014). The study proves that 5E model is election as an inquiry tool were used as platform for CSs. For instance, the engagement and exploration step comprise the students’ prior conceptions stage. The next steps of 5E are designed to help students gain a better conceptual and procedural understanding. As a result, more emphasis should be placed on constructivist strategies, as a constructivist approach promotes meaningful learning and a deep understanding of physical phenomena (Dori & Belcher, 2005, p.246), and provides students the opportunity to build, test, and evaluate their own learning (Papert, 2020; Hirshman & Bjork, 1988; Stieff, Bateman & Uttal, 2005). In addition, the results support the information process perspective that when learning occurs, information is entered from the environment, processed, stored in memory and released in the form of educational capabilities (McLeod, 2008; Zhou & Brown, 2015). In this way, CSs enables students to participate meaningfully in content, like; easily collect data, perform complex analysis, and individualized feedback needed for learning (Brown, Hinze & Pellegrino, 2008). It is also recommended that curricula and learning practices be combined so that students can build their knowledge internally, and use it effectively to solve problems, support their learning process, and provide some sort of interaction between students and programs.

Sixth, more emphasis should also be placed on CSs within an inquiry-based learning environment. It is observed that students in physics classes in the UAE have the opportunity to participate in a scientific dialogue, where students can interpret and defend their thinking. This engagement improves students’ confidence in learning when using computer-based learning resources. One explanation for the increased confidence in EGs came from the use of PhET simulations. As shown by Blum, Borglund and Parcells (2010). They found that the use of CSs can increase students' confidence, since CSs provide the opportunity to conduct experiments. Similarly, Lundberg (2008) stated that when students engage in PhET simulations, immediate feedback and appropriate testing opportunities increase student confidence. Additionally, Bunker (1991) found that students' confidence can be increased if they challenge the results of others. In this study, CSs within an inquiry-based learning environment encourages students not only engage in the investigative activities, but also engage in discussion and argumentation. For example, the final phase of the 5E strategy involves student presentations. It encourages students to share their ideas, and other students to challenge the results by using the style of scientific ideas. The study also found that in CSs within an inquiry-based learning environment, confidence learning plays an important role in conceptual and procedural learning. Thus, this study encourages physics teachers to use PhET simulations in their future teaching. However, it should be noted that interactive CSs do not replace the role of teachers or traditional experimental laboratories. It should be used as a useful reserve tool by teachers to improve student's outcome.

5.7 Future Research Opportunities

Based on the results, further research should explore ways to take full advantage of CSs within an inquiry-based learning environment, such as the 5E strategies, to achieve conceptual and procedural understanding of students at different educational levels. There should be a focus on the process of the inquiry-based approach and its role in adapting the conceptual and procedural structure of students. The use of scientific discourse and CSs in inquiry-based learning is also deserves further investigation.

Additionally, studies using more students in multiple international contexts are needed to better understand educational offerings, which combine inquiry-bases pedagogy and interactive computer-based simulations.

Finally, the current study found a relationship between conceptual knowledge, procedural knowledge, inquiry- based learning, attitudes toward physics, and CSs. However, further research is needed to investigate how these relationships work in the context of physics. Visionaries of the 20th century, mastering the dynamic processes underlying the acquisition and manipulation of knowledge is the critical strength of the 21st century. Our formal education systems do not seek to develop these capabilities, but rather people of all ages develop them through a variety of digital mediation mechanisms (Galarneau & Zibit, 2007). CSs within an inquiry-based learning environment might be effective for developing students' critical thinking skills and developing 21st century skills. Given a number of studies support the positive effects of CSs on learning, researchers are looking to explore how CSs could influence the development of these much need skills in schools. Moreover, the results need to be treated with the appropriate caution. In the long-term future, similar studies will provide further insights into the interpretation of this study. Future research is also needed to provide a holistic view of NSLOM topic by expanding the sample to include other classes and other stages of education, including stages of primary and higher education in private and public schools.

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List of Publications

Tairab, H., Al Arabi, K., Rabbani, L., & Hamad, S. (2020). Examining Grade 11 science students' difficulties in learning about vector operations. *Physics Education, 55*(5), 055029. DOI: 10.1088/1361-6552/aba107

Alarabi, K., Al Wardat, Y. (2021). UAE-based Teachers' Hindsight Judgments on Physics Education during the COVID-19 Pandemic. *Psychology and Education Journal, 58*(3), 2497-2511. DOI: https://doi.org/10.17762/pae.v58i3.4283

Appendices

Appendix A: The first version of the two-tire MCQ

1. Which of the following accurately describes how the net force on an object affects its state of motion?

❑ The velocity of the object is inversely proportional to its mass and inversely proportional to the net force acting on the object.

❑ The velocity of the object is inversely proportional to the net force acting on the object and directly proportional to its mass.

❑ The acceleration of the object is directly proportional to the net force acting on the object and directly proportional to its mass.

❑ The acceleration of the object is directly proportional to the net force acting on the object and inversely proportional to the object's mass.

Explain your answer: ……………………………………………………………………………………..
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2. An object of mass 10 kg is accelerated **downward** at (2 m/s^2). If (g = 10 m/s^2), **what is the force of air resistance?**

❑ 20 N upward

❑ 80 N upward

❑ 100 N upward

❑ 120 N upward

Explain your answer: ……………………………………………………………………………………..
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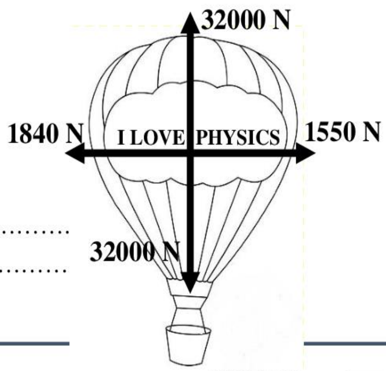
3. In the free-body diagram shown below. In which direction will the balloon move? (Note: the length of the arrows doesn't represent the amount of the force).

❑ Up ↑

❑ Down ↓

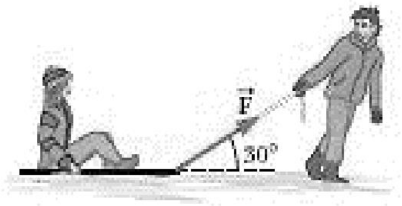
❑ Right →

❑ Left ←



Explain your answer: ……………………………………………………………
……………………………………………………………………………………

4. A boy pulls his sister by applying a net force equal 50 N at an angle of 30° north of east. **Which two components equivalence to the applied force**?



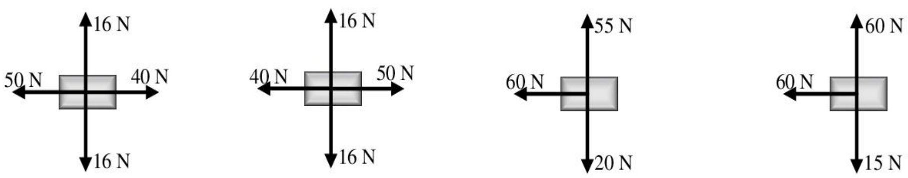
- ❑ 43 N, east and 25 N, north
- ❑ 43 N, east and 7 N, north
- ❑ 35 N, east and 15 N, north
- ❑ 25 N, east and 25 N, north

Explain your answer: ……………………………………………………………………………………..
……
……

5. A cyclist of mass 30 kg exerts a force of 250 N to move his cycle. The acceleration is 4 m/s^2. What will be the force of friction between the road and tires?

- ❑ 115 N
- ❑ 120 N
- ❑ 130 N
- ❑ 150 N

6. Which **one** of the following force diagrams depict an object moving to the right with a constant speed?



❑ ❑ ❑ ❑

Explain your answer: ……………………………………………………………………………………..
……
……

7. According to Newton's second law. What will happen when the same force is applied to two objects of different masses.

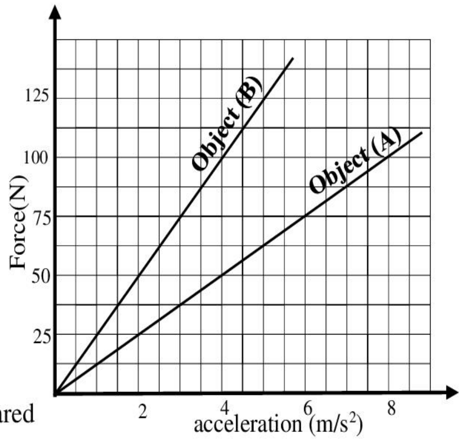
❑ the object with greater mass will experience a great acceleration, and the object with less mass will experience an even greater acceleration.

❑ the object with greater mass will experience a small acceleration, and the object with less mass will experience an even smaller acceleration.

❑ the object with greater mass will experience a smaller acceleration, and the object with less mass will experience a greater acceleration.

❑ the object with greater mass will experience a greater acceleration, and the object with less mass will experience a smaller acceleration.

8. Depending on the adjacent shape, which represents the relationship between the force acting and acceleration of two objects A and B. Which of the following statements is true?



❑ Object A has a mass greater than Object B

❑ Object B has a mass greater than Object A

❑ Object A has a mass equal to Object B

❑ The mass of the two Objects cannot be compared

Explain your answer: ……………………..………………………………………………………....
……..
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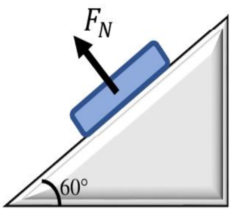
9. A book with a mass of 6.0 kg is held in equilibrium on a board with a slope of 60° by a horizontal force. **What is the normal force exerted on the book**?



❑ 30 N

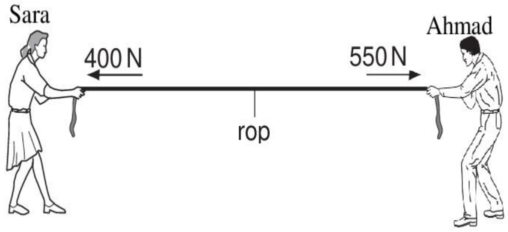
❑ 51 N

❑ 60 N

❑ 120 N

Explain your answer: ……………………..………………………………………………………....
……..
……..

10. Ahmad and Sara are pulling in opposite directions on a rope. The forces acting on the rope are shown in the diagram. Which single force has the same effect as the two forces shown?



- ❑ 150 N acting towards the boy
- ❑ 550 N acting towards the boy
- ❑ 150 N acting towards the girl
- ❑ 550 N acting towards the girl

Explain your answer: …………………………………………………………………………………….
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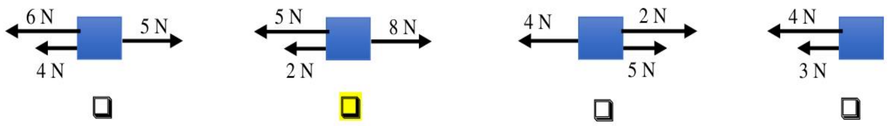
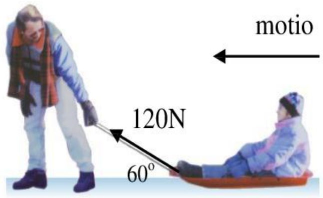
11. If the mass of the block is the same, which figure shows the smallest acceleration?



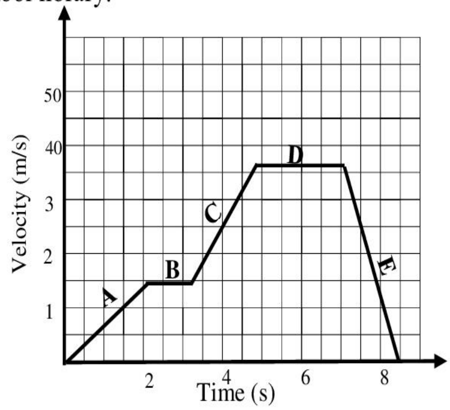
12. Ahmed pulls his brother 80 kg with a force of 240 N at an angle of 60° on a frictionless horizontal surface, as shown. **What is the acceleration of his brother?**



- ❑ 4 m/s^2
- ❑ 3 m/s^2
- ❑ 2.5 m/s^2
- ❑ 1.5 m/s^2

Explain your answer: ……………………………………………………………………………....
………………………………………………………………………………………………………..
……………………………………………………………………………………………………….

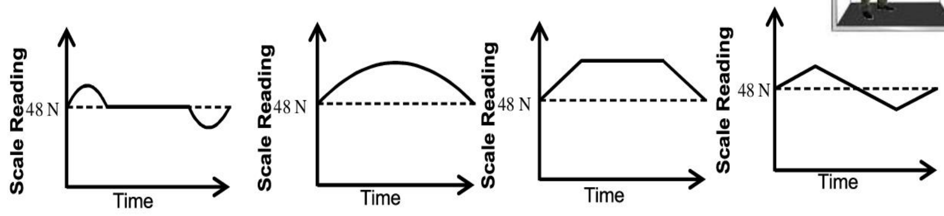
13. The graph shows Saeed's car journey from his house to school library.
During which section(s) was the acceleration equal zero



- ❑ A & C & E
- ❑ B & D
- ❑ A & C
- ❑ E

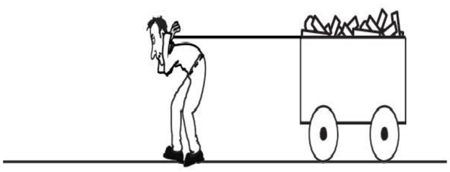
Explain your answer: ………………………………...…………
………………………………………………………………...
………………………………………………………………...

14. A man weighs a fish with a spring scale attached to the ceiling of an elevator, as shown in the figures. While the elevator is at rest, he measures a weight of 48 N. The elevator accelerates upward to a constant speed and then slows to a stop. **Which of the following graphs best represents the reading on the scale?**



❑ ❑ ❑ ❑

15. A cleaner pulls a laundry cart of mass 60 kg on a frictionless surface. The cleaner pushes with a net external force of 150 N. What is the magnitude of the cart's acceleration?



❑ $0.67\ m/s^2$

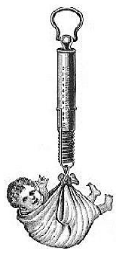
❑ $1.5\ m/s^2$

❑ $2.5\ m/s^2$

❑ $4.5\ m/s^2$

Explain your answer: ……………………………………………………………………………………..
………
………

16. Consider the baby being weighed in the shown figure. **What is the mass of the infant** if a scale reading of 67 N is observed? Consider the acceleration due to gravity to be $g = 10\ m/s^2$?



❑ 10 kg

❑ 7.6 kg

❑ 6.7 kg

❑ 0.0 kg

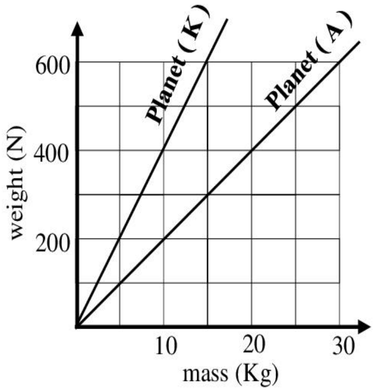
Explain your answer: ……………………………………………………………………………………..
………
………

17. A scientist measures the acceleration of an object after a known force is applied to the object. Using only the acceleration measurements and the magnitude of the applied force, what the scientist can calculate?

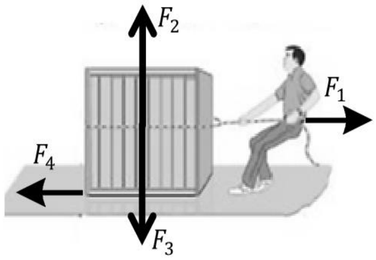
- ❑ weight
- ❑ density
- ❑ mass
- ❑ volume

18. The graph shows how weight varies with mass on **planet K** and on **planet A**. If an object weighs 600 N on **planet K**. And then the object is taken to **planet A**. Which row is correct?

	mass of object on planet **A**(kg)	weight of object on planet **A**(N)
❑	15	600
❑	15	300
❑	10	100
❑	10	400



19. In the following free-body diagram a person applies a force to a box in order to slide it across the floor. If the box is sliding at a constant velocity, which of the following forces in the free-body diagram must be equal in magnitude?



- ❑ F_1 & F_4
- ❑ F_1 & F_3
- ❑ F_4 & F_2
- ❑ F_4 & F_3

Explain your answer: ……………………..……………………………………………………....

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

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

20. Which of the following statements does **not** describe force?

- ❑ Force causes objects to stop moving
- ❑ Force causes objects to change direction
- ❑ Force causes objects to start moving
- ❑ Force causes objects at rest to remain stationary

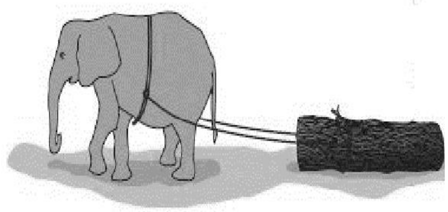
21. An elephant pulls a 600 kg log on a horizontal surface at a constant accelerator 3.5 m/s^2 as shown. What is the magnitude of the force?

❑ 6000 N

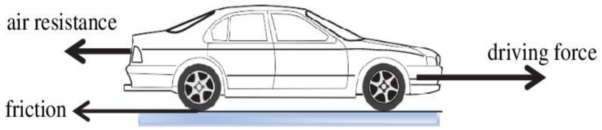
❑ 3500 N

❑ 2100 N

❑ 171 N



22. Which combination of forces would result in the car moving at constant speed?



	air resistance	friction	driving force
❑	500 N	800 N	1300 N
❑	500 N	1300 N	800 N
❑	800 N	1300 N	500 N
❑	1300 N	800 N	500 N

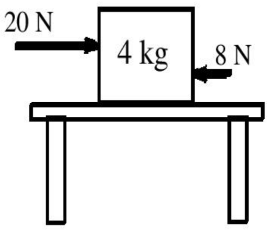
23. An object whose mass is 4 kg influenced by two forces F_1= 20 N and F_2= 8 N as in the adjacent figure. What is **the magnitude** and **the direction** of the acceleration?

❑ 3 N to the right (the same direction of F_1)

❑ 4 N to the right (the same direction of F_1)

❑ 2 N to the left (the same direction of F_2)

❑ 4 N to the left (the same direction of F_2)



Explain your answer: ……………………..……………………………………………………....
……………………………………………………………………………………………………..
……………………………………………………………………………………………………..

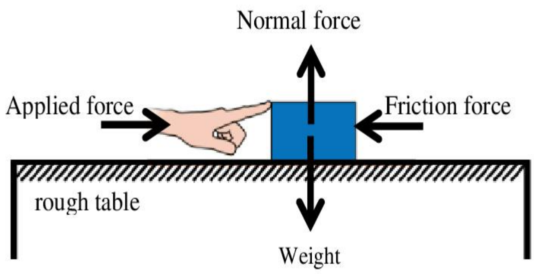
24. According to the diagram, if the mass of the box increased which force remain constant?

❑ Applied force

❑ Normal force

❑ Friction force

❑ Weight



Turn over

25. Newton's laws, when applied in a particular situation, give the following equations.

$$F_n + F \sin\theta - mg = 0$$

$$F \cos\theta - \mu F_n = ma$$

Which of the following equations correctly expresses μ?

❑ $\mu = \frac{-ma+F\cos\theta}{F\sin\theta-mg}$

❑ $\mu = \frac{-ma+F\cos\theta}{-F\sin\theta+mg}$

❑ $\mu = \frac{ma+F\cos\theta}{F\sin\theta-mg}$

❑ $\mu = \frac{ma-F\cos\theta}{-F\sin\theta-mg}$

26. A bag with weight of 30 N supported by a cord and pulley. A force of 15 N acts on the bag and one end of the cord pulled by a force of 100 N.
Determine the net force acts on the bag?

❑ 55 N

❑ 70 N

❑ 85 N

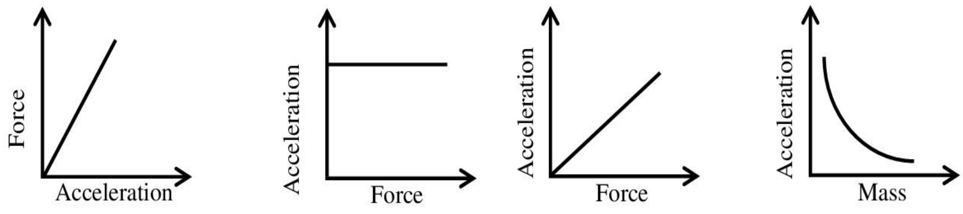
❑ 115 N

Explain your answer: …………………………………………………………………………………….....

……..

……..

27. Which graph represents the motion of a car that is travelling along a straight road with a **constant force**?



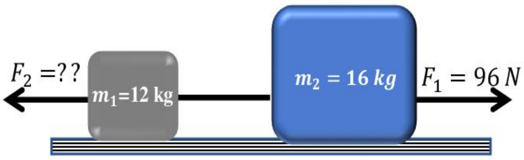
❑ ❑ ❑ ❑

28. The ratio between the masses of two bodies at rest is 15:10. If a force of magnitude F acts on each of them, what is the ratio between the resultant acceleration of each body?

- ❑ 15: 10
- ❑ 10:15
- ❑ 5:3
- ❑ 3:2

29. Two crates, $m_1 = 12\ kg$ and $m_2 = 16\ kg$ respectively, are connected with light inextensible string rope according to the diagram. A force, to the right, of $F_1 = 96\ N$ is applied. The boxes move with an acceleration of $2\ m/s^2$ to the right. **What will be the force F_2?**

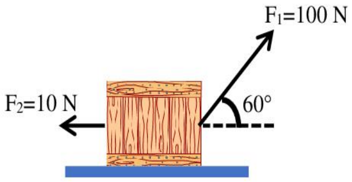
- ❑ $F_2 = 72\ N$
- ❑ $F_2 = 56\ N$
- ❑ $F_2 = 48\ N$
- ❑ $F_2 = 40\ N$



Explain your answer: …………………………………………………………………………………….....
……..
……..

30. Some forces act on an object with a mass of 20 kg, as shown in the figure below. What will be the acceleration of the object?

- ❑ $0.5\ m/s^2$
- ❑ $2\ m/s^2$
- ❑ $4.5\ m/s^2$
- ❑ $5\ m/s^2$



Explain your answer: …………………………………………………………………………………….....
……..
……..

Appendix B: The two-tire MCQ after revision

Dear Sir/Madam: ---

I am writing to seek your assistance in validating the content of the enclosed test that has been developed.

Specifically, I need to gather information on students' performance in Newton's second law of motion.

The information will be used as part of a PhD research and therefore your input towards improving the validity of this test will be highly appreciated.

Please use the attached sheet to express your view with regard to test questions in terms of ***relevance*** and ***clarity***.

Thank you for your kind assistance.

Khaleel Shehadeh Alarabi

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0507937673

UAEU/ Department of Curriculum and Instruction

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Personal Data of the Arbitrator:

Name		Current job	
Qualification		The Academic title	
Employer		Date of Arbitration	

Questions	Related to grade 11 context		Clarity		Culture relevance		Suggestions
	Yes	No	Clear	Not clear	Yes	No	
1							
2							
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22							

Turn over

1. Which of the following accurately describes how the net force on an object affects its state of motion?

A The velocity of the object is inversely proportional to its mass and inversely proportional to the net force acting on the object.

B The velocity of the object is inversely proportional to the net force acting on the object and directly proportional to its mass.

C The acceleration of the object is directly proportional to the net force acting on the object and directly proportional to its mass.

D The acceleration of the object is directly proportional to the net force acting on the object and inversely proportional to the object's mass.

Reason for my answer to the question is:

❶ Because $F = m.a$, therefore F proportional to a and a proportional to m i.e. acceleration is directly proportional to force and mass.

❷ Because $F = m.a$, therefore F proportional to a and a proportional $\frac{1}{m}$ i.e. acceleration is directly proportional to force and inversely proportional to mass.

❸ Because $\frac{m}{a} = F$ and $\frac{v}{t} = a$, therefore F proportional $\frac{1}{v}$ i.e. velocity is inversely proportional to force.

❹ Because $\frac{F}{m} = a$ and $\frac{v}{t} = a$, therefore $\frac{1}{m}$ proportional to $\frac{v}{t}$ i.e. velocity is inversely proportional to mass.

---

2. An object of mass 10 kg is accelerated **downward** at (2 m/s^2). If ($g = 10\ m/s^2$), **what is the force of air resistance?**

A 20 N upward

B 80 N upward

C 120 N upward

D 120 N upward

Reason for my answer to the question is:

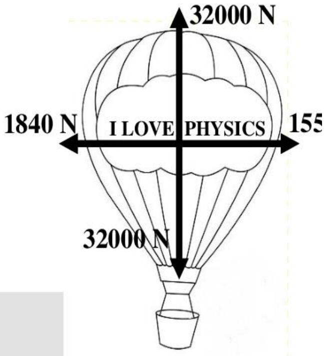
❶ Since the air resistance is opposite to the gravity,
so $air\ resistance = 10 \times 10 - 10 \times 2 = 80\ N\ upward$

❷ Since the air resistance is the same direction to the gravity,
so $air\ resistance = 10 \times 10 + 10 \times 2 = 120\ N\ upward$

❸ Since the air resistance is the same direction to the gravity,
so $air\ resistance = 10 \times 10 = 100N\ upward$

❹ Since the air resistance is opposite direction to the gravity,
so $air\ resistance = 10 \times 2 = 20\ N\ upward$

3. In the free-body diagram shown below. In which direction will the balloon move?
(Note: the length of the arrows doesn't represent the amount of the force).



A ❑ Up ↑

B ❑ Down ↓

C ❑ Right →

D ❑ Left ←

Reason for my answer to the question is;

❶ The net forces exirted only to the left and equal zero at vertical direction.

❷ The air force is bigger than other forces so the ballon moves up.

❸ The gravitational force pulls the ballon towards earth since it's the large one.

❹ The net forces exirted only to the right and equal zero at vertical direction.

---

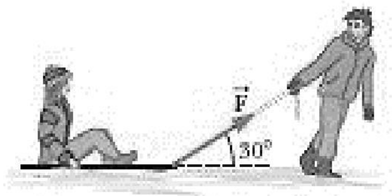
4. A boy pulls his sister by applying a net force equal 50 N at an angle of $30°$ north of east.
Which two components equivalence to the applied force?

A 43 N, east and 25 N, north

B 43 N, east and 7 N, north

C 35 N, east and 15 N, north

D 25 N, east and 25 N, north



Reason for my answer to the question is;

❶ Since there is motion along north east direction then horizontal component of force is $F = 50\ \cos 30° = 43\ N, east$ and vertical component of force is $F = 50\ \sin 30° = 25\ N, north.$

❷ Since there is motion along north east direction then horizontal component of force is $F = 50\ \cos 30° = 43\ N, east$ and vertical component of force is $F = 50 - 43 = 7\ N, north$

❸ Since there is more force applied against gravity then horizontal therefore 35 N along $east$ and 15 along $north.$

❹ Since there is motion along $north$ east direction then horizontal component of force is $F = 50\ \cos 60° = 25\ N, east$ and vertical component of force is $F = 50\ \sin 30° = 25\ N, north$

5. According to Newton's second law. What will happen when the same force is applied to two objects of different masses.

A The object with greater mass will experience a great acceleration, and the object with less mass will experience an even greater acceleration.

B The object with greater mass will experience a small acceleration, and the object with less mass will experience an even smaller acceleration.

C The object with greater mass will experience a smaller acceleration, and the object with less mass will experience a greater acceleration.

D The object with greater mass will experience a greater acceleration, and the object with less mass will experience a smaller acceleration

Reason for my answer to the question is;

❶ Since force is directly proportional to the product of mass and acceleration therefore greater be the force greater be the mass and acceleration.

❷ Since mass is inversely proportional to the acceleration therefore greater be the mass lesser be the acceleration.

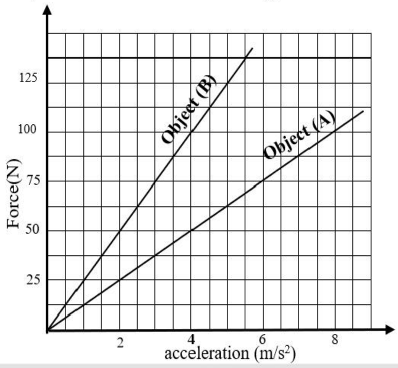
❸ Since mass is directly proportional to the acceleration therefore greater be the mass lesser be the acceleration and vice versa

❹ Since force is directly proportional to the product of mass and acceleration therefore lesser be the force lesser be the mass and acceleration.

---

6. Depending on the adjacent shape, which represents the relationship between the force acting and acceleration of two objects A and B.

Which of the following statements is true?



A Object A has a mass greater than Object B.

B Object B has a mass greater than Object A.

C Object A has a mass equal to Object B.

D The mass of the two Objects cannot be compared.

Reason for my answer to the question is;

❶ Since mass is directly proportional to the acceleration therefore greater be the mass greater be the acceleration.

❷ Since mass is inversely proportional to the acceleration therefore greater be the mass lesser be the acceleration.

❸ Since the force is directly proportional to the acceleration and mass is constant therefore mass of A and B are same.

❹ Since the force is directly proportional to the acceleration and mass is constant therefore mass of A and B cannot be compared.

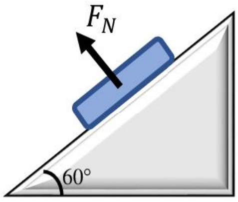
7. A book with a mass of 6.0 kg is held in equilibrium on a board with a slope of 60 °by a horizontal force. What is the normal force exerted on the book?

A 30 N

B 52 N

C 60 N

D 104 N



Reason for my answer to the question is;

❶ The normal force will be 6.0 × 10 $cos(60)$ =30 N

❷ The normal force will be 6.0 × 10 $sin(60)$ =51.9 N

❸ The normal force will be 6.0 × 10 =60 N

❹ The normal force will be 6.0 × 10 $tan(60)$ =103.9 N

---

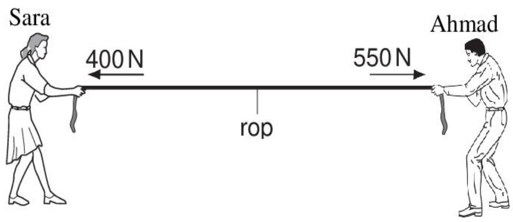
8. Ahmad and Sara are pulling in opposite directions on a rope. The forces acting on the rope are shown in the diagram. Which single force has the same effect as the two forces shown? C

A 150 N acting towards the boy

B 550 N acting towards the boy

C 150 N acting towards the girl

D 400 N acting towards the girl



Reason for my answer to the question is;

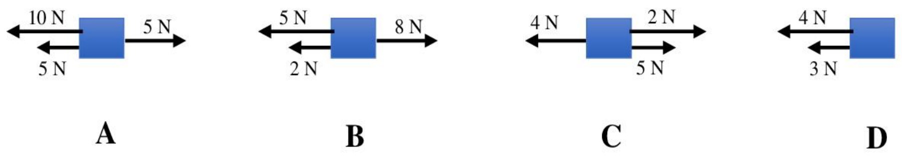
❶ Because the two forces are in opposite directions, we subtract them from each other, and the result is toward the boy.

❷ We can ignore the force exerted by the girl because the boy is stronger than girl, so he pulls her towards him.

❸ Because for every action there is reacts, the girl pulls the boy toward her with the same force.

❹ Because the two forces are opposite directions, we subtract them from each other, and the result is toward the girl.

9. If the mass of the block is the same, which figure shows the smallest acceleration?



Reason for my answer to the question is;

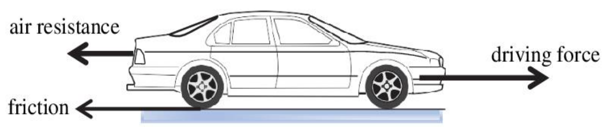
❶ The net forces acting on the block as little as possible ($8N - 5N - 2N$)

❷ The number of forces acting on the block is less ($4N + 3N$)

❸ The force acting on the block towards the left is lower($4N$)

❹ The sum of forces acting on the block is lower ($10N - 5N - 5N$)

10. Which combination of forces would result in the car moving at constant speed?



	air resistance	friction	driving force
A	500N	800N	1300N
B	500N	1300N	800N
C	800N	1300N	500N
D	1300N	800N	500N

Reason for my answer to the question is;

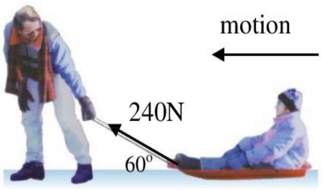
❶ Driving force = air resistance + friction = 500+800 = 1300N

❷ Driving force = friction - air resistance = 1300 – 500 = 800N

❸ Driving force = friction - air resistance = 1300 – 800 = 500N

❹ Driving force = air resistance - friction = 1300 - 800 = 500 N

11. Ahmed pulls his brother 80 kg with a force of 240 N at an angle of 60° on a frictionless horizontal surface, as shown. What is the acceleration of his brother?



A $4\ m/s^2$

B $3\ m/s^2$

C $2.6\ m/s^2$

D $1.5\ m/s^2$

Reason for my answer to the question is;

❶ The acceleration will be $\frac{240\ \cos 60}{80} = 1.5\ m/s^2$

❷ The acceleration will be $\frac{240\ \sin 120}{80} = 2.59\ m/s^2$

❸ The acceleration will be $\frac{240}{80} = 3\ m/s^2$

❹ The acceleration will be $\frac{240}{60} = 4\ m/s^2$

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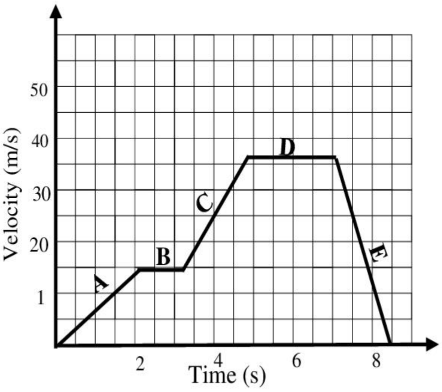
12. The graph shows Saeed's car journey from his house to school library. During which section(s) was the acceleration equal zero?



A A & C & E

B B & D

C A & C

D E

Reason for my answer to the question is;

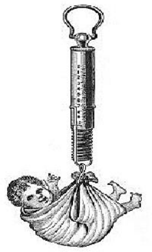
❶ In B & D the car moves at constant velocity. Therefore, the sum of the external forces is zero.

❷ In A & C & E, the acceleration of the car increased or decreased. So, the sum of velocity equal zero.

❸ In A & C, the car moves until it stops completely at its maximum point.

❹ In E, the car moves until it stops completely at its minimum point.

13. Consider the baby being weighed in the shown figure. What is the mass of the infant if a scale reading of 67 N is observed? Consider the acceleration due to gravity to be $g = 10\ m/s^2$?



A 10 kg

B 670 kg

C 6.7 kg

D 0.0 kg

Reason for my answer to the question is;

❶ According to newton's second law of motion. The mass equal $\frac{67}{10} = 6.7\ kg$

❷ According to newton's second law of motion. The mass equal $g = 10\ kg$

❸ According to newton's second law of motion. The mass equal $0.0\ kg$ because the infant is stable

❹ According to newton's second law of motion. The mass equal $67 \times 10 = 670\ kg$

14. A scientist measures the acceleration of an object after a known force is applied to the object. Using only the acceleration measurements and the magnitude of the applied force, what the scientist can calculate?

A weight

B density

C mass

D volume

Reason for my answer to the question is;

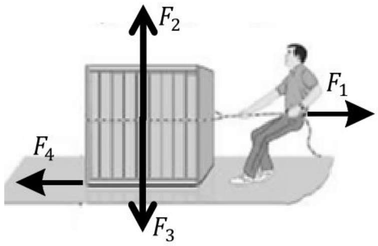
❶ Newton second law states that the acceleration of an object is dependent upon two variables; the net force acting upon the object and the mass of the object.

❷ Newton second law states that the acceleration of an object is dependent upon two variables, the net force acting upon the object and the volume of the object.

❸ Newton second law states that the acceleration of an object is dependent upon two variables, the net force acting upon the object and the weight of the object.

❹ Newton second law states that the acceleration of an object is dependent upon two variables, the net force acting upon the object and the density of the object.

15. In the following free-body diagram a person applies a force to a box in order to slide it across the floor. If the box is sliding at a constant velocity, which of the following forces in the free-body diagram must be equal in magnitude?



A F_1 & F_4

B F_1 & F_3

C F_4 & F_2

D F_4 & F_3

Reason for my answer to the question is;

❶ Since there is no vertical motion therefore, F_1 and F_4 are same.

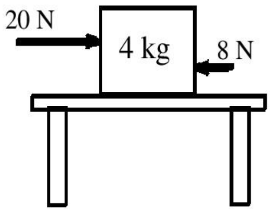
❷ Since force is applied against gravity to overcome the weight then F_1 and F_3 are same.

❸ Since friction force does not let the box to move and normal reaction force does not let the box in upward motion therefore F_4 and F_2 are same.

❹ Since friction force does not let the box to move and weight does not let the box in downward motion therefore F_4 and F_3 are same

---

16. An object whose mass is 4 kg influenced by two forces F_1= 20 N and F_2= 8 N as in the adjacent figure. What is **the magnitude** and **the direction** of the acceleration?



A 3 *N* to the right (the same direction of F_1)

B 4 *N* to the right (the same direction of F_1)

C 2 *N* to the left (the same direction of F_2)

D 4 *N* to the left (the same direction of F_2)

Reason for my answer to the question is;

❶ Because $a = \frac{(F_1 - F_2)}{m} = \frac{(20-8)}{4} = 3\ N$ (in the direction of F_1).

❷ Because $a = 8\ N - 4\ kg = 4\ N$ (in the direction of F_1).

❸ Because $a = \frac{F_2}{m} = \frac{8}{4} = 2\ N$ (in the direction of F_2).

❹ Because $a = 8\ N - 4\ kg = 4\ N$ (in the direction of F_2)

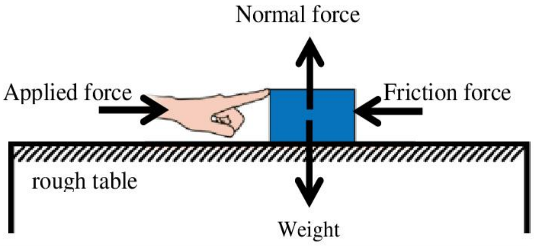
17. According to the diagram, if the mass of the box increased which force remain constant?

A Applied force

B Normal force

C Friction force

D Weight



Reason for my answer to the question is;

❶ Since normal force and weight = mg, friction is also depending on mass therefore applied force is constant.

❷ Since normal reaction force is due to the atmospheric pressure therefore it will remain constant.

❸ Since friction is depends on the smoothness and roughness of the surface.

❹ Since weight depends on acceleration due gravity which is constant.

---

18. A bag with weight of 30 N supported by a cord and pulley. A force of 15 N acts on the bag and one end of the cord pulled by a force of 100 N.

Determine the net force acts on the bag?

A 55 N

B 70 N

C 85 N

D 115 N

Reason for my answer to the question is;

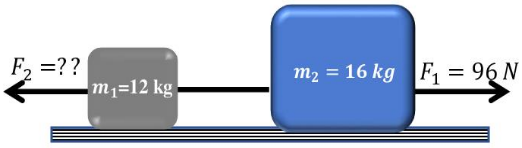
❶ $F = 100 - (30 + 15) = 100 - 45 = 55\ N$

❷ $F = 100 - 30 = 70\ N$

❸ $F = 100 - 15 = 85\ N$

❹ $F = 100 + 15 = 115 N$

19. Two crates, $m_1 = 12\ kg$ and $m_2 = 16\ kg$ respectively, are connected with light inextensible string rope according to the diagram. A force, to the right, of $F_1 = 96\ N$ is applied. The boxes move with an acceleration of $2\ m/s^2$ to the right. What will be the force F_2?



A ❑ $F_2 = 72\ N$

B ❑ $F_2 = 56\ N$

C ❑ $F_2 = 48\ N$

D ❑ $F_2 = 40\ N$

Reason for my answer to the question is;

❶ $F_2 = F_1 - (m_1 \times a) = 96 - 12\times2 = 96-24 = 72$ N

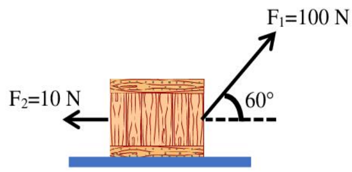
❷ $F_2 = (m_1+m_2) \times a = (16+12) \times 2 = 28 \times 2 = 56$ N

❸ $F_2 = m_2 + m_2 \times a = 16 + 16 \times 2 = 16 + 32 = 48$ N

❹ $F_2 = F_1 - (m_1+m_2) \times a = 96 - (16+12) \times 2 = 96 - 56 = 40$ N

---

20. Some forces act on an object with a mass of 20 kg, as shown in the figure below. What will be the acceleration of the object?



A $0.5\ m/s^2$

B $2\ m/s^2$

C $4.5\ m/s^2$

D $5\ m/s^2$

Reason for my answer to the question is;

❶ Because $a = \frac{F}{m} = \frac{10}{20} = 0.5\ m/s^2$.

❷ Because $a = \frac{F}{m} = \frac{(F_1 \cos 60^\circ - 10)}{20} = \frac{(100 \times 0.5 - 10)}{20} = 2\ m/s^2$.

❸ Because $a = \frac{F}{m} = \frac{(F_1 \sin 60^\circ)}{20} = \frac{(0.866)}{20} = 4.5\ m/s^2$.

❹ Because $a = \frac{F_1}{m} = \frac{100}{20} = 5\ m/s^2$.

21. If a nonzero net force is acting on an object, what we can describe the object?

A being accelerated

B at rest

C losing mass

D moving with a constant velocity

Reason for my answer to the question is;

❶ Because the net force is constant, the body will move at a constant velocity.

❷ Do not move, because no force affect them.

❸ With the effect of the net force the body mass gradually decreases

❹ Because the net force is not zero, the body will the body will gain steady acceleration.

---

22. The ratio between the masses of two bodies at rest is 15:10. If a force of magnitude F acts on each of them, what is the ratio between the resultant acceleration of each body?

A 15: 10

B 10:15

C 5:3

D 3:2

Reason for my answer to the question is;

❶ Since acceleration is directly proportional to mass then $\frac{a_1}{a_2} = \frac{m_1}{m_2} = \frac{15}{10}$.

❷ Since acceleration is inversely proportional to mass then $\frac{a_1}{a_2} = \frac{m_2}{m_1} = \frac{10}{15}$.

❸ Since acceleration is inversely proportional to mass then $\frac{a_1}{a_2} = \frac{(m_{1+} m_2}{m_1} = \frac{15+10}{15} = \frac{25}{15} = \frac{5}{3}$.

❹ Since acceleration is directly proportional to mass then $\frac{a_1}{a_2} = \frac{m_1}{m_2} = \frac{15}{10} = \frac{3}{2}$.

Appendix C: Jury of Referees for Validating NSLMAT

Name	Current Job	Qualification
1. Prof. Hassan Tairab	College of Education, UAEU	Professor / Curriculum & Instruction
2. Dr. Ehab Malkawi	College of Science, UAEU	Associate Professor /Physics
3. Dr. Abdellateef Alqawasmi	Science Lead Teacher, MOE, UAE	PhD in Curriculum & Instruction
4. Dr. Yahya Al-Ossaily	Educational supervisor, MOE, Jordan	PhD in Curriculum & Instruction
5. Zakiah Ali Al Disi	Academic Quality improvement officer, MOE, UAE	Master’s in education
6. Jamal Bani Younes	Teacher, MOE, UAE	Master’s in physics
7. Nitin Kumar Tyagi	Teacher, MOE, UAE	Master’s in physics
8. Aziza Alazizi	Teacher, MOE, UAE	Bachelor’s in physics
9. Iman Jaradat	Teacher, MOE, UAE	Bachelor’s in physics
10. Latifa Al Neyad	Teacher, MOE, UAE	Bachelor’s in physics

Appendix D: The last version of the two-tire exam

1. An object of mass 10 kg is accelerated downward at ($2 m/s^2$). If ($g = 10 m/s^2$) what is the force of air resistance?

A 20 N upward

B 80 N upward

C 120 N upward

D 200 N upward

Reason for my answer to the question is:

❶ Since air resistance is opposite to gravity, then $air\ resistance = 10 \times 10 - 10 \times 2$

❷ Since the air resistance is the same direction to the gravity, then $air\ resistance = 10 \times 10 + 10 \times 2$

❸ Since the air resistance is the same direction to the gravity, then $air\ resistance = 10 \times 10$

❹ Since the air resistance is opposite direction to the gravity, then $air\ resistance = 10 \times 2 \times 10$

---

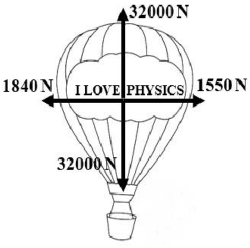
2. The free-body diagram shows the forces on a balloon. In which direction will the balloon accelerate? (Note: the length of the arrows doesn't represent the amount of the force).

A Up ↑

B Down ↓

C Right →

D Left ←



Reason for my answer to the question is;

❶ The net forces directed to the right. The net force equals zero in the vertical direction.

❷ Air resistance is greater than other forces so the balloon moves up.

❸ The net force is directed to the left. The net force equals zero in the vertical direction.

❹ The gravitational force pulls the balloon towards earth since it's the largest.

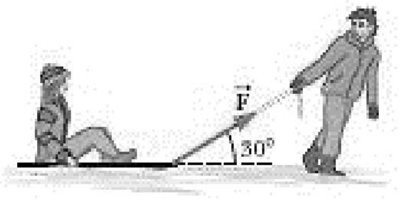
3. A boy pulls his sister by applying a force equals 50 N at an angle of $30°$ north of east. Which two components are equivalent to the applied force?

A 43 N- east and 7 N- north

B 43 N- east and 25 N- north

C 35 N- east and 15 N- north

D 25 N- east and 25 N- north



Reason for my answer to the question is;

❶ The horizontal component of force is $F = 50\ \cos 60^{\circ}, east$ and vertical component of force is $F = 50\ \sin 30^{\circ}, north$

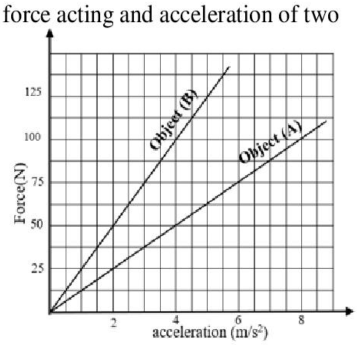
❷ The horizontal component of force is $F = 50\ \cos 30^{\circ}, east$ and vertical component of force is $F = 50 - 43, north$

❸ The horizontal component of force is $F = 30\ \cos 50^{\circ}, east$, and vertical component of force is $F = 50 - 35, north.$

❹ The horizontal component of force is $F = 50\ \cos 30^{\circ}, east$ and vertical component of force is $F = 50\ \sin 30^{\circ}, north.$

---

4. The figure on the right represents the relationship between the force acting and acceleration of two objects $\boldsymbol{A}$ and $\boldsymbol{B}$. Which of the following statements is true?



A Object A has a mass greater than object B.

B Object A has a mass equal to object B.

C Object B has a mass greater than object A.

D The mass of the two objects cannot be compared.

Reason for my answer to the question is;

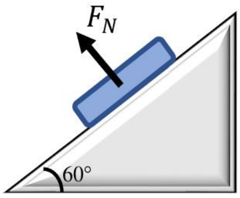
❶ Since mass is directly proportional to the acceleration therefore greater be the mass greater be the acceleration.

❷ Since mass is inversely proportional to the acceleration therefore greater be the mass lesser be the acceleration.

❸ Since the force is directly proportional to the acceleration and mass is constant therefore mass of objects A and B are same.

❹ Since the force is directly proportional to the acceleration and mass is constant therefore mass of objects A and B cannot be compared.

5. A book with a mass of 6.0 kg is held in equilibrium on a surface inclined at an angle of 60 °. What is the normal force $\mathbf{F_N}$ exerted on the book?



A 30 N

B 52 N

C 60 N

D 104 N

Reason for my answer to the question is;

❶ The normal force will be 6.0 × 10

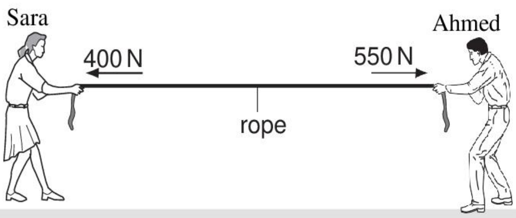
❷ The normal force will be 6.0 × 10 $sin(60)$

❸ The normal force will be 6.0 × 10 $cos(60)$

❹ The normal force will be 6.0 × 10 $tan(60)$

---

6. Ahmed and Sara are pulling a light rope opposite directions. The forces acting on the rope are shown in the diagram. Which single force has the same effect as the two forces?



A 150 N acting towards the girl

B 550 N acting towards the boy

C 150 N acting towards the boy

D 400 N acting towards the girl

Reason for my answer to the question is;

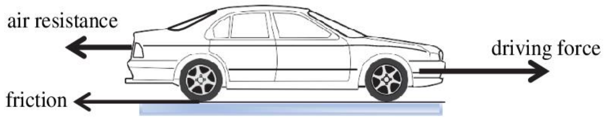
❶ Because the two forces are in opposite directions, we subtract them from each other, and the result is towards the larger force.

❷ We can ignore the force exerted by the girl because the boy is stronger than girl, so he pulls her towards him.

❸ Because for every action there is reaction, the girl pulls the boy towards her with the same force.

❹ Because the two forces are in opposite directions, we subtract them from each other, and the result is towards the smaller force.

7. Which combination of forces would result in the car moving at constant speed?



	air resistance	friction	driving force
A	500 N	800 N	1300 N
B	500 N	1300 N	800 N
C	800 N	1300 N	500 N
D	1300 N	800 N	500 N

Reason for my answer to the question is;

❶ Driving force = friction - air resistance = 1300 – 800

❷ Driving force = friction - air resistance = 1300 – 500

❸ Driving force = air resistance + friction = 500+800

❹ Driving force = air resistance - friction = 1300 - 800

---

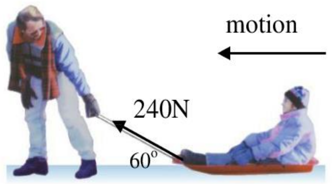
8. Ahmed pulls his brother 80 kg with a force of 240 N at an angle of 60° on a frictionless horizontal surface, as shown. What is the acceleration of his brother?

A $4\ \mathrm{m/s^2}$

B $3\ \mathrm{m/s^2}$

C $2.6\ \mathrm{m/s^2}$

D $1.5\ \mathrm{m/s^2}$



Reason for my answer to the question is;

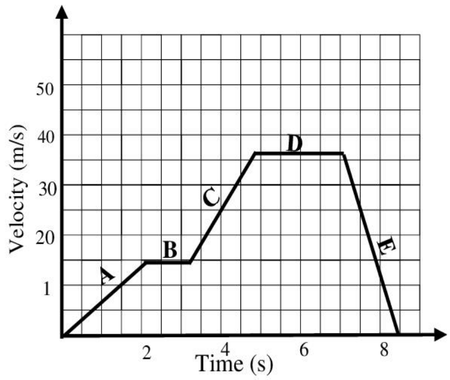
❶ The acceleration will be $\frac{240\ \sin 120}{80}$

❷ The acceleration will be $\frac{240\ \cos 60}{80}$

❸ The acceleration will be $\frac{240}{80}$

❹ The acceleration will be $\frac{240}{60}$

9. The graph shows Saeed's car journey from his house to school library. During which section(s) the acceleration equals zero?



A A & C & E

B B & D

C A & C

D E

Reason for my answer to the question is;

❶ In A & C & E, the acceleration of the car increased or decreased. So, the sum of velocities equal zero.

❷ In A & C, the car moves until it stops completely at its maximum point.

❸ In E, the car moves until it stops completely at its minimum point.

❹ In B & D the car moves at constant velocity. Therefore, the sum of the external forces is zero.

---

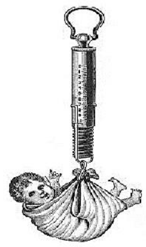
10. Consider the baby being weighed in the shown figure. What is the mass of the baby if a scale reading is 67 N ? Consider the acceleration due to gravity to be $g = 10\, m/s^2$?

A 10 kg

B 670 kg

C 6.7 kg

D 0.0 kg



Reason for my answer to the question is;

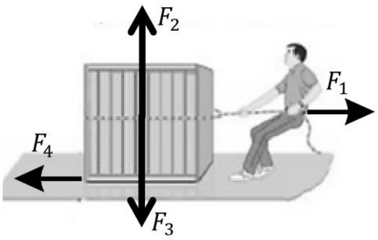
❶ According to newton's second law of motion. The mass equal $\frac{67}{10} kg$

❷ According to newton's second law of motion. The mass equal $g = 10\ kg$

❸ According to newton's second law of motion. The mass equal $0.0\ kg$ because the baby is stable

❹ According to newton's second law of motion. The mass equal $67 \times 10 = 670\ kg$

11. The figure shows a free-body diagram, a man exerting a force on a box in order to slide it across the floor. If the box is sliding at a constant velocity, which of the following forces in the free-body diagram must be equal in magnitude?



A F_1 & F_4

B F_1 & F_3

C F_4 & F_2

D F_4 & F_3

Reason for my answer to the question is;

❶ Since force is applied against gravity, then F_1 and F_3 are equal.

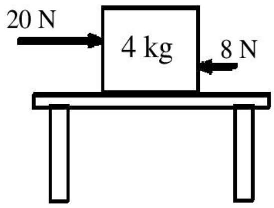
❷ Since the box is not accelerated therefore, F_1 and F_4 are same.

❸ Since friction force does not let the box to move and normal reaction force does not let the box in upward motion therefore F_4 and F_2 are equal.

❹ Since friction force does not let the box to move and weight does not let the box in downward motion therefore F_4 and F_3 are equal.

---

12. Two forces F_1= 20 N and F_2= 8 N are acting on a 4 kg object as shown in the figure. What is the magnitude and the direction of the acceleration?



A 4 m/s^2 to the left (the same direction of F_2)

B 2 m/s^2 to the left (the same direction of F_2)

C 4 m/s^2 to the right (the same direction of F_1)

D 3 m/s^2 to the right (the same direction of F_1)

Reason for my answer to the question is;

❶ Because $a = \frac{(F_1 - F_2)}{m} = \frac{(20-8)}{4}$ (in the direction of F_1).

❷ Because $a = 8\,N - 4$ (in the direction of F_1).

❸ Because $a = \frac{F_2}{m} = \frac{8}{4}$ (in the direction of F_2).

❹ Because $a = 8\,N - 4\,kg$ (in the direction of F_2)

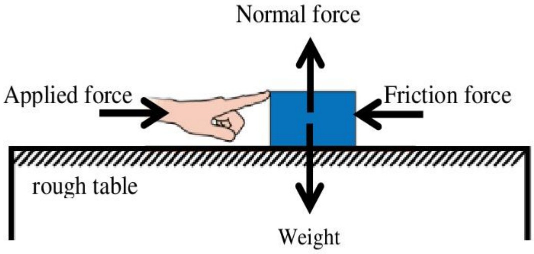
13. According to the diagram, if the mass of the box increased which force could remain constant?

A Applied force

B Normal force

C Friction force

D Weight



Reason for my answer to the question is;

❶ Since friction depends on the smoothness and roughness of the surface.

❷ Since normal reaction force is due to the atmospheric pressure therefore it will remain constant.

❸ Since normal force and weight are equal, friction is also depending on mass therefore applied force could be constant.

❹ Since weight depends on acceleration due to gravity which is constant.

---

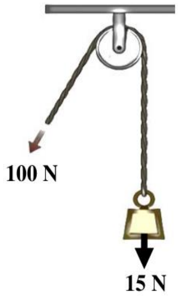
14. A bag with weight of 30 N is supported by a cord and frictionless pulley. A force of 15 N acts on the bag and one end of the cord is pulled by a force of 100 N, as shown in the figure. Determine the net force acts on the bag?

A 115 N

B 85 N

C 70 N

D 55 N



Reason for my answer to the question is;

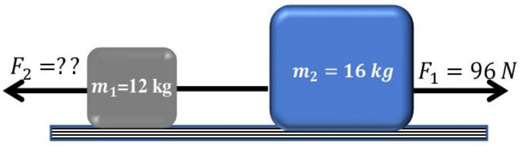
❶ $F = 100 - 30$

❷ $F = 100 - (30 + 15)$

❸ $F = 100 - 15$

❹ $F = 100 + 15$

15. Two crates, $m_1 = 12\ kg$ and $m_2 = 16\ kg$ respectively, are connected with light inextensible string rope as shown in the diagram. A force, to the right, of $F_1 = 96\ N$ is applied. The crates move with an acceleration of $2\ m/s^2$ to the right. What the magnitude of force F_2?



A $F_2 = 72\ N$

B $F_2 = 56\ N$

C $F_2 = 40\ N$

D $F_2 = 48\ N$

Reason for my answer to the question is;

❶ $F_2 - (m_1 \times a) = 96 - 12 \times 2$

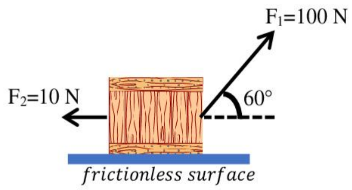
❷ $F_2 = (m_1 + m_2) \times a = (16 + 12) \times 2$

❸ $F_2 = F_1 - (m_1 + m_2) \times a = 96 - (16 + 12) \times 2$

❹ $F_2 = m_2 + m_2 \times a = 16 + 16 \times 2$

---

16. Two forces are acting on an object with a mass of $20\ kg$, as shown in the figure below. What will be the acceleration of the object?



A $0.5\ \text{m/s}^2$

B $2\ \text{m/s}^2$

C $4.5\ \text{m/s}^2$

D $5\ \text{m/s}^2$

Reason for my answer to the question is;

❶ Because $a = \frac{F_1}{m} = \frac{100}{20}$

❷ Because $a = \frac{F}{m} = \frac{(F_1\ \sin 60^{\circ})}{20} = \frac{(0.866)}{20}$

❸ Because $a = \frac{F}{m} = \frac{10}{20}$

❹ Because $a = \frac{F}{m} = \frac{(F_1\ \cos 60^{\circ} - 10)}{20} = \frac{(100 \times 0.5 - 10)}{20}$

Appendix E: Test judging results

Name		Current job	
Qualification		The Academic title	
Employer		Date of Arbitration	

Questions	Related to grade 11 context		Clarity		Culture relevance		Suggestions
	Yes	No	Clear	Not clear	Yes	No	
1	10		4	6	10		
2	10		10		10		
3	10		8	2	10		
4	10		10		10		
5	10		2	8	10		
6	10		9	1	10		
7	10		7	3	10		
8	10		7	3	10		
9	10		3	7	10		
10	10		8	2	10		
11	10		10		10		
12	10		10		10		
13	10		7	3	10		
14	10		4	6	10		
15	10		7	3	10		
16	10		9	1	10		
17	10		8	2	10		
18	10		10		10		
19	10		10		10		
20	10		10		10		
21	10		3	7	10		
22	10		1	9	10		

Appendix F: Permission from TOSRA Authors

Letter Seeking Permission to Use TOSRA Tool

KA Khaleel Ali AlArabi
Dear Prof. Fraser Thanks for your cooperation and understanding Thank you very much Regards, Khaleel
Sun 5/24/2020 12:45 PM

BF Barry Fraser <b.fraser@curtin.edu.au>
Sun 5/24/2020 12:41 PM
To: Khaleel Ali AlArabi

Khaleel

You are welcome to modify and use TOSRA.

Good luck.

Dr Barry J Fraser
FIAE FTSE FASSA FAAAS FAERA FACE
John Curtin Distinguished Professor
STEM Education Research Group (formerly SMEC)
School of Education

Executive Director | International Academy of Education | www.iaoed.org
Editor-in-Chief | *Learning Environments Research* | www.springernature.com
Co-Editor | *Second International Handbook of Science Education* www.springernature.com

Tel | +61 8 9266 7896
Fax | +61 8 9266 2503
Email | B.Fraser@curtin.edu.au
Web | http://curtin.edu/stem-group
Address | GPO Box U1987 Perth WA 6845

Curtin University

Appendix G: Subscale of Test of Science-Related Attitude (TOSRA)

Dear Students,

The purpose of this survey is to collect information about your interest level while learning physics.

This test contains number of statements about physics. You will be asked what you yourself think about these statements.

There is no 'right' or 'wrong' answers. Your opinion is what is wanted.

After reading each statement, put (√) which reflects your opinion.

Practice item:

The statement: It would be interesting to learn about physics.

Suppose then you like this: that you **AGREE** with this statement, would put (✓) on your Answer Sheet.

you **STRONGLY AGREE** with the statement	you **AGREE** with the statement	you are **NOT SURE**	you **DISAGREE** with the statement	you **STRONGLY DISAGREE** with the statement
			✓	

If you change your mind about an answer, cross it out and circle another one.

Although some statements in this test are fairly like other statements, you are asked to indicate your opinion about all statements

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

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

Thank you

Dear Students,

Instructions:

This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted. For each statement, put "check" in the box that reflects your opinion.

Statement	you **STRONGLY AGREE** with the statement	you **AGREE** with the statement	you are **NOT SURE**	you **DISAGREE** with the statement	you **STRONGLY DISAGREE** with the statement
1. I would prefer to find out why something happens by doing an experiment than by being told.					
2. Physics lessons are fun.					
3. I would dislike being a scientist after I leave school.					
4. Doing experiments is not as good as finding out information from teachers.					
5. I dislike physics lessons.					
6. When I leave school, I would like to work with people who make discoveries in physics.					
7. I would prefer to do experiments than to read about them.					
8. School should have more physics lessons each week.					
9. I would dislike a job in a physics laboratory after I leave school.					
10. I would rather agree with other people than do an experiment to find out for myself.					

Statement	you **STRONGLY AGREE** with the statement	you **AGREE** with the statement	you are **NOT SURE**	you **DISAGREE** with the statement	you **STRONGLY DISAGREE** with the statement
11. Physics lessons bore me.					
12. Working in a physics laboratory would be an interesting way to earn a living.					
13. I would prefer to do my own experiments than find out information from a teacher.					
14. Physics is one of the most interesting school subjects.					
15. career in physics would be dull and boring.					
16. I would rather find out about things by asking an expert than by doing an experiment.					
17. Physics lessons are a waste of time.					
18. I would like to teach physics when I leave school.					
19. I would rather solve a problem by doing an experiment than be told the answer.					
20. I really enjoy going to physics lessons					

Statement	You **STRONGLY AGREE** with the statement	you **AGREE** with the statement	you are **NOT SURE**	you **DISAGREE** with the statement	you **STRONGLY DISAGREE** with the statement
21. A job as a scientist would be boring.					
22. It is better to ask the teacher the answer than to find it out by doing experiments.					
23. The material covered in physics lessons is uninteresting.					
24. A job as a scientist would be interesting.					
25. I would prefer to do an experiment on a topic than to read about it in physics magazines.					
26. I look forward to physics lessons.					
27. I would dislike becoming a scientist because it needs too much education.					
28. It is better to be told scientific facts than to find them out from experiments.					
29. I would enjoy school more if there were no physics lessons.					
30. I would like to be a scientist when I leave school					

Appendix H: Permission to use PhET

Letter Seeking Permission to Use PhET

PhET Help <phethelp@Colorado.EDU>
Tue 5/26/2020 8:06 PM
To: Khaleel Ali AlArabi

Thanks for reaching out to PhET.

As you may already know, PhET is an Open Education Resource, and as such, can be licensed under the Creative Commons-Attribution (CC-BY). Under this license, you (whether educational, commercial or non-commercial) can distribute/use our sims either through the internet or through a DVD/CD. The licenses only require attributing the work to:
PhET Interactive Simulations
University of Colorado Boulder
http://phet.colorado.edu/
(Note: please use the full title of the project, not just the logo.)

Please note that the CC-BY license does not apply to the PhET name and PhET logo, which are registered trademarks of The Regents of the University of Colorado, a body corporate. Under the CC-BY license, you are permitted to use the PhET name and PhET logo ONLY for attribution purposes not for promotional, marketing, or advertising purposes.

Lastly, please complete the following form to provide us info about your use of PhET. This is important for us to receive more grant and foundation support:
https://docs.google.com/forms/d/1vNTUPvXCQ20BtWqBK1niKj0-5j866ZY2iC3ulvdYhss/viewform?usp=send_form

Thanks and with best wishes,

Oliver

...

Appendix I: Formal Permission from ADEK

دائـــرة التـعـلـيـم والـمـعـرفـة
DEPARTMENT OF EDUCATION AND KNOWLEDGE

Date:30/10/2019	التاريخ : 30/10/2019
To:Public Schools Principals	**الساده / مديرى المدارس الحكومية المحترمين**
Subject : Letter Of Permission	**الموضوع : تسهيل مهمة باحثين**
Dear Principals,	**تحية طيبة وبعد،**
The Department of Education and Knowlegde would like to express its gratitude for your generous efforts and sincere cooperation in serving our dear researchers.	يطيب لدائرة التعليم و المعرفة ان تتوجه لكم بخالص الشكر والتقدير لجهودكم الكريمة و التعاون الصادق لخدمة ابنائنا الباحثين
You are kindly requested to allow the researcher /**خليل العربي**, to complete his research on:	و نود اعلامكم بموافقة دائرة التعليم و المعرفة علي موضوع **خليل العربي /** الدراسة التى سيجريها الباحث بعنوان:
Impact of Computer Simulation on UAE Students' Learning of Newton's Second Law of Motion and Attitudes toward Physics within the Context of Scientific Inquiry Instruction.	**Impact of Computer Simulation on UAE Students' Learning of Newton's Second Law of Motion and Attitudes toward Physics within the Context of Scientific Inquiry Instruction.**
Please indicate your approval of this permission by facilitating her meetings with the sample groups at your resoected schools.	لذا يرجى التكرم بتسهيل مهام الباحث و مساعدته علي إجراء الدراسة المشار إليها
For Futher information : please contact **Mr Helmy Seada** on 02/6150140	للاستفسار : يرجي الاتصال **بالسيد / حلمي سعدة علي** هاتف 02/6150140
Thank you four ur cooperation. Sincerely yours,	شاكرين لكم حسن تعاونكم وتفضلوا بقبول خالص الاحترام و التقدير

ص ب 36005 أبوظبي، الإمارات العربية المتحدة PO Box 36005 Abu Dhabi, United Arab Emirates
T +971 (0)2 615 0000 F +971 (0)2 615 0602 E info@adec.ac.ae

أ.د. مسعود عبد الله بدري
مدير وحدة البحوث والتخطيط وقياس الأداء

Appendix J: Newton's Second Law of Motion Worksheet

Instructional Activities:

Engage:

- List all the things you know about force.
……

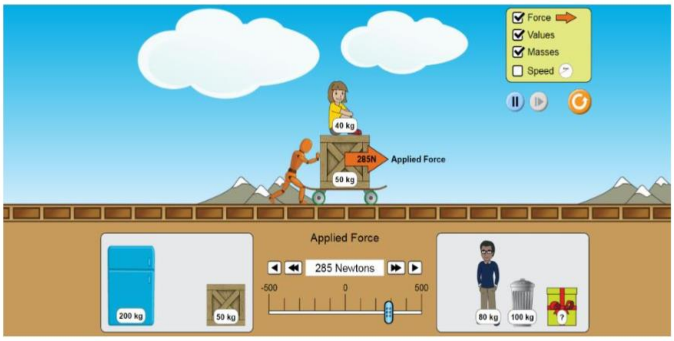
……
- Names the different types of forces?
……

……
- What are the differences between mass and force?
……

……

Warm up (practice): please be familiar with PhET simulations window

- Use "The Moving" simulation (Figure 1) to be familiar with the main functions and features of the software such as: using click-and-drag option, alternating variables, using control buttons, and showing graphs.



https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html

Figure (1)

Questions
1. What would you do to clear your data and start over again?

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

2. If you stop a running simulation, how can you restart the same clip again?

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

3. observe velocity makes the man moves? Use the simulation to confirm your answer.

4. If you want to make the man run faster and faster (accelerate). What will you do? ………………………………………………………………………………………………………

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

5. Try different ways to find an approximate value of acceleration that makes the man moves (fill the table below).

Force (N)	mass (Kg)	Acceleration(m/s^2)

2. Explore*:*

What to Do (based on the simulation represented in figure 2).

1. Reflect on the questions.

a) Can you tell how did the box begin sledding?

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

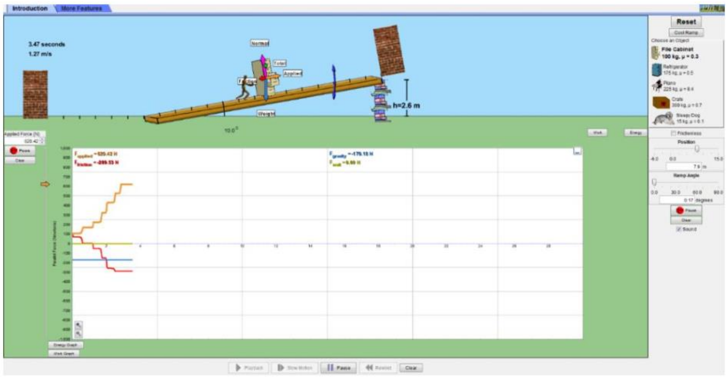


Figure 2

b) What could have happened to the box, if the friction force stronger?

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

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

c) How come! Despite steady friction, the box was sledding faster and faster. ………………………………………………………………………………………………………

d) If you were in the simulation, and the box was coming towards you, how could you respond to stop it?

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

e) In contrast, what would be the scenario, if the same events have happened on a plane snow ground?

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

2. Think of other questions to pose.

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

3. Share with the class your ideas about the results.

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

3. Explain!

Your Task

Use "Force in 1D" simulation (Figure 3) to conduct an experiment into the relationships between force, mass, and acceleration.

1. *Make a prediction!* See Figure 3.

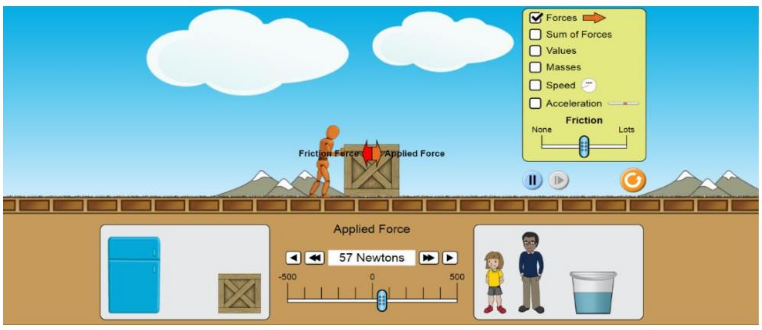


Figure 3

• Compare the motion (change in velocity or acceleration) of the box.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

2. *Design procedures to test your prediction!* First, Log on to “Force in 1D” simulation. And choose an object (make your front screen like Figure 3).

- Think of procedures to investigate how different applied forces affect the acceleration of an object:

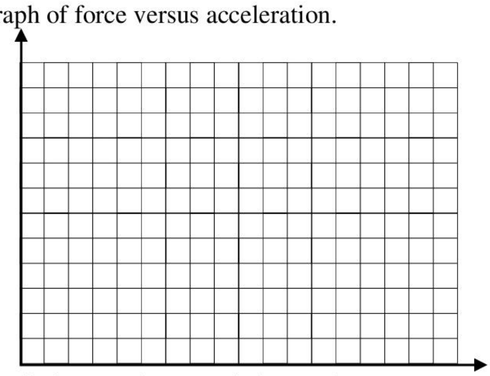
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

- Collect your data in the table blow and plot a graph of force versus acceleration.

Force (N)	mass (Kg)	Acceleration(m/s^2)



- Conclude your result and compare it with the prediction you have made in part 1.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Questions

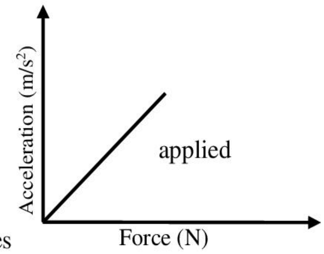
1. Referred to the collected data, fill in the following blanks:

❒ If the applied force doubles, the acceleration……….………… for a constant mass.

❒ As the mass decreases to one-third, the acceleration ……………...……. for a constant force.

2. If a graph shows a straight line passes through the origin does the line describe a direct or inverse relationship?

……………………………………………………………



3. Consider the procedures you have designed to investigate how force is related to the acceleration for a constant mass. Choose the appropriate term that describes force, mass, and acceleration as variables in your experiment.

- ❐ The force is a …………………... (control, manipulating, responding) variable.
- ❐ The acceleration is a ………………… (control, manipulating, responding) variable.
- ❐ The mass is a ……………………… (control, manipulating, responding) variable.

4. Elaborate:

1. Complete the data table and compare answers.
2. After analyzing the data, answer the following:

❐ What do you notice about the motion when there is no force added?

…………………………………………………………………………………………

❐ Why was it important to have a group of data where there was no force added to the object?

…………………………………………………………………………………………

…………………………………………………………………………………………

❐ How did the motion of the object change when more force was added?

…………………………………………………………………………………………

❐ How did the motion of the object change when more mass was added?

…………………………………………………………………………………………

5.Evaluate

- Using the essential vocabulary, group discussion notes, data table, and graph data as textual evidence to answer each question.

1. How do mass and force affect the motion of an object?

…………………………………………………………………………………………

2. What is a control group in an investigation? Why is the control important?

………………………………………………………………………………………………

………………………………………………………………………………………………

• Create another object with a friction surface to show the effects of friction on the motion of an object.

…………………………………………………………………………………….………

…………………………………………………………………………………………….

• Design your own inquiry, demonstrating the effect of mass on forces.

…………………………………………………………………………………….………

…………………………………………………………………………………………….

• In your notebooks, explain how Newton's Second Law of Motion is being illustrated in the simulation.

…………………………………………………………………………………….………

…………………………………………………………………………………………….

• Write a general statement relating the acceleration and mass, when the force acting is constant:

…………………………………………………………………………………….………

…………………………………………………………………………………………….

Appendix K: Student's Consent Form

[*Impact of Computer Simulation on UAE Students' Learning of Newton's Second Law of Motion and Attitudes toward Physics within the Context of Scientific Inquiry Instruction.*]

Consent to take part in research

I, __________________, confirm that Khaleel Alarabi asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had enough opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the Newton's Second Law exam and attitudes scale.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname…………………………………………….……… (please print)

Participant Signature……………..………………………………………..Date…………………

Researcher's Name: Khaleel Shehadeh Alarabi, the College of Education, United Arab Emirates University (UAEU)

Researcher's signature…………………………………………...Date…………………

Appendix L: Parent's Consent Form

Dear Parents:

We would like to inform you that your child will participate in a research study to explore the Impact of Computer Simulations on UAE Students' Learning of Newton's Second Law of Motion and Attitudes toward Physics within the Context of Scientific Inquiry Instruction. The students will study one unit using Computer Simulation and he/she will be targeted to respond to Pretest and Posttest to measure physics achievement and a survey to measure their attitudes toward physics. ***Participating in this survey is voluntarily*** and student's data will be used for research purposes. The collected data will be confidential and anonymous and used only for the research purposes. It is interesting to state that the study may raise the students' awareness to the learning physics and attitudes items.

If you approve of your child participation in the study, please complete the following and return this letter to the school.

_________ I approve   __________ I DO NOT approve

Parent's Signature: ___________________________

Thank you,

Appendix M: Newton's Second Law of Motion Lesson Plan Template

5 E (Inquiry–based Lesson Plan)

Grade/ 11 Advanced	**Topic:** Newton's second law of motion	**Lesson #**
Brief Lesson Description:		
Materials: PhET Simulations		
Performance Expectation(s): This lesson focuses on the study of how a given force affects an object's motion. - Describe how the change in an object's motion depends on the sum of the forces acting on the object and the mass of the object. - Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. - State Newton's second law of motion, and apply it, in qualitative terms, to explain the effect of forces acting on objects		
Specific Learning Outcomes: Student will be able to: Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object. Student will be able to: Investigate and describe that the more mass an object has, the less effect a given force will have on the object's motion.		
Narrative / Background Information		
Sir Isaac Newton is regarded by some to be the most influential scientist in history. His contributions to math, physics, astronomy, and optics are heavily relied upon still today and have led to countless innovations and achievements including getting humans to the Moon. Although he suffered from a rough childhood, Newton rose above these difficulties, and would eventually be knighted. We will examine the life and contributions of Sir Isaac Newton, who is arguably the most influential scientist in history.		
Possible Preconceptions/Misconceptions: • Objects that are in motion will eventually stop moving because rest is the natural state of all things •For continuous motion to occur, a constant force always needs to be applied •Heavy objects are harder to push than lighter ones •Heavier objects fall faster than lighter ones •Mass and weight are the same thing •The force an object applies to another object depends only on its acceleration (this is based on the equation F = ma)		
LESSON PLAN – 5-E Model		
ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions: •List all the things you know about force. •Names the different types of forces. •Distinguish between mass and force.		
EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions: Use "The Moving" simulation (https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html) to be familiar with the main functions and features of the software such as: using click-and-drag option, alternating variables, using control buttons, and showing graphs. **Reflect on the questions.** a) Can you tell how did the box begin sledding? b) What could have happened to the box, if the friction force stronger? c) How come! In spite of steady friction, the box was sledding faster and faster. d) If you were in the simulation, and the box was coming towards you, how could you respond to stop it? e) In contrast, what would be the scenario, if the same events have happened on a plane snow ground?		

EXPLAIN: Concepts Explained and Vocabulary Defined:

1. Use “Force in 1D” simulation (Figure 2) to conduct an experiment into the relationships between force, mass, and acceleration.

•Compare the motion (change in velocity or acceleration) of the box.

2. Design procedures to test your prediction! First, Log on to “Force in 1D” simulation. And choose an object (make your front screen similar to Figure 2).

•Think of procedures to investigate how different applied forces affect the acceleration of an object:

ELABORATE: Applications and Extensions:

1.Complete the data table and compare answers. Once everyone agrees, students will begin to complete their comparative bar graph using the figure in the mean column of the data table to compare the data.

2.After analyzing the data, the students should answer the following:

3.What do you notice about the motion when there is no force added?

□ Why was it important to have a group of data where there was no force added to the object?

□ How did the motion of the object change when more force was added?

□ How did the motion of the object change when more mass was added?

EVALUATE:

• Using the essential vocabulary, group discussion notes, data table, and graph data as textual evidence to answer each question.

1. How do mass and force affect the motion of an object?

2. What is a control group in an investigation? Why is the control important?

• Create another object with a friction surface to show the effects of friction on the motion of an object.

• Design your own inquiry, demonstrating the effect of mass on forces.

1.In your notebooks, explain how Newton's Second Law of Motion is being illustrated in the simulation.

• Write a general statement relating the acceleration and mass, when the force acting is constant:

Notes:

Appendix N: The UAEU College of Education Approval

UAEU College of Education

جامعة الإمارات العربيــة المتحدة
United Arab Emirates University

6 October 2019

No Objection Letter

This is to confirm that Mr. Khaleel Al Arabi is a PhD student at the Curriculum and Instruction Department at the College of Education, UAE University. Mr. Khaleel intends to conduct research on the "Impact of Computer Simulation on Students' Performance and Attitudes toward Physics." The College of Education has no objection to Mr. Khaleel carrying out this research project. This letter has been issued upon his request to facilitate getting an approval from ADEK and MoE to visit schools and conduct the research with students and teachers. We highly appreciate your cooperation with Mr. Khaleel Al Arabi.

Assistant Dean for Graduate Studies and Research

Ali Ibrahim

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Assistant Dean for Research and Graduate Studies
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/graduateprogram/www.cedu.uaeu.ac.ae

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Appendix O: The UAEU Social Sciences Research Ethics Committee Approval

UAEU Faculty of Humanities and Social Sciences

جامعة الإمارات العربية المتحدة
United Arab Emirates University

Social Sciences Ethics Sub-Committee
Approval Letter

May 29 2020

This is to certify that research proposal N: *ERS_2020_6116*, titled: *Impact of Computer Simulation on UAE Students' Learning of Newton's Second Law of Motion and Attitudes toward Physics within the Context of Scientific Inquiry Instruction*, submitted by *Khaleel Alarabi* has been reviewed and approved by the UAEU sub-committee for research ethics in social sciences.

Sincerely

Professor Sami Boudelaa
Chair of the UAEU Research Ethics Sub-Committee for Social Sciences
Department of Cognitive Sciences
United Arab Emirates University
UAE
Email: s.boudelaa@uaeu.ac.ae
Tel: 037136178