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The Impact of Integrating Computer Simulations On The Achievement of Grade 11 Emirati Students In Uniform Circular Motion

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THE IMPACT OF INTEGRATING COMPUTER SIMULATIONS ON THE ACHIEVEMENT OF GRADE 11 EMIRATI STUDENTS IN UNIFORM CIRCULAR MOTION

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This thesis is submitted in partial fulfillment of the requirements for the degree of Master of Education (Curriculum and Instruction)

Under the Supervision of Dr. Hassan Tairab

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Declaration of Original Work

I, Mohamad Fadi N. Aoude, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*The Impact of Integrating Computer Simulations on the Achievement of Grade 11 Emirati Students in Uniform Circular Motion*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. 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 Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions.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 thesis.

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Abstract

Education has been affected by the advancement of technology, especially computer software. This thesis focuses on the impact of computer simulations on students' acquisition of Physics concepts related to the topic of Uniform Circular Motion. The main purpose of this thesis is to examine to what extent can computer simulations help students of grade 11 from Al Ain, United Arab Emirates (UAE), learn factual, conceptual and procedural knowledge related to Uniform Circular Motion. It also aims to investigate how simulations affect students of different abilities in terms of their achievement in Physics. A quazi- experimental method was used, where participants were divided into an experimental group and a control group. The experimental group was taught using computer simulations, and the control group was instructed with the help of real- life videos and animations. The main instrument was an achievement test administered before and after the intervention. The study showed a statistically significant advantage for the experimental group over the control group, especially in the procedural knowledge dimension. In addition, results showed that students of medium and low academic levels benefit from the simulations more than students of high level. Results drawn from this study provide valuable information on effective integration of technology in physics teaching, because it examines the impact of simulations on different knowledge dimensions, as well as their effect on students of different abilities. As a result, it encompasses a large spectrum of variables in terms of the effectiveness of simulations, giving room for further researches on technology integration in science education in the UAE and the Arab world context.

Keywords: Computer simulations, science achievement, teaching physics, UAE, Uniform circular motion.

Title and Abstract (in Arabic)

أثر استخدام برامج المحاكاة الحاسوبية على مستوى طلبة الصف الحادي عشر من الامارات في درس "حركة المجسمات الدائرية بسرعة ثابتة"

ملخص

لقد كان أثر التقدم التكنولوجي واضحاً على كافة جوانب العملية التعليمية بشكلٍ عام وخصوصاً استخدام برامج الحاسوب. ركزت هذه الدراسة على أثر استخدام برامج المحاكاة الحاسوبية على قدرة الطلبة في اكتساب المفاهيم الفيزيائية المتعلقة بموضوع "حركة المجسمات الدائرية بسرعة ثابتة". ويكمن الهدف الرئيسي لهذه الدراسة في معرفة مدى الفائدة التي يمكن أن يقدمها استخدام مثل هذه البرامج للطلبة من الصف الحادي عشر من مدينة العين في الامارات، ضمن نطاق المعرفة بالحقائق و المعرفة النظرية و المعرفة الإجرائية المتعلقة بحركة المجسمات الدائرية بسرعة ثابتة. وتهدف هذه الدراسة أيضاً لمعرفة تأثير استخدام برامج المحاكاة الحاسوبية على الطلبة من مستويات مختلفة في مادة الفيزياء. وفيما يتعلق بالأسلوب الذي تم اتباعه في هذه الدراسة ، فقد استخدم الباحث أسلوب البحث الشبه تجريبي حيث تم تقسيم المشاركين في الدراسة إلى مجموعتين : المجموعة الأولى (المجموعة التجريبية) والمجموعة الثانية (المجموعة الضابطة). هذا وقد استُخدمت برامج المحاكاة الحاسوبية مع المجموعة التجريبية فيما تم تدريس المجموعة الضابطة باستخدام الفيديوهات والرسوم المتحركة. طبق الباحث اختباراً لتقييم أداء الطلبة قبل وبعد تدريس الوحدة على طلبة المجموعتين و أظهرت نتائج الدراسة من الناحية الإحصائية الفائدة الكبيرة التي حصل عليها الطلبة في المجموعة التجريبية مقارنة بالمجموعة الضابطة خصوصاً فيما يتعلق بالمعرفة الإجرائية المتبعة في الدرس. أظهرت النتائج ايضا أن مستوى الإستفادة لدى الطلبة من ذوي المستوى الضعيف والمتوسط كانت أكثر من مستوى الاستفادة لدى الطلبة ذوي المستوى المرتفع. بالاضافة الى ذلك، تظهر النتائج المستقاة من الدراسة معلومات قيّمة حول الأثر الواضح لاستخدام التكنولوجيا الحديثة في تدريس مادة الفيزياء، حيث تبين هذه الدراسة أثر استخدام برامج المحاكاة الحاسوبية على اكتساب الطلبة للجوانب المعرفية المختلفة، فضلاً عن أثرها على الطلبة من مستويات وقدرات مختلفة. وتحتوي الدراسة أيضاً على نطاقٍ واسعٍ من المتغيرات المتعلقة بفاعليّة استخدام برامج المحاكاة، ولكنها تترك الباب مفتوحاً أيضاً أمام مزيدٍ من الدراسات والأبحاث حول استخدام

تكنولوجيا المعلومات في التعليم في دولة الإمارات العربية المتحدة خصوصاً والعالم العربي عموماً.

مفاهيم البحث الرئيسية: برامج المحاكاة الحاسوبية، مستوى الاداء في مادة العلوم، تدريس مادة الفيزياء، الامارات العربية المتحدة،"حركة المجسمات الدائرية بسرعة ثابتة.

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Dedication

To my beloved parents and family, I hope I will always make you proud

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List of Abbreviations

HL	High Level
ML	Medium Level
LL	Low Level
DGBL	Digital Game- Based Learning
AB	Ability
StGrp	Student Group

Chapter 1: Introduction

New educational technologies are expected to change forever the way students learn and teachers teach, and the support for the use of computers in education keeps increasing (Kent and McNergney, 1999). The growth in technology integration in education has been spurred from the intent to improve teaching pedagogies and consequently student learning. In higher education, the use of different technologies has been put in action in order to positively influence students' academic achievement, course completion or degree attainment (Nora and Blanca, 2009). At school levels, teachers are educating students who are expected to spend all of their future lives in a technology- based society (Shelly, Gunter and Gunter, 2012). In the United States of America, federal government, state governments and school districts are offering massive funding to equip classrooms with computers, which are connected to networks, and have access to the Internet. In addition, teachers in these classrooms should be prepared to use both current and emerging computer technologies.

1.1 Impact of Technology on Teaching and Learning

Following the influx of technological influences, today's education focuses on equipping students with skills that help them search for, organize and make use of information from different sources. Students are supposed to integrate information technology in their education and daily life. For this reason, teachers have to identify skills that are mentioned in the curriculum and can be developed by using information technology (Kozielska & Kedzierski, 2007). However, the importance of technology in education actually lies in how much it can support, enhance and even improve learning (Selwyn, 2011).

In recent years, many scholars have studied the influence of computer technology on how people think (Selwyn, 2011). In fact, neurobiologists have investigated the possibility that there is a relation between technology use and young people's capabilities for learning and processing information. This has attracted the attention of some academics and educators to the technology induced capacity of young learners, which enables them to think and process information in a totally different way from their predecessors (Prensky, 2001a). According to Greenfield (1984), the repeated exposure to computer games and other digital media may enhance many thinking skills such as:

- Representational competence: It includes reading visual images as representations of 3D space.
- Multi- dimensional visual- spatial skills
- Developing mental maps
- Mental paper- folding
- Inductive discovery: It includes conducting observations, making hypotheses, and discovering the rules that govern the behavior of a dynamic representation.
- Attention deployment: It consists of simultaneously monitoring many locations.
- Faster response to expected or unexpected stimuli (as cited in Prensky, 2001b).

Moreover, due to the vast networks of information provided by digital technologies such as the Internet, young people are exposed to an increased amount of learning, and as a result, their mental skills and ability to learn are observed to be reconstructed and extended (Prensky, 2009).

Research has also reported that technology- supported instruction helps students improve their higher- order thinking skills. In fact, a study that focused on assessing Kindergarten students' higher- order thinking skills, has shown that students that were instructed with the use of a computer program called the "Webber Interactive WH Questions Program" performed better at answering "why" questions than their peers who did not receive computer- based instruction (Bradberry-Guest, 2011).

The impact of technology on education has been so considerable that it has led to the appearance of new educational philosophies such as ”Digital Wisdom”. Prensky (2009) believes that digital technology does not only make people smarter, but also wiser. As a result, he defines "Digital wisdom" as the wisdom that arises from the use of digital technology in order to access cognitive capabilities beyond our innate ability, as well as the wisdom to use technology prudently in order to improve our capabilities (Prensky, 2009).

1.2 Types of Computer Software Integrated in Education

The impact of technology on education may be explored through different computer software and applications that has been developed to enhance the teaching-learning process. These software and applications can be classified into different categories such as:

1.2.1 Drill and practice software and applications: The "drill- and-practice" computer programs are used to reinforce basic skills such as spelling words, development of reading vocabulary, improving letter recognition and developing phonics skills. Based on the same principle, tutorial software packages present new concepts in a step- by- step approach, and guide leaners to complete specific objectives (Selwyn, 2011).

1.2.2 Tutoring software and applications: In addition to “drill and practice” computer programs, intelligent tutoring systems (ITS) proved to be effective for middle- school students, as well as for undergraduate college students in terms of uncovering and rectifying misconceptions in Physics concepts (Myneni, 2011).

Intelligent tutoring systems are computer programs that are used for improving the teaching and learning processes in multiple domains, as they function based on 4 modules:

- Domain and Expert Module: it includes expert knowledge in a certain domain and the capability to solve problems related to that domain.
- Student Module: it consists of gathering information about each student’s knowledge states based on student’s interaction and responses to the system.
- Pedagogical (or Tutor) Module: it reflects the instructional prowess of the system, integrating different instructional strategies.
- Communication Module: it represents the human computer interface of the ITS (Myneni, 2011).

1.2.3 Digital games: In addition to the simulation- based tutoring systems, gaming environments have also proved to support constructivist approaches of learning through exploration, problem- solving and reflection on experience. According to Papert (as Cited in Selwyn, 2011), this type of technology reflects a childlike view of learning through building things and treating inanimate objects as if they have their own intelligence. In this manner, it elicits the emotional aspect of learning, and consequently engages students to learn in a totally different way than they do in a traditional classroom environment.

A research study conducted by Yang (2015) also shows that when effective teaching and learning approaches such as scaffolding and collaborative learning are blended with digital game- based learning (DGBL) in a vocational education setting, students' higher- order thinking skills are significantly improved. These skills include creative thinking, critical thinking and problem solving (Yang, 2015).

1.3 United Arab Emirates Context

In the context of UAE, many educational institutions have implemented policies and developed projects that are based on technology integration in education. For example, the Abu Dhabi Educational Council (ADEC) has implemented an award- winning application called "iADEC", which can be used by teaching staff, parents and community members as well. This application features many services, such as school search, access to the latest ADEC publications, news, videos, and a platform for users to share their concerns and suggestions with ADEC's central operations in different multimedia formats. ADEC stated that the purpose of this implementation to offer quality services to customers, which parallels the transformation into smart government as envisioned by UAE's leadership (ADEC, 2014). ADEC has also that technology has become a major component in education in general and in ADEC's mission in particular, and it aims to raise the standard of education delivered to people in Abu Dhabi (Sutton, 2011).

Furthermore, ADEC initiated the "iClass" project, and started conducting pilot studies in six public schools. The project requires connecting grade 3 and grade 4 classrooms with a range of connected solutions, such as IPads, Microsoft Surface, video conferencing and interactive whiteboards, in order to assess how they can be used to enhance collaboration and cooperation in students' learning process (Sutton, 2011).

The UAE Ministry of Education has also taken an essential role in promoting technology in education, as it launched in 2014 the "Etisalat Education Technology Center". This initiative was the result of the partnership between the Ministry and Etisalat, the leading telecommunication operator in UAE, in association with Microsoft. The purpose of this initiative was to train educators on how to effectively use and integrate technology in their classes, and how to develop students' skills for their future work and life (Ministry of Education, 2014).

In addition, the Ministry of Education has also collaborated with Etisalat in designing a YouTube channel called "Duroosi". This channel provides grade 11 and grade 12 students a self- learning educational tool with visual aids, to help them in their studies across different subjects (Ministry of Education, 2014).

Besides ADEC and UAE Ministry of Education, the United Arab Emirates University (UAEU) stress on the importance of technology in the development of education. For instance, the UAEU organized in 2014 the 10th International Conference on Innovations (Innovations 14) in Information Technology. The conference illustrated 29 research projects and working papers presented by a total of 80 participants from different countries. Many topics have been discussed during the conference, one of which was the impact of ICT on enhancing education. In addition, different workshops were conducted for students on the sidelines of the conference (UAEU, 2014).

The UAEU also held a video games conference in March 2015, as part of the third cognitive science day. The conference aimed to promote cognitive science and inter-disciplinary cooperation between scientific research, technology and humanities. It also stressed on the importance of integrating video games in the teaching- learning process because they help their users to analyze information and make decisions (UAEU, 2015).

Furthermore, the UAEU established the Center for Excellence in Teaching and Learning (CETL), which provides a wide variety of professional development for faculty of all disciplines, in order to make the classroom and engaging and active learning environment. Some of CETL's services include consultation on Smart Learning Course Transformation, Smart Learning teaching pedagogies and instructional software troubleshooting (UAEU, n.d.).

1.4 Computer Simulations and Physics Learning

As mentioned previously, technology is becoming increasingly important in today's classroom, and has been integrated in a variety of ways. However, interactive computer simulations are among the most commonly used software in education, especially in the discipline of Physics (Adams, Reid, LeMaster, …, and Wieman, 2008).

A computer simulation is a computer program that creates animated, interactive, game- like environments, which focus on connecting real- life phenomena to the underlying science. Within this process, it makes the visual and conceptual models of experts and scientists simple, so that they can be understood by learners (Adams et al., 2008).

In 2000, Hartel conducted a study about a simulation program called "xyZET" for Physics teaching. In his study, Hartel believed that simulations could be considered as basic tools to enhance understanding of Physics. He explained that the traditional approach of teaching Physics depends extensively on quantitative mathematical methods. Consequently, these methods have to be mastered as a prerequisite before any Physics learning takes place. With the advancement of the graphical capabilities of simulations, this dependence is not mandatory, as these simulations allow students to directly experience physics phenomena, without the need to rely on mathematics (Hartel, 2000).

Although computer simulations are virtual, they give students the opportunity to observe and study physical phenomena in a situation where it is impossible to carry out research, due to time restrictions, safety requirements or lack of proper equipment. They also reduce the gap between the real and theoretical worlds (Kozielska and Kedzierski, 2007).

Another advantage of using computer simulations is that a teacher can speed up or slow down the process of a physical phenomenon, which can never be done in real- life experiments. A teacher may also exhibit this phenomenon to his/her students as many times as he/she needs to, and easily change different parameters so that they observe their influence on the way it is processed. As such, computer simulations push students to ask questions, predict, formulate hypotheses, observe and interpret results (Kozielska, Kedzierski, 2007). This shows that simulations engage students to learn different types of knowledge.

1.5 Statement of the Problem

According to Hartel (2000), Kozielska and Kedzierski (2007), and Adams et al. (2008), the use of computer simulations was proved to be beneficial for teaching and learning physics. However, after conducting interviews with many teachers and students in Al Ain, UAE, it was noted that they were still hesitant about integrating this technology in their day- to- day classroom activities. They claimed that it was time consuming, in terms of taking away part of the teacher- talking- time, and students' practice- time as well. They also believed that simulations distracted students from focusing on the main concepts to be learned.

This study therefore investigated the impact of using computer simulations in supporting students' performance in Physics. It was focused on the unit of "Mechanics", specifically the topic of "Uniform Circular Motion", which was taught to grade 11 students in Al Ain.

1.6 Purpose of the Study

This study aims to assess the impact of computer simulations on the achievement of grade 11 students in Uniform Circular Motion in al Ain. Specifically, the study is set to examine the impact of computer simulations on the achievement of students:

- in factual knowledge, conceptual knowledge and procedural knowledge; and
- of the topic of circular motion based on their abilities.

1.7 Research Questions

This research investigated whether computer simulations can help grade 11 students in Al Ain improve their overall achievement in Physics. More specifically, it focuses on answering the following questions:

- How much can computer simulations help students acquire factual knowledge?
- How much can computer simulations help students acquire conceptual knowledge?

- How much can computer simulations help students acquire procedural knowledge?
- What impact do computer simulations have on students achievement based on their ability grouping?

1.8 Significance of the Study

By quantitatively providing evidence on the impact of computer simulations on student achievement of Physics related concepts, this study can be a significant endeavor in promoting the use of simulations in Physics classes. Students can start trusting this technology as a genuine learning tool, which can help them turn from passive learners who mainly depend on their teacher, into active, independent and life- long learners.

This study can also be a stepping stone for teachers to start implementing more technology in their classrooms, and as a result, to start adopting new teaching strategies that foster students' involvement in the learning process, their creativity and their cognitive skills. Consequently, teachers' role could be upgraded from being mere knowledge disseminators who are limited to spoon feeding students with information, to being knowledge facilitators, and focus on teaching students how to think and how to properly use technological resources to learn new information.

Furthermore, the findings of this research can contribute to the educational research in the UAE by providing knowledge base that may help future research on the integration of technology in teaching and learning. In doing so, it allows researchers, policy planners, and curriculum developers to take measures related to the integration of technology in UAE context.

Finally, data drawn from this study may provide evidence on how students of different academic levels, ranging from low, to medium, to high, benefit from simulations in grasping physics concepts. It also investigates which category of knowledge (factual, conceptual and procedural) these simulations mostly impact, by comparing students' improvement in each of these categories before and after the intervention takes place. As a result, teachers will have an idea on how to use new technological tools to help students acquire these categories of knowledge as well as to conduct lessons that match their ability.

1.9 Operational Definition of Terms

- Computer simulation: an event, process, or scenario that is created on a computer ("Computer Simulation", 2015). In this study, a computer simulation is limited to computer software that showcases, in an animated way, how physical systems work, provided that users are able to control variables that impact the outcome of the simulation. Also, when a simulation is used to conduct a lab experiment, it may be called "virtual lab".
- Factual Knowledge: The basic elements that students have to know to be familiar with a discipline or solve problems in it. It includes:
    - Knowledge of terminology
    - Knowledge of specific details and elements (Krathwohl, 2002)
- Conceptual Knowledge: The interrelationships among the basic elements within a larger structure which allow them to function together. It includes:
    - Knowledge of classifications and categories
    - Knowledge of principles and generalizations
    - Knowledge of theories, models, and structures (Krathwohl, 2002)

- Procedural Knowledge: The way of doing something. It encompasses the methods of inquiry, and criteria for using skills, algorithms, techniques, and methods, including:
    - Knowledge of subject-specific skills and algorithms
    - Knowledge of subject-specific techniques and methods
    - Knowledge of criteria for determining when to use appropriate procedures (Krathwohl, 2002)

1.10 Scope and Limitations

The study is limited to 93 Emirati students from one school in Al Ain based on the fact that the researcher had an easy access to that school, and especially because the school settings offered a distinguished research environment, where the integration of technology is a requirement rather than an option. In addition, the presence of students of different academic levels learning a common physics subject was also an asset to the study. Furthermore, the Physics curriculum of the school focused on Physics content based on factual, conceptual and procedural knowledge. These factors were convenient to the study, which focuses on the impact of computer simulations on students' learning in Physics, based on different types of knowledge and different abilities of students.

As such the findings of the present study should be interpreted within this context and the sampling procedures adopted in this study.

Chapter 2: Literature Review

2.1 Chapter Overview

Literature review is an essential component of any research studies, for it allows the researcher to adequately conceptualize and address the research questions, identify pathways to implement the research plan, and provide identity for the research. It is essential therefore to review previous studies that are related to the research topic. This helps in gathering some knowledge about the research problem, and provides a theoretical background to the study.

The literature review is divided into the following parts:

- Theoretical framework.
- Brief history of technology integration in education.
- Impact of computer simulations on acquiring factual, conceptual and procedural knowledge in science.
- Impact of computer simulations on the achievement of students with different abilities.
- Studies related to the UAE and the regional context.
- Summary.

2.2 Theoretical Framework

Any research study should be built on a relevant theory, which constitutes a foundation to the knowledge base of the topic to be studied. The main goal of a study is to develop knowledge that can contribute to practice, and a theoretical framework can be a map that guides a research, and provides it with a solid background.

This study is mainly founded on the following theories:

- Constructivism
- Modeling
- Spatial visualization

2.2.1 Constructivism: Constructivism is a theoretical perspective which proposes that learners do not learn by just passively absorbing knowledge, but by constructing a body of knowledge from their experiences and background information (Ormrod, 2011). Simulations provide students with a bridge that connects their prior knowledge to their learning of new physics concepts, thus helping them construct physics understanding by actively reformulating their misconceptions (Jimoyiannis and Komis, 2001). Many of the simulations that were used by the researcher aimed to help students understand physics concepts by using a constructive approach.

For example, in the simulation "Interactive: Banked Curve" (McGraw- Hill Global Education Holdings, 2015) students had to investigate how banked curves help cars maintain a circular trajectory at a high speed. To understand this concept, they had to combine their background knowledge about components of forces, with their newly learned knowledge about centripetal forces. The simulation, by presenting an animated diagram of the forces acting on the car during its motion from different angles (rear view and overhead view of the car), helped students make the link between their prior knowledge about "forces" and the new knowledge they learned about "uniform circular motion".

In his theory of cognitive development, Piaget introduces the concepts of "assimilation and accommodation". Piaget believes that "children learn through a combination of assimilation and accommodation" (as cited in Ormrod, 2011). During assimilation, children tackle newly received information in a way that is consistent with their existing schemes (Ormrod, 2011) or mental structures that are stored in their long- term memory (Lawson, 2010).

This cognitive process was observed by the researcher with students of the experimental group, when they used a game- based simulation entitled as “Alien Invasion” (Mangiacapre, n.d**)**. The goal of the simulation was to use a uniformly rotating ball attached to a rope in order to hit alien targets. As students released the ball to hit the targets, they observed that it followed a linear path tangent to the circular trajectory. This outcome was consistent with their existing schemes, which were based on personal experiences they have faced in their daily lives that were relevant to what they observed in the simulation. Consequently, they followed a deductive reasoning to build new knowledge consisting that the velocity of an object moving in a uniform circular motion is tangent to the circular path at a specific position.

On the other hand, if there is a mismatch between an expected and an actual outcome, then students will experience a state of disequilibrium, and will need to accommodate by either changing their existing schema or by creating a new one (Ormrod, 2011).

The researcher noticed this state of disequilibrium in his students when they faced some misconceptions. For example, when students were asked about the direction of the force causing an object to move in a circular path, some answered that the force has the same direction as the velocity, and others replied that the force has a “curved” direction. When they were informed that the direction of the force is centripetal, they were not totally convinced, thus experiencing a state of “disequilibrium”. Upon working on a simulation related to “gravity and orbits”

(PhET, 2015), students accommodated and changed their schema as they saw that the force causing Earth's circular motion around the sun was the force of gravity, directed towards the center of the circular trajectory. They have also learned that if this force of gravity was canceled, then the Earth would continue moving along a straight path.

2.2.2 Modeling: When trying to solve a problem, according to Rumelhart (1980), learners use their memory to look for a schema, or a technique that has already been learned in order to organize and interpret information in a certain subject (as cited in Boston, 2003). Glaser and Baxter (1999) believe that these learners can eventually build mental models to guide their problem solving in an efficient manner. In this way, they can create analogies and make inferences to support new learning instead of depending on trial- and error approaches (as cited in Boston, 2003).

Computational modeling consists of using mathematics, physics and computer science to analyze the behavior of a complex system by computer simulation. A computational model includes many variables that are characteristics to the system being studied. Simulation is done by changing these variables and observing how they affect the outcomes predicted by the model ("Computational Modeling", n.d).

2.2.3 Spatial visualization: Spatial visualization is the mental ability to manipulate spatial information in order to identify how a certain spatial configuration would appear if parts of this configuration were folded, rotated, or have changed their positions (Salthouse, Babcock, Skovroned, Mitchell and Palmon, 1990). Advanced spatial visualization skills, especially the ability to visualize in 3D, are cognitive skills that lead to performing at a high level in Science, Technology, Engineering and Mathematics (Metz, Donohue and Moore, 2012). Also, improving students' spatial visualization is an effective way to address some of their misconceptions in Physics (Huang, Becker, Mejia and Neilson, 2015).

In this study, a 3D simulation entitled as "Simple Circular Motion Rides" (Open Source Physics, 2013) was used, and it featured a person standing on a merry-go- round, and students were able to control the magnitudes of the angular speed and the radius of the circular trajectory. The purpose of using this 3D simulation was not only to allow students to investigate the impact of the angular speed (ω) and the radius (r) on the force (F) exerted on the person riding the merry- go- round, but also to observe the interaction between ω, r and F from different viewpoints and angles (Gallis, 2013). This might allow them to improve their spatial visualization of the uniform circular motion.

2.3 Historical Development of Technology Integration in Education

When we think about technology, we have a natural tendency to look forwards rather than backwards, to anticipate the future of technology rather than to make sense of what has already happened. Actually, new technologies often pay homage to preceding technologies. They redesign them, and challenge them as well. Throughout the history of development of technology, new forms of technologies often seek to both borrow from and surpass earlier forms. This shows that the evolution of technology may be seen in terms of continuity as well as change. In this sense, we can fully understand the significance and importance of a new technology only if we have a good understanding of its predecessors (Selwyn, 2011).

Over the long history of education, many technological inventions have played an important role in supporting learning and the development of knowledge, and all have had an impact on changing and transforming education from era to era. However, this study will focus on the recent rather than the ancient history of technology integration in education, because the examination of distant events, before reliable records began to emerge, is problematic (Edwards, 2012). In addition, it will only exhibit the educational technologies that have somehow led to the invention of computers and their integration in education.

2.3.1 Mechanized printing: One of the first inventions that changed the face of education from being accessible to a limited part of the society to becoming widely spread was the mechanized printing. In 1436, Johann Gutenberg invented a way of printing by using metal type, which could be easily arranged and rearranged. Therefore, printing press could mass-produce any text with reduced costs. As a result, knowledge could be standardized, preserved and disseminated very easily, new ideas could be developed and challenged by a wider range of people, and many books and resources became available to enhance learning and teaching across a wide spectrum of subjects. (Edwards, 2012)

The mechanized printing also induced a major change in the learning process. According to McLuhan (as cited in Edwards, 2012), printing is the technology of individualism, because it emphasized reading, an activity that allows an individual to learn on his own. As a result, oral learning became less popular, and visual learning took its place as the dominant mean of transmitting ideas.

2.3.2 Spelling machine: After Gutenberg, the printed book became the primary learning tool until Halcyon Skinner, an American industrialist and a master mechanic, invented in 1866 the first machine that can teach students how to spell. His machine was mainly made of three parts: an upper window that showed a picture, a series of keys that were used by students to type a word that represented the picture, and a lower window which exhibited the typed word. However, Skinner's "spelling machine" could not give immediate feedback for its users, unless a teacher intervened. This made a lot of researchers consider that Skinner's machine was more like a tool that helped teachers, rather than a teaching machine. The development of devices that could interactively "teach" students would emerge in the twentieth century (Edwards, 2012).

2.3.3 Pressey's machine: The first attempt at designing a device that could actually instruct and assess students was made by Sidney Pressey in 1928. Pressey believed that it was mandatory to combine educational science and inventive educational technology in order to improve education. His machine was mainly made of a typewriter, and could be operated in two different modes: the testing mode and the teaching mode (Edwards, 2012).

In the testing mode, students were subject to thirty multiple- choice questions with increasing difficulty levels. They answered those questions by pressing one of four keys. The machine would move to the next question automatically. When all the questions had been answered, it provided an indication of intelligence by counting the number of correct answers. In the teaching mode, the same procedure was followed a student could only move fro one question to another if he entered the correct answer. The machine allowed multiple responses until the correct key was pressed (Edwards, 2012).

2.3.4 Skinner's machine: Another American psychologist who had a strong impact on educational technology was B. F. Skinner, who argued that teachers would benefit from the use of mechanical devices that were capable of timely reinforcement and have the capacity to provide for differentiated and sequential learning (as cited in Edwards, 2012).

Skinner's personal invention consisted of a box that had a window on its top. This window displayed questions that were printed on paper. Users constructed their answers on sliders. Correct answers would result in a bell ringing, to provide some sort of reinforcement and to allow the transition to the following question. Incorrect answers would prevent users from moving to the next question until the mistake was corrected (Edwards, 2012).

Although Skinner's work may seem similar to Pressey's work, but their educational approaches were different. In Pressey's machine, a student needed to have background knowledge before he could use the device. While Skinner's machine was based on the concepts that new material should only be delivered to the student in small steps, via a response repertoire and that students would benefit the most from a teaching machine if they were allowed to construct their responses rather than select one from a set of predetermined alternatives (Edwards, 2012).

Beside Skinner, many educators have worked on integrating other technologies in education, specifically the motion picture, the radio and the television, which can all be grouped under the audio-visual technology.

2.3.5 Motion picture: The use of motion picture in the classroom started to grow during the first decades of the twentieth century. Many educators believed that the motion picture contributed to education in terms of providing a strong tool to the mass delivery of public education, as well as in terms of its ability to reflect reality in a visual form and to give life to the written and spoken word. According to Allen (1956), visual instruction provided by the motion picture assisted in achieving three main instructional objectives- "imparting a knowledge of facts, teaching perceptual-motor skills and influencing motivation, attitudes and opinions" (as cited in Selwyn, 2011, p.46).

In addition, Allen (1956) also reported that educational benefits of motion pictures were assessed by many quazi- experimental studies. For instance, a study found that groups of students that were taught with the help of film had a better grasp of information and concepts than students taught with traditional methods. Also, a number of surveys and evaluations stated that high- school science could be taught solely by film almost as effectively as by a teacher that uses conventional classroom procedures, and even better if films were properly introduced supported by a study guide (as cited in Selwyn, 2011).

However, by the 1950s, the use of motion picture in education witnessed a considerable decline. Many explanations for this failure were suggested, including teachers' lack of skills in using films, the difficulty to find and use the right film with the right class, the need for more central coordination and the high cost of equipment (Selwyn, 2011).

2.3.6 Radio: Motion picture was not the only educational technology that had success in the twentieth century. During the 1920s and 1930s, educational researchers showed great interest in the use of radio in classrooms (Selwyn, 2011).

The most celebrated "radio based" educational programs were the so- called Schools of the Air. These programs were designed to offer remote access to school education, by providing learning support material for classroom use, over a wide range of subject areas. Darrow (1932) reported that in the United States of America, the university- run "Ohio School of the Air" broadcasted educational material for schools across 29 states at that time (as cited in Selwyn, 2011).

The reason behind the great success of the "educational radio" was the fact that it helped high quality teaching and learning content to be received by a large number of classrooms, regardless of their geographic or socio- economic circumstances (Selwyn, 2011).

However, by the end of the 1940s, the integration of radio in education was not being executed to its full potential. Despite the fact that many schools have had radio sets, many studies reported that most teachers were only using radio occasionally. Also, Cuban (1986) mentioned that in 1941, a survey examined the reasons of the decline in the use of radio by schools (as cited in Selwyn, 2011). These main reasons were the following:

- no radio- receiving equipment
- school schedule difficulties
- unsatisfactory radio equipment
- lack of information
- poor radio reception
- programs not relevant to the curriculum
- preference of class work over the radio
- teachers' lack of interest

2.3.7 Television: After the radio, the television became the new trendy technology used in schools. In the 1950s, federal institutions and commercial organizations from the United States invested greatly in educational television projects (Ford Foundation funded 70 million Dollars for these projects). The popularity of educational television grew up in Europe as well. In the United Kingdom, for example, national television channels were annually producing around 50 TV series for schools and colleges by 1980, with 75 per cent of the schools using television in their classrooms (Selwyn, 2011).

As with earlier enthusiasms for film and radio, many educational researchers supported the use of the television for its ability to enhance learning quantitatively and qualitatively. Bates (1988), for example, stated that the television is a unique teaching tool that facilitates the transition of learning from the concrete to the abstract. He also mentioned that the visual and entertaining qualities of the television offer a window to the world for students (as cited in Selwyn, 2011).

Nevertheless, television, similarly to the film and the radio, found its way to loose some of its popularity in schools. By the 1980s, it was observed that most teachers used television infrequently in their classrooms and for short periods of the instructional time. This might be caused by the fact that television was often introduced in classrooms without sufficient thought for the nature of the social backgrounds of schools. Also, the applications of the technology were designed and adopted by non- teachers (Cuban, 1986), which made the material of TV programs irrelevant to the curriculum and the students' needs (as cited in Selwyn, 2011).

2.3.8 Computer: All of the technologies mentioned earlier in this historic review were the stepping-stones that led to one of the most recent and most enduring technologies used in education, the computer. In their early ages, computers were strictly used in universities for research and administrative purposes. In the early 1960s, computers started to be used in teaching and learning, but were merely limited within the "numeric" uses for engineering, mathematics and computer programming. Later on in the 1960s, the "computer- assisted instruction" emerged as a "savior" of school and university education because, according to Suppes (1966), it was able to provide education for young and adults in a flexible and individualized manner (as cited in Selwyn, 2011).

As educational computing continued to develop in the 1960s, it was used by learners under many forms as described by Martin and Norman (1970). These forms included (as cited in Selwyn, 2011):

- Tutorial and coaching instruction: the computer acts like a tutor that instructs and then assesses the learner about the material he acquired.
- Drill- and- practice instruction: mostly used in grammar, arithmetic, vocabulary and grammar of foreign language, this computer- based instruction helps the learner to gain skills through repetitive practice.
- Problem- solving: the learner is assigned to solve a problem and then to discuss the result with the computer in a conversational style.
- Simulation/ computer- as laboratory: the computer exhibits simulated versions of experiments on a screen.
- Database use: the computer provides the learner with access and selective browsing to large files of instructional information.
- Educational games: computer- generated games that have an educational background.

The use of these applications, supported by federal government and private firms such as Apple, Tandy and IBM, boomed during the 1970s and the 1980s across schools and universities in the US. By 1983, computers were being used in more 40 percent of all American primary schools and more than 75 per cent of all American secondary schools. Also, between 1981 and 1991, the proportion of American schools equipped with computers rose from 18 to 98 per cent (Selwyn, 2011).

Moreover, the instructional value of computers was highlighted by Martin and Norman (1970) in terms of enhancing student- centered learning, encouraging critical thinking, enhancing creativity, and its flexibility that could match all learning styles (as cited in Selwyn, 2011).

Unfortunately, history would repeat itself, as computers would suffer from inconsistency in their use in schools. The factors that lead to this misfortune were attributed to the fact that many computers were only accessible for teachers and students in dedicated computer “labs”, and that the technology, according to Conte (1997), was most frequently used to reproduce work through word- processing, drill- and- practice software rather than to teach higher- order thinking skills like synthesis, analysis and communication (as cited in Selwyn, 2011). Hawkridge (1983) also identified other reasons behind the low reception of the technology. Some of these reasons were (as cited in Selwyn, 2011):

- The restricted quantity, quality and variety of software and courseware
- Perceptions of the overdependence on mediated learning associated by computer use
- Concerns over the weakening of public educational systems
- Concerns over commercial bias
- Teachers’ ambivalence towards technological innovation
- Concerns over the social and political bias introduced with information technology

After revisiting the historical steps that led to the implementation of computers in education, the proposal will investigate the recent studies that focused on technology integration (especially computers). Some of these studies reported that technology does have an impact on education, and some others didn’t.

2.4 Impact of Computer Simulations on Acquiring Factual, Conceptual and Procedural Knowledge in Science

Technology plays an important role in learning 21st century science. Allowing students to use technology in their learning would give them a glimpse on how scientists are currently working, as they frequently use a number of technological tools in their daily practice, such as virtual environments and simulations, models of scientific phenomena, and collaborative tools such as email, video conferencing and shared workspaces like wikis (Bran, Gray, Piety & Silver-Pacuilla, 2010).

Computer simulations provides students with an open learning environment, which gives them an opportunity to:

- develop an understanding of physical phenomena and laws by developing hypotheses and testing ideas
- develop an understanding of the relations between physical concepts, variables and phenomena by isolating and manipulating parameters
- utilize a variety of representations, including pictures, animations, graphs, vectors and numerical data displays, which help them understand the underlying concepts, relationships and processes
- demonstrate their portrayal and mental models of the physical world
- employ an investigative approach about phenomena that are difficult to experience in a classroom or lab environments, due to their complexity, technical difficulty, money or time consumption, or because they occur too fast to be understood by just observing them in real- life settings (Jimoyiannis and Komis, 2001).

Adams et al. (2008) performed a study on the integration of simulations in the topic of “Sound Waves”. Adams and her colleagues found that one of the benefits of using these simulations was the fact that not only they drew the students’ attention by the animations they presented, but they also gave students an opportunity to see an animated motion instantly change as it was responding to their self-directed interaction with the simulation. As a result, new ideas formed and students began to make connections between the information provided by the simulation and their previous knowledge.

The study of Adams and her colleagues also resulted in more findings, which were illustrated when students encountered a word in the simulation that they did not know. When that happened, they attempted to play with the control that was labeled with the unknown word and subsequently created a working definition for the word. For example, “Frequency” and “Amplitude” were words students were unable to clearly describe before exploring the “Sound Waves” simulation. After playing around with the simulation, students correctly explained the meaning of these words by using visuals from the simulation. A few weeks later, the same students were interviewed about “Radio Waves”, and they used the visual descriptions from “Sound Waves’ to describe frequency and amplitude. Later on, these same students used “Radio Waves” to create an accurate working definition of an “Electric Field” (Adams et al., 2008)

In a study conducted on science students learning about electric circuits, Finkelstein, Adams, Keller, … and LeMaster (2005) pulled out a shocking result about computer simulations. In their study, they provided a group of students with real lab equipment, while they provided another group of students with computer simulations that modeled electron flow. Both groups were asked to fill a conceptual survey and to perform challenging tasks consisting of assembling real circuits and describing how they worked. Surprisingly, the group of students who used the computer simulations performed better than the other group in both the conceptual survey and in the hands- on tasks. This showed that these computer simulations could enhance students' manipulative skills and mastery of physics concepts better than traditional laboratory experiments (Finkelstein et al., 2005).

Podolefsky, Perkins and Adams (2010) conducted a study on how students use computer simulations to engage with and explore physics topics, particularly, the topic of "Wave Interference". In this study, the researchers focused on observing one type of inquiry, the "engaged exploration". It can be explained as a process during which students actively interact with educational materials, explore through their own questioning, and are engaged in sense making. Upon observing and interviewing students, they noticed that with minimal explicit guidance, students were able to use the simulation to explore the topic of wave interference in ways that were similar to how scientists explore physics phenomena.

Although these simulations were flexible enough to give students a chance to choose their own learning path, they also had some constraints, which were beneficial in making students' choices generally productive. These simulations also brought the advantage of connecting students to the concrete world, by providing them with representations that were not available in the real world, and by creating analogies to help learners understand and create connections across multiple representations and phenomena. Furthermore, these simulations also ensured a high level of interactivity with dynamic and immediate feedback to the students. Those features enabled students to ask questions and answer them in ways that is usually not supported in traditional educational settings (Podolefsky, Perkins and Adams, 2010).

In 2008, McKagan, Perkins, Dubson, … and Wieman conducted a study about integration of simulation in learning “Quantum Mechanics”. They reported that the simulations’ high interactivity, which enabled students to adjust controls and observe immediate animated response, has helped students engage with the content and establish cause-and-effect relationships. This interaction also appeared to be particularly effective for helping students construct understanding and intuition for abstract and unfamiliar quantum phenomena.

Additionally, many of the quantum simulations took advantage of the power of computers to quickly do complex calculations without exposing the user to the details. Thus, students were able to explore quantum tunneling and quantum wave interference qualitatively and focus on understanding the concepts without digging down in the math. According to McKagan et al. (2008), this has the potential to radically transform the way quantum mechanics is taught because it allows the instructor to focus on the problems that are most important for students to understand rather than on the problems that are easiest to calculate.

Further studies were also performed to test the effectiveness of simulations on the students’ performance in “Quantum Physics” subject.

Results from these studies confirmed that with the implementation of simulations in the curriculum, including both interactive lectures and homework using the simulation, learning was much greater than with traditional instruction. For example, on an exam question about whether increasing the voltage between the plates would lead to electrons being ejected when the light frequency was too low, an average of 83% of students answered correctly with correct reasoning in the courses using the simulation, compared to 20% of students in a traditional course, and 40% of students in a traditional course accompanied by a research- based computer tutorial (McKagan et al., 2008).

Eylon, Ronen and Ganiel (1996) studied the impact of the RAY computer simulation on understanding the concept of “Optics”. In their study, they had 2 experimental groups. For the first experimental group, one computer was used in the classroom as a “smart blackboard” and controlled by the teacher. It was used to investigate optical phenomena, to explain concepts, to interpret experiments and to represent theoretical problems. The second experimental group used the simulation individually. They followed a sequence of tasks on the computer, and were assisted by written enrichment of concepts and were engaged in a process of reflection and reformulation of knowledge. The control groups conducted the same type of activities as both experimental groups by adopting traditional methods. The results showed positive impact of the simulation in developing problem- solving skills, with limited impact on conceptual understanding for the first experimental group. For the second group, results showed gain in both problem- solving and conceptual understanding. Eylon, Ronen, and Ganiel deduced that three aspects of the learning process contributed in their study:

- RAY allows students to explore and provides them with immediate feedback while they are solving.
- The task design directly addresses the learning difficulties experienced by students.
- Giving students the opportunity to reflect on problem solutions and to reformulate knowledge.

A study that was done by Sierra- Fernandez and Perales- Palacios (2003) assessed the effect of computer simulations on students' learning in Newtonian mechanics. In this matter, they assigned a concept test and an attitude test to two groups of students, one group received instruction by using a textbook, and another group received instruction with computer simulation. As the statistical analysis of students' tests scores showed insignificant difference between the two groups, Sierra- Fernandez and Perales- Palacios commented that computer simulations lacked in systemization in the confirmation of hypotheses, which led students to wrong conclusions. They also added that some students couldn't easily interpret the space- time and velocity- time graphs shown on the screen, and even the students who were able to identify their incorrect hypotheses after carrying out the simulation activities, couldn't explain the unexpected phenomena shown on the screen. At the end of their study, they concluded that students, regardless of the instructional approach they received, needed additional help such as immediate feedbacks.

The experimental aspect of physics learning is mostly observed in vocational education, where the traditional teaching approach for vocational engineering majors consists of textbook- based instruction and practical, hands- on lessons. In the field of electrical engineering, textbooks offer a reliable resource to develop factual knowledge (by providing facts and definitions) and procedural knowledge (by providing laws and equations to solve problems). On the other hand, practical lessons allow students to build electrical circuits and carry out measurements, thus developing students' skills in manipulating real electric equipment, as well as building conceptual knowledge in the domain (Kollöffel and de Jong, 2013). However, there are some drawbacks in the practical lessons, which prevent students from building a strong conceptual understanding of electric circuits. For instance, according to Schauble, Klopfer and Raghavan (1991), students focus on making circuits work rather than on understanding the "causal relations between variables and outcomes" (as cited in Kollöffel and de Jong, 2013). Also, the fact that when working with real circuits, students may obtain results from measurements that do not match their expectations based on the formulae they have learned, may cause them to fail linking their hands- on activities with the theories they learn from their textbooks. Moreover, setting- up or adjusting lab equipment may require considerable time and effort. Computer simulations may offer a solution for all the difficulties that students may tackle when using real lab equipment. In fact, lab experiments may be set up and manipulated fast and with ease, which allows students to remain focused on the inquiry process without any distraction. Consequently, students can better synthesize the basic concepts of electricity into a coherent framework, thus improving their conceptual and procedural knowledge (Kollöffel and de Jong, 2013).

Tambade and Wagh (2011) investigated the effectiveness of computer simulations in facilitating physics concepts, specifically electrostatics, for third- year undergraduate students. Their research focused on testing how much computer simulations could help students interpret verbal, vector and diagrammatic representations in electrostatics, as well as maintain conceptual understanding in that area of Physics. Participants were divided into a control group, who received traditional instruction through lecturing, and an experimental group, who was taught using cooperative learning approach, with integration of "Interactive Electrostatics Simulation Package". The most beneficial features of this package consisted in supporting student- student and student- teacher interactions, in providing information about every aspect of the phenomena related to the subject, and in representing phenomena in different ways (verbal, vector, and diagrammatic representations).

Results of the study showed that the interactive computer- aided instruction was efficient in promoting conceptual understanding of electrostatics, as the experimental group, who received such instruction, had an average normalized gain 2.46 times more than that of the control group. Also, more results showed that students of the experimental group better understood the verbal, vector and diagrammatic representations of electrostatic phenomena than their peers from the control group. Consequently, this study proved that computer simulations could help students diminish their misconceptions in electrostatics and develop a functional understanding of Physics concepts (Tambade and Wagh, 2011).

2.5 Impact of Computer Simulations on the Achievement of Students with Different Abilities

Research shows that computer simulations have different effects on students depending on their academic levels or abilities. Yildiz and Atkins (1996) studied the effect of three different simulation environments (physical, procedural, and process) on the learning of students with different characteristics. The physics topic that was taught in this study was “Energy”. The analysis of students’ performance showed mixed results. They found that the same simulation could have different impact on students of different genders and prior achievement levels. For example, middle achieving students took advantage of the possibility to repeat the same experiment many times to build confidence in their understanding. However, high achieving male students scored less in the posttest compared to the pretest. This was attributed to the fact that the lack of challenge in using computer simulations might have caused boredom and loss of concentration for these students. Regarding students with low prior achievement, they didn’t have a smooth learning experience because the simulations didn’t provide them with clear learning objectives and immediate feedback. At the end of their study, Yildiz and Atkins recommended that computer simulations should be carefully differentiated for students of different characteristics (Yildiz and Atkins, 1996).

A study that was done in Nigeria, focused on the effect of computer simulations on students’ achievement in practical Physics, based on their levels of mathematical reasoning abilities. It consisted of 3 experimental groups. The first group used computer- simulated experiments only, the second group used hands- on experiments only, and the third group used both simulated and hands- on experiments. Students’ achievement was a combination of their scores on Manipulative Skills in Physics Practical (MSPP) and Physics Achievement Test (PAT). Results showed that students who used both computer- simulated and hands-on experiments performed best among the three groups while students who only used hands-on experiments had the lowest score in MSPP and PAT. Additionally, students with moderate mathematics reasoning ability performed best in all the groups, which shows that computer simulations are useful to enhance the performance of a student with average mathematical ability (Adegoke and Chukwunenye, 2013).

Chang, Chen, Lin and Sung (2008) conducted a study in Taipei and investigated the effect of learning support on simulation-based learning in three learning models: experiment prompting, a hypothesis menu, and step guidance. The study focused on the topic of optical lenses, and adopted 2 experiments. The first experiment included 153 junior high school students, which were divided into a control group (undergoing laboratory learning, N = 39), experimental group 1 (undergoing simulation-based learning with experiment prompting, N = 39), experimental group 2 (undergoing simulation-based learning with a hypothesis menu, N = 40), and experimental group 3 (undergoing simulation-based learning with step guidance, N = 35). Results from this experiment showed that students who adopted a simulation- based learning environment had a significant advantage over students who adopted laboratory- based learning, which reflected that any type of simulation-based learning that provides learning support is more efficient than laboratory learning. The second experimental group included 231 junior high school students who were divided into experimental group 1 (experiment prompting, N = 78), experimental group 2 (a hypothesis menu, N = 79), and a control group (step guidance, N = 74). Results of this experiment reflected a significant effectiveness of learning models and of abstract reasoning ability. However, the insignificant interaction between learning models and abstract reasoning abilities proved that different learning models do not have different effects on individuals with different abstract reasoning abilities. Furthermore, it was noted that students with higher abstract reasoning had higher gains from simulation-based learning than students of lower abstract reasoning, and that students who were subjected to experiment prompting and a hypothesis menu had higher results than those who received step guidance (Chang, Chen, Lin and Sung, 2008).

2.6 Studies Related to the UAE and the Regional Context

Many studies conducted in the Arab world shared some common ground with this research in terms of integrating technology in the process of teaching and learning. One study was about the impact of Computer Assisted Language Learning (CALL) on the achievement and attitude of UAE students in English as a Foreign

Language (Almekhlafi, 2006). The findings of this study showed that CALL users had a clear advantage in their achievement over nonusers. In addition, a questionnaire was administered to CALL users to investigate their attitude, perceived utility, and intention to use CALL in the future. Students in the experimental group had a positive attitude toward CALL, considered it as helpful in their learning of EFL, and had a strong intention to use it in the future. (Almekhlafi, 2006).

In the regional context, a study that took place in Kuwait investigated the impact of computer simulations on teaching primary science. The participants included 365 students from grade 5, who were instructed by 8 female science teachers, from 8 different primary schools in Al Kuwait. All participating schools were single- sex, with 4 of them having male students, and the other 4 having female students. The study adopted a quazi- experimental design, as participating students were divided into 2 experimental and 2 control groups. The 2 control groups received traditional instruction, while the first experimental group used computer simulations in a lab environment, and the second experimental group used computer simulations inside the classroom. The instruments used in the study to collect data were a pre-posttest, and an attitude questionnaire. Results reported that there was no significant difference between the first experimental group compared to students of the control group after collecting their scores from the posttest. However, there was considerable effect of using simulations in the classroom, as students from the second experimental group outperformed their peers from the control group in the posttest. The study also showed that computer simulations help students acquire conceptual understanding as well as rectify some of their misconceptions in specific topics. "Electric Circuits" was one of the topics the study focused on. At the pretest, 82.9% of students from the second experimental group and 74.4% of students from the corresponding control group were at low conceptual understanding level about "Electric circuits". At the posttest, 9.8% of students from the second experimental group and 33.3% from the control group were still at low conceptual understanding level. On the other hand, 0% of students were on a very good conceptual understanding level at the pretest, and this percentage rose to 12.2% for the experimental group, and to 10.3% for the control group. Finally, the questionnaire used in the study reported positive attitudes of students towards the usability of computer simulations, specifically regarding their "opinion about the program" and their "experiences with using the program" (Alfajjam, 2013).

Another study, conducted at Al Hussein- Bin- Talal University in Jordan, focused on the effect of integrating computer simulations on students' learning of electricity and magnetism concepts, as well as the impact of those simulations on students' attitudes towards learning Physics. The study used two instruments. The first instrument was a concepts test to assess students' understanding of the electricity and magnetism concepts, prepared by the researchers. The second instrument was the Colorado Learning Attitudes about Science Survey, designed at the University of Colorado. The experimental group, consisted of 120 students, was taught by using simulations, and the control group, containing 115 students, was taught in a traditional way. Results drawn from this study showed that simulations had a significant positive impact on students' acquisition of Physics concepts. The researchers attributed this outcome to the presentation of Physics concepts in multiple ways by simulations (figures, charts, movements, shapes, etc). Another feature of simulations that might have reflected the observed outcomes was the opportunity provided by simulations for the students to repeat them by using different values, which helped students recognize the relationships and principals underlying the concepts taught during the study. However, there were no differences of statistical indications regarding attitudes of the students in both the experimental and control groups, which was explained by the fact that changing attitudes towards Physics learning needed a long period of time (Alrsa'i and Aldhamit, 2014).

Ahmed (2010) has also conducted a study in Egypt about "the effect of using a e-lab on the physics concepts achievement, acquisition of higher-order thinking skills and motivation toward science learning among students of the third preparatory class". In his study, he used a quasi- experimental approach, as he divided his sample of 90 female students from the third preparatory class into an experimental group and a control group. To collect data, he used instruments: an achievement test in physics concepts, an achievement test that measures the acquisition of higher-order thinking and a motivation scale towards science learning. The experimental group was taught about "sound and light" by using e- lab software, while the experimental group was taught the same subject via traditional teaching methods. Results showed reflected positive impact of e- lab software, as there was a significant advantage in favor of the experimental group in the achievement and in the acquisition of higher- order thinking skills. In addition, the study showed that members of the experimental group have a higher motivation towards learning Physics than their peers from the control group.

2.7 Summary

The above review of past research studies on the technology integration pointed to a number of implications that can be drawn. Starting with the review of the history of educational technology, it is noticed that all these technologies go through the same cycle. Every new technology gains huge success at the dawn of its invention, and it becomes the solution to all problems faced in schools, which ignites researchers to study its effectiveness. After a while, as this technology fails to gain wide acceptance in schools, new studies will emerge blaming teachers for not using it frequently. This phenomenon can be explained by the fact that technology has not been invented for the sake of education itself, but rather for luxury and economical purposes. So it was more like “forced” into education in order to become inline with the rest of the society.

The review of literature also reported different effects of simulations on different types of knowledge. Some studies showed that simulations had a significant impact on factual knowledge (Adams et al. (2008), others on conceptual knowledge (Tambade and Wagh, 2011) and others on procedural knowledge (Finkelstein et al. (2005), Podolefsky, Perkins and Adams (2010)). In some cases, simulations had a positive impact on 2 types of knowledge (McKagan et al. (2008), Eylon, Ronen and Ganiel (1996), Kollöffel and de Jong (2013)).

Furthermore, simulations also had different effects on students of different abilities. In some studies, students of high cognitive abilities benefited the most from simulations (Chang, Chen, Lin and Sung (2008)), while in other studies, students of moderate cognitive abilities took advantage from the simulations the most (Yildiz and Atkins (1996), Adegoke and Chukwunenye (2013)).

Finally, in the UAE and regional context, studies generally outlined the advantage of using computer simulations over the traditional teaching methods in terms of students’ achievements (Alfajjam (2013), Alrsa’i, Aldhamit (2014)). However, different results were reported regarding students’ attitude towards learning Physics in general, and towards learning Physics through simulations in particular (Ahmed (2010), Alrsa’i and Aldhamit (2014)).

Taking the findings reported from these previous studies, the present study stands out by focusing on how simulations affect students' achievement in general, and by highlighting the impact of these simulations on different knowledge dimensions (factual, conceptual and procedural knowledge) and on students of different academic levels in particular.

Chapter 3: Methodology

3.1 Chapter Overview

The purpose of the methodology chapter is to provide a complete description of the steps that were undertaken to address the research questions, which investigate the impact of computer simulations on students' achievement in factual, conceptual and procedural knowledge of uniform circular motion, along with the impact of these simulations on the performance of students of different academic abilities, using a quasi- experimental, pre- posttest design.

This chapter is divided into 6 sections. The first section describes the participants and the sampling procedures. More specifically, this section presents information about the students involved in this study, including their average age, their gender, their nationality, and their academic backgrounds. Also, this part of the chapter explains the sampling procedure that was followed in choosing members of the experimental and the control group respectively.

The second section focuses on the main instrument, the achievement test, which was conducted to collect data. It sheds the light on how the instrument was designed according to curriculum content objectives and cognitive objectives. Also, it reports how the instrument's validity and reliability were established.

The third section illustrates the research design the study was based on, which was quasi- experimental, as well as the rationale behind adopting it. Furthermore, this section explains in details how the study was conducted, including the teaching tools and pedagogies that were implemented when delivering instruction to the experimental and control group respectively.

The fourth section explains how data was collected via pretest and posttest, and provides a description of the different statistical methods that were used to analyze the results. The fifth section focuses on data analysis, while ethical issues are discussed in the sixth section.

3.2 Sampling

The sample of the study consisted of 93 male Emirati students from grade 11 (16 – 17 years old) at a high school located in al Ain, UAE. Students involved in this study learn 6 core subjects, including English Language, Arabic Language, Islamic Education, Mathematics, Sciences (Physics, Chemistry and Biology) and Information and Communication Technology. Despite sharing the core subjects mentioned earlier, students are given the choice to take cluster courses, according to their personal preferences and their scores in math and sciences.

The participants were divided into 2 major groups, the experimental group and the control group. Students of the experimental group were instructed with the assistance of computer simulations, while students of the control group were instructed using other technologies (real- life and animated videos).

Also, the participants in each group (experimental and control) were stratified into 3 categories, based on their overall performance in Physics over a period of 3 months. The overall score of each student was calculated as the average of his classwork, homework, quizzes and lab reports obtained during that period of time. Students who had an average of 90% and above were classified as High Level (HL), while students who averaged between 70% and 89% were classified as Medium Level (ML), and students whose average was below 70% were classified as Low Level (LL).

The participating students were distributed over 5 sections, as shown in table1:

Table 1: Number of students per section

Section	Number of students
Section A	20
Section B	17
Section C	19
Section D	17
Section E	20
Total	93

As part of the school settings, students of section A were higher achievers than students of the other sections, in terms of science subjects in general, and physics in particular. Consequently, the results collected from the participants showed that there was a considerable gap between section A from one side and sections B, C, D and E from the other side, as most of the HL students were concentrated in the section A. As a result, the researcher could not adopt random sampling when choosing which sections would represent the experimental group and which sections would represent the control group, because students would not have been fairly distributed between the 2 groups in terms of their academic level. Under those circumstances, the researcher adopted sampling procedure shown in table 2.

Table 2: Distribution of students based on their ability level

Section	Distribution based on Ability Level		
	HL	ML	LL
Section A	14	6	0
Section B	1	11	5
Section C	0	13	6
Section D	2	11	4
Section E	1	13	6
Total	18	54	21

Sections B and C were joined together to make the experimental group, whereas sections D and E were joined together to make the control group. In order to distribute the sample equally between the experimental and control groups, taking into consideration the ability level grouping, students from section A, which contained the most HL students, were randomly selected to either join the first or the second group. This sampling method has resulted in having:

- 9 HL, 27 ML and 11 LL students to form the experimental group
- 9 HL, 27 ML and 10 LL students to form the control group

3.3 Instrument

The main instrument used in this study is a purposely- developed achievement test, which consisted of 29 multiple- choice questions, on the physics topic of "Uniform Circular Motion".

Two resources were used to construct the questions, "Physics Principles and Problems" (by McGraw Hill Companies, Inc, 2013) and "College Physics 9th

Edition" (by Serway- Vuille, 2012). Items were chosen and modified from resources to encompass:

- the content objectives, which featured the learning outcomes of the physics curriculum provided by the school.
- the knowledge dimensions, which included:
    - Factual knowledge - The basic elements that students must know to be acquainted with a discipline or solve problems in it (Krathwohl, 2002)
    - Conceptual knowledge - The interrelationships among the basic elements within a larger structure that enable them to function together (Krathwohl, 2002).
    - Procedural knowledge - How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods (Krathwohl, 2002).

3.4 Test Validity

Upon designing the test according to the criteria mentioned above, 35 questions were initially developed and presented for test validity. A group of educators, which included two physics teachers from the school at which the study took place, and three professors from the College of Education of the United Arab Emirates University, reviewed those items. Each member of the group was provided with a copy of the test, in which each question was associated with the content objective and the knowledge dimension it was related to. Accordingly, each evaluator commented on each question in terms of its content validity and construct validity.

Content validity measures the extent to which a test measures an intended content area. More specifically, it evaluates whether test items are relevant to the measurement of the targeted content area (item validity), as well as whether the test illustrates all of the content area being tested (Gay, Mills and Airasian, 2011).

Construct validity, on the other hand, measures the extent to which a test reflects the construct it is supposed to measure (Gay, Mills and Airasian, 2011). In this regard, each committee member evaluated each question whether it reflects the intended knowledge dimension the researcher associated it to. After taking into consideration the feedback received from the test evaluators, the final version of the test included, as shown in table 3:

- 6 factual knowledge questions
- 8 conceptual knowledge questions
- 15 procedural knowledge questions

Table 3: Distribution of test items based on knowledge dimensions

Knowledge Dimension	Questions	Total
Factual Knowledge	1, 4B, 5, 10B, 16, 18	6
Conceptual Knowledge	2, 3, 11A, 11B, 15, 22, 23, 25	8
Procedural Knowledge	4A, 6, 7, 8, 9, 10A, 12, 13, 14, 17, 19A, 19B, 20, 21, 24	15

The rationale behind having most of the questions focused on procedural knowledge is the fact that the physics school curriculum primarily focuses on this type of knowledge, as students are mostly trained to apply their physics knowledge in solving physics problems that require mathematical- logical procedure. However, students are also trained to answer questions that require explanation of physics concepts, as well as recalling physics facts, but to a lesser degree.

3.5 Test Reliability

Reliability assesses how consistently a test measures what it is expected to measure. More specifically, reliability measures the confidence that scores obtained from a test are approximately the same scores that would be obtained if the test was retaken by the same students in another time, or by different students (Gay, Mills and Airasian, 2011).

Reliability analysis was performed on the test items and the results are shown in table 4.

Table 4: Values of Cronbach's Alpha coefficients for subsets and total test items

	Cronbach's Alpha	Number of items
Factual knowledge questions	.52	6
Conceptual knowledge questions	.56	8
Procedural knowledge questions	.67	15
Total	.81	29

The reliability was calculated by using the SPSS package via Cronbach's alpha for a 29-items test. Upon calculation, alpha of .81 was obtained for the total test items. Consequently, the test was accepted as reliable (George and Mallery, 2003). Results obtained for the reliability of specific types of questions show that alpha ranges from .52 for factual knowledge questions to .67 for the procedural knowledge questions. These results may be explained due to the small number of items and participants.

3.6 Research Design

The study employed a quazi- experimental, pre- posttest design to examine the effect of computer simulations on students' learning of the topic of Uniform Circular Motion. According to Gay, Mills and Airasian (2011), this design is deemed to be an appropriate one because it provides a context in which two groups are to be compared based on a particular intervention (computer simulations). The independent variable is represented by computer simulations, while the dependent variables are the scores of students on factual, conceptual, and procedural knowledge of Uniform Circular Motion, as well as their scores of students based on their ability levels.

Results from the pretest and the posttest were compared to measure the impact of simulations in improving students' knowledge. Also, students' scores were compared among different levels (HL, ML and LL) to investigate which student level is mostly benefited by these simulations.

3.7 Data Collection Procedures

At the beginning of the study, all participants sat for a pretest before instruction took place. During the instruction phase, the experimental group was taught using computer simulations, and the control group was instructed using other technologies such as real- life and animated videos. A lesson plan was prepared by the researcher, and it included some activities that were common for the experimental and the control groups, and other activities that were different between the 2 groups. The lesson plan included the following parts: (see appendix D)

- Content objectives of the lesson

- Introduction
- Definition of uniform circular motion
- Velocity in uniform circular motion
- Force and acceleration in uniform circular motion
- Examples of centripetal force
- Magnitude of centripetal acceleration and centripetal force
- Period and frequency
- Conclusion

After 2 weeks of instruction and 1 week of application and practice, both experimental and control groups sat for a posttest and by the end of the study, data from pre-posttests were collected.

The experimental group included section B (total of 17 students), section C (total of 19 students) and 11 students from section A. Those students studied the topic of Uniform Circular Motion, in a student- centered cooperative learning environment. The teacher took the role of a facilitator, as students were engaged in many activities that guided them to learn new concepts through the use of computer simulations. Students worked collaboratively to answer questions that guided them to learn about Uniform Circular Motion, starting from the most basic to the more complex concepts.

Different online resources websites were for simulations. The first resource was "PhET INTERACTIVE SIMULATIONS", developed in the University of Colorado Boulder (http://phet.colorado.edu). Originally, PhET (Physics Education Technology) focused solely on designing Physics Simulations, and then it expanded to other disciplines, such as Chemistry, Biology, Earth Science and Mathematics. PhET's research- based simulations received many awards (such as SIGOL Online

Learning Award, 2nd place (2012), and the Microsoft Education Award (2011)). PhET grants permissions for students and educators to use its simulations freely for educational purposes.

The second resource was “Physics, (Companion Site), 2/e” developed by McGraw-Hill Higher Education. This is a companion site for the “Physics Second Edition” book written by Giambattista, Richardson and Richardson (2010). It provides multiple online resources based on topics covered in the book, among which were free computer simulations.

An example of simulations that were used in the study is the PHET simulation entitled “Gravity and Orbits” (PhET, 2015). This simulation allowed students to understand through investigation that the force that causes uniform circular motion is centripetal (directed towards the center of the circular path), and that the velocity vector is tangent to the circular path at every point of the trajectory (see figure 1). Students also observed that if they drag Earth far from the sun, the gravitational force of the sun decreases. As a result, they concluded that the greater the radius of the trajectory is, the smaller the centripetal force (see figure 2), which lead them later to discover that the centripetal force is inversely proportional to the square of the radius of the trajectory. The simulation also allowed students to understand visually and dynamically the meaning of the term “Period” in a uniform circular motion.

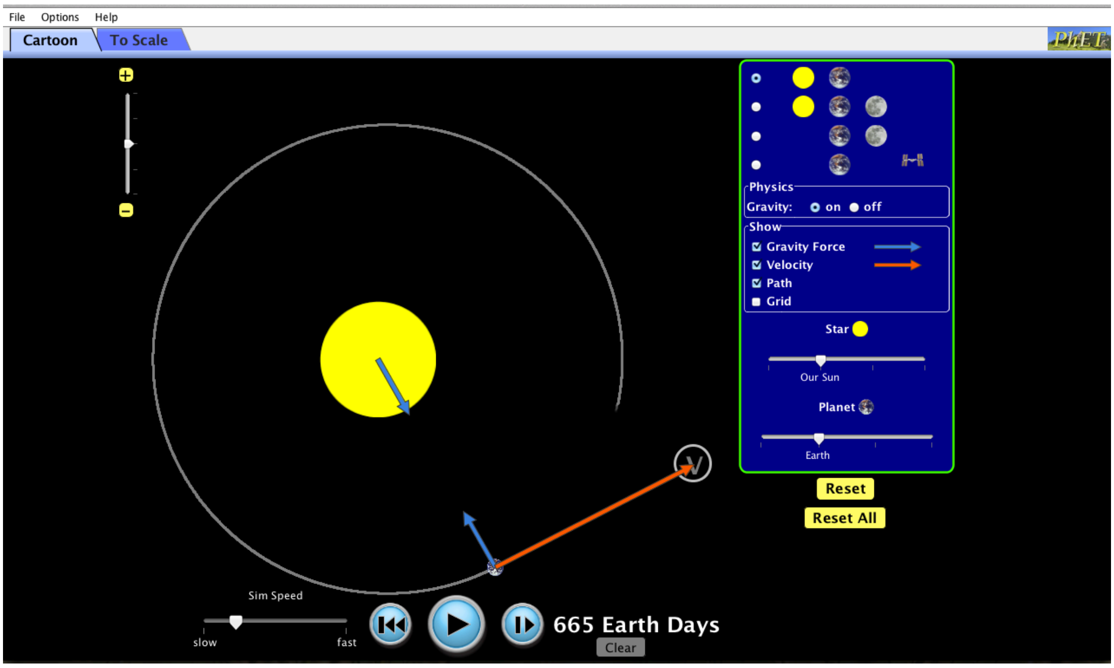

Figure 1: Gravity and Orbits 1 (PhET, 2015)

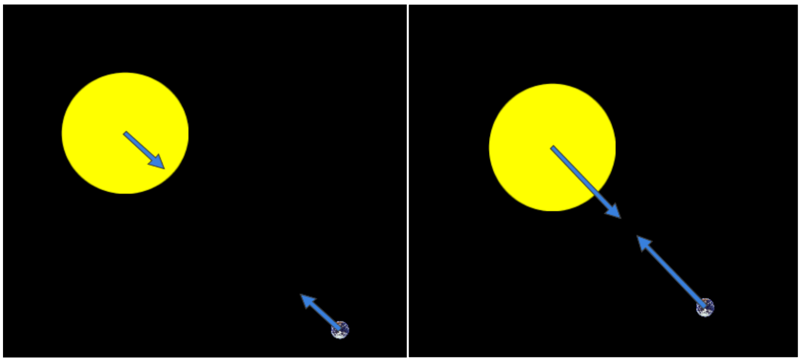

Figure 2: Gravity and Orbits 2 (PhET, 2015)

Another example of simulations used with the experimental group is one entitled as “Interactive: Banked Curve” (McGraw- Hill Global Education Holdings, 2015). This simulation helped students understand how banked curves help increase the centripetal force acting on a car, by showing them from a rear view and from an overhead view of the car, how the force of gravity, the normal force and the static friction of the surface on which the car moves result in a net force directed towards the center of the curve. In addition, the feature of controlling variables such as velocity, track incline and coefficient of static friction included in this simulation, allowed students to understand the mathematical and physical relationships among those variables (see figure 3).

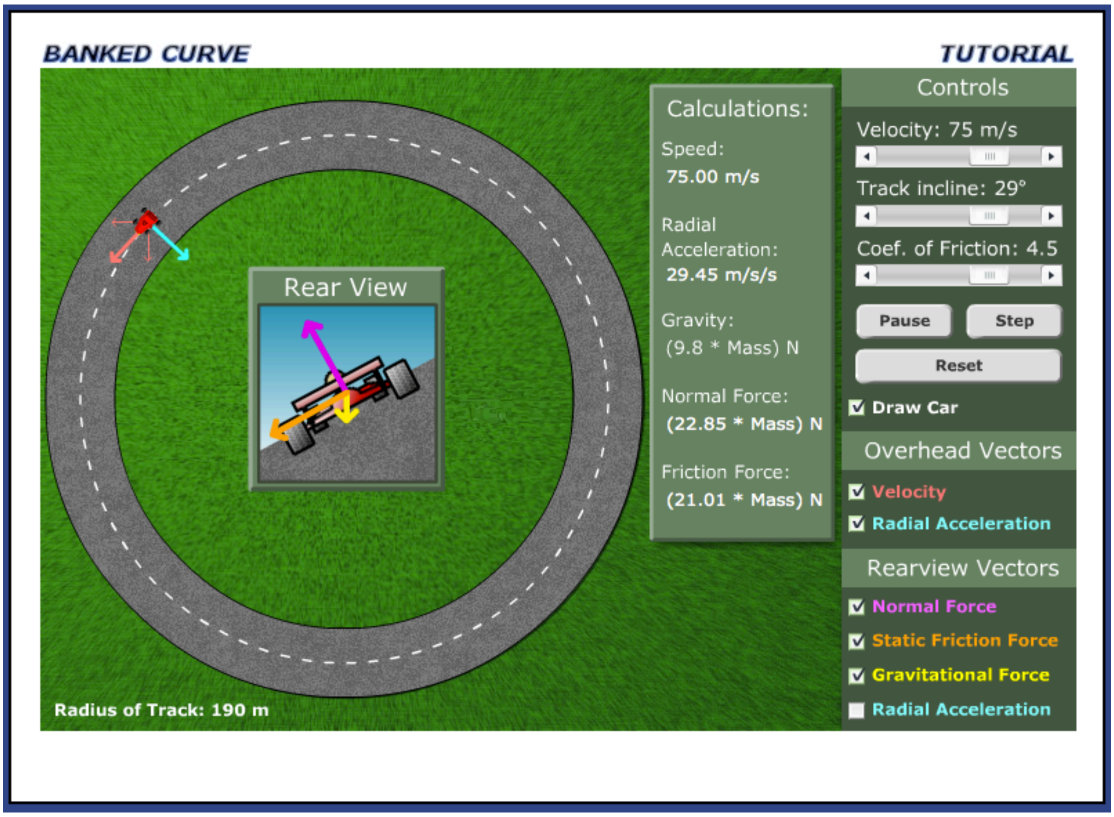

Figure 3. Interactive: Banked Curve (McGraw- Hill Global Education Holdings, 2015)

On the other hand, the control group included section D (total of 17 students), section E (total of 20 students) and 9 students from section A. Students of this group were taught in a cooperative student- centered environment similar to that of experimental group, with the only difference of using videos as assistive technology instead of simulations. Even though real- life and animated videos are interactive technological tools, they lack the advantage of controlling variables and observing the resulting outcomes, an option that is featured in simulations.

An example of a video used with the control group is one entitled as "Centripetal Force Demo - Rutgers University", which could be found on youtube.com (St. Mary's Physics Online, 2013). In this video, students were able to observe that if a bowling ball, initially moving along a straight line, is hit continuously by a hammer towards a fixed point; it would undergo a circular motion. This observation helped them understand the centripetal nature of the net force acting on an object that undergoes a uniform circular motion (see figure 4).

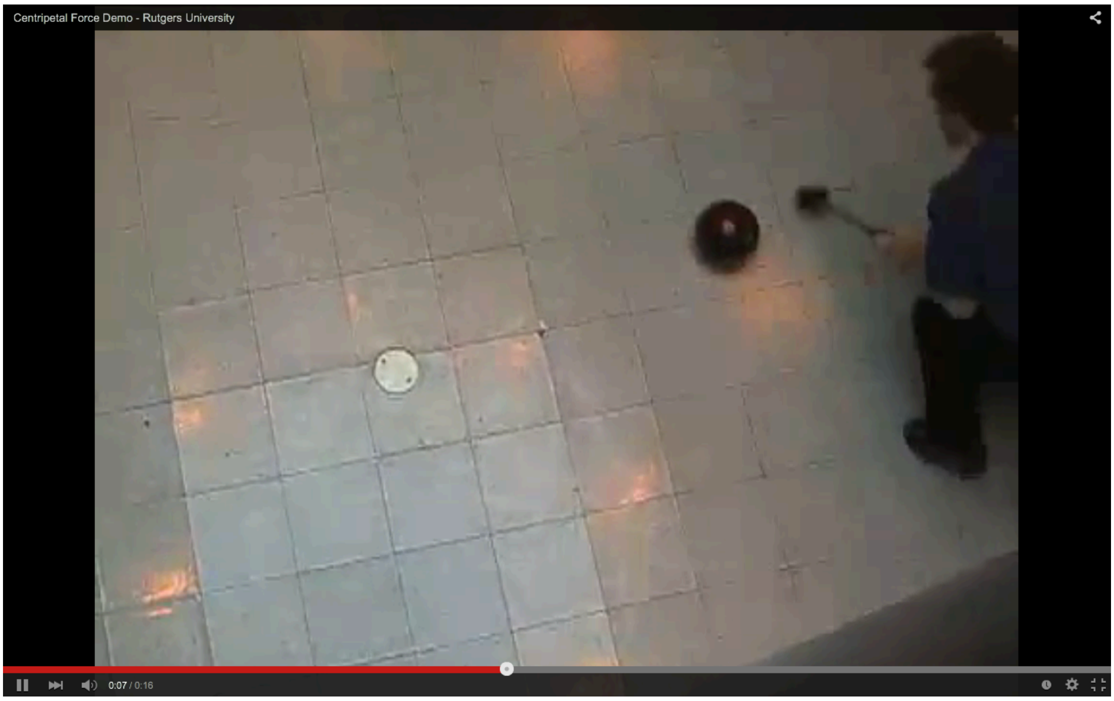

Figure 4. Centripetal force demo - Rutgers University (St. Mary's Physics Online, 2013)

Another video that was used with the control group is one entitled as "m16 1", which also could be watched on www.youtube.com (Dabhangg, 2011). This video explained how banked curves help a car go through a circular path, even with the absence of the force of friction, by showing the students how the combination of the gravitational force and the normal force result in a centripetal force (see Figure5).

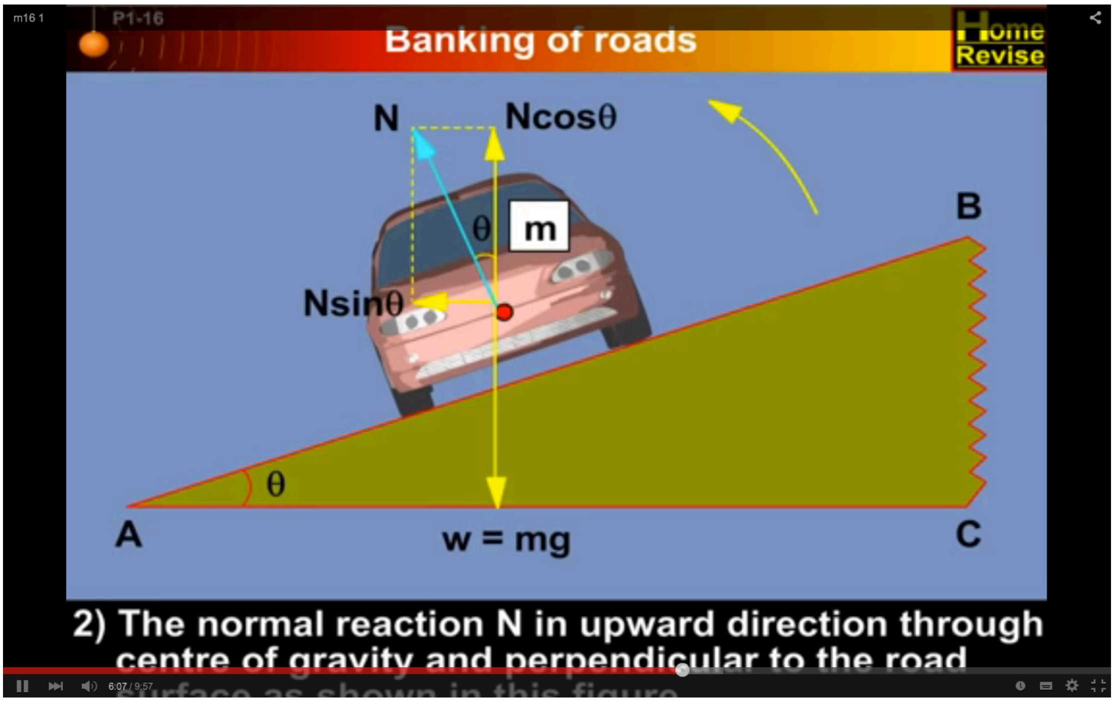

Figure 5. m16 1 (Dabhangg, 2011)

3.8 Data Analysis

Students' scores from the pre and the posttests were collected and then analyzed via SPSS package, using descriptive statistics (mean, standard deviation and standard error) and inferential statistics (One- way ANOVA, two- way ANOVA, paired samples t- test and two- way MANOVA).

Analysis of these scores aimed to:

- Present the initial level of students by collecting their scores on the pretest.
- Compare posttest results of the experimental group to posttest results of the control group to investigate the impact of simulations on student performance.
- Compare the scores of students from the experimental group to the scores of students from the control group in each knowledge dimension.
- Present comparisons based on the grouping of ability levels of students from both the experimental and the control group.

- Investigate interactions between student groups (experimental and control) and student ability groupings (HL, ML, LL).

3.9 Ethical Considerations

Initially, the researcher developed a proposal to his study, and presented it to the thesis committee. Upon examining the proposal, and making sure that no participants would be placed at risk due to the proposed treatment, the committee gave the researcher the approval to proceed with the study.

In the next step, the researcher asked the school's administration to grant him permission to conduct the study, and he presented a letter of consent to conduct the study, issued from the College of Education at the United Arab Emirates University (UAEU).

Also, students and the school administration were assured that the pre and the posttests scores would not affect students' marks, and that the data collected from these tests only serve for research. The researcher also explained to the students and the administration that the time assigned for the pre and the posttests would not affect the teaching- learning time, because the pretest, taking place before instruction, might serve as a way to introduce students to the concepts to be learned, as well as a way to diagnose students' background knowledge of the topic. On the other hand, the posttest, which takes place after instruction, might serve as reinforcement for students.

In addition, students' confidentiality was respected, as individual participants' performance on both tests was not reported using participants' names. Instead, each student was presented with a code number, in order to track his performance during the study.

3.10 Summary

This chapter concentrated on the procedure that was followed during the study. It started with describing the participants, including their age, nationality, and grade level. This part also featured how the sampling mechanism went, taking into consideration the settings of the school in which the study were conducted. In this matter, students were divided into experimental group and control group, taking into account the academic level of students, which was based on their achievements in homework, classwork, lab reports and quizzes over a time period of 3 months. The second part of the chapter described how the instrument, which was used in the study, was constructed. The test included 29 multiple- choice questions, which were based on content and construct objectives. The content objectives were issued from the school's Physics curriculum, while the construct objectives were based on 3 types of knowledge (factual knowledge, conceptual knowledge and procedural knowledge). Upon establishing its validity and reliability, the test contained 6 fact-based questions, 8 concept- based questions and 15 procedure- based questions. The third part of the chapter shed the light on the research design adopted in the study, which was quazi- experimental, based on a pretest and a posttest. The fourth part of the chapter described the data collection procedure. It consisted of administering a pretest to both the experimental and the control groups prior to instruction, and then administering a posttest to both groups after instruction, keeping in mind that the experimental group was taught using simulations, while the control group was taught using videos and animations. The fifth part shed the light on how the collected data was analyzed, using statistical functions such as one- way ANOVA, two- way ANOVA, paired samples T- test and two- way MANOVA via SPSS package. The main purpose of using those functions was to compare students' performance between the experimental and control group, as well as to investigate the impact of simulations on students' achievements at different academic levels and for different knowledge dimensions. Finally, ethical issues were presented in terms of respecting participants' privacy, as well as following necessary protocols in terms of taking permission from the university and the school to conduct the study.

Chapter 4: Results

4.1 Chapter Overview

This chapter presents the results pertaining to the data that was collected from the research completed in this study, which aimed to investigate the impact of computer simulations on students' understanding of physics concepts related to "Uniform Circular Motion".

Quantitative data was collected using a 29- item test instrument, which was purposely developed based on the content objectives related to "Uniform Circular Motion". Specifically, the test assesses three knowledge dimensions, including factual, conceptual and procedural knowledge. Data was collected in 2 phases. The first phase occurred before instruction, as students' scores from a pretest were collected, and the second phase took place after instruction, when data was gathered from students' scores on the posttest.

The purpose of this chapter is to present findings related to answers to the research questions that were presented in chapter 1 as follows:

- How much can computer simulations help students acquire factual knowledge?
- How much can computer simulations help students acquire conceptual knowledge?
- How much can computer simulations help students acquire procedural knowledge?
- What impact do computer simulations have on students achievement based on their ability grouping?

This chapter is divided into 2 sections. In the first section, students' scores in the pretest are presented for the experimental and the control groups. This section includes students' scores for the entire test (total scores), and it also presents students' performance in the pretest based on their abilities, ranging from high, to medium and to low level.

The second section of this chapter features students' scores in the posttest after both the experimental and the control groups have completed their learning about "Uniform Circular Motion", with the experimental group using computer simulations and the control group using videos and animations. First, students' total scores on the posttest from the experimental group are compared to the total scores of students on the posttest from the control group. Second, the posttest total scores of students from the experimental and the control groups are compared based on students' abilities. Finally, a detailed comparison between the experimental group and the control group performance on the posttest is presented, taking into consideration their scores on factual knowledge questions, conceptual knowledge questions and procedural knowledge questions, as well as their ability levels. Finally, a summary of all the findings is presented at the end of the chapter.

4.2 Comparison of Student Performance in the Pretest

Before teaching took place, all participants from the experimental and the control groups were subjected to a pretest in order to check their background knowledge about "Uniform Circular Motion". Data from the pretest is divided into 3 parts:

4.2.1 Comparison of pretest results of experimental and control groups: In this part, a one- way analysis of variance (one- way ANOVA) is used to compare the means of the experimental group and the control group in the pretest.

Table 5 shows the descriptive statistics of the experimental group versus the control group in terms of their performance in the pretest. The experimental group has a higher mean score (*M* = 2.47) than the control group (*M* = 2.39). In addition, the distribution of scores around the mean is slightly higher in the control group (*SD* = 1.96 and *SE* = .29) compared to the experimental group (*SD* = 1.65 and *SE* = .24).

Table 5: Descriptive Statistics of the Pretest Total Score

	N	Mean	Std. Deviation	Std. Error
Experimental Group	47	2.47	1.65	.24
Control Group	46	2.39	1.96	.29
Total	93	2.43	1.80	.19

Table 6 features a one- way ANOVA to determine whether there is any significant difference between the groups regarding their performance in the pretest. Results collected from the 2 groups show that there is no significant difference between them $F\,(1, 91) = .042$, $p = .839$.

Table 6: One- Way ANOVA of the Pretest Total Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.14	1	.14	.042	.839
Within Groups	298.66	91	3.28		
Total	298.80	92			

4.2.2 Comparing pretest total scores between the experimental and the control groups based on students' abilities: In this part, a univariate Analysis of Variance (two- way ANOVA) is conducted to compare between the total scores of the experimental and the control groups on the pretest, taking into consideration their ability levels. Students from both groups have been classified into 3 ability levels, High Level (HL), Medium Level (ML) and Low Level (LL) based on their mean scores in Physics on different types of assessment over a period of 3 months, including Homework, Classwork, Lab reports and Quizzes.

Table 7 presents descriptive statistics that report the performance of students from the experimental and the control groups on the pretest, based on their ability levels. In the experimental group, the pretest mean score was found to be in the range of 1.27, *SD* = 1.10 for low ability students, to 2.59, *SD* = 1.53 for medium ability students to 3.56, *SD* = 1.81 for high ability students. In the control group, the pretest mean score is ranged from .80, *SD* = .63 for low ability students, to 2.41, *SD* = 1.65 for medium ability students, to 4.11, *SD* = 2.42 for high ability students. The same order is observed in the mean score of the whole sample, starting from low ability (*M* = 1.05, *SD* = .92) to medium ability (*M* = 2.50, *SD* = 1.58) to high ability (*M* = 3.83, *SD* = 2.09). Finally, it can be noticed that students from the experimental group, of medium and low abilities, outscored their peers of the control group, while high-ability students from the control group outscored their peers from the experimental group.

Table 7: Descriptive Statistics of Pretest Total Score based on Student Abilities

Student Group	Ability of student	N	Mean	SD
Experimental Group	High ability	9	3.56	1.81
	Medium ability	27	2.59	1.53
	Low ability	11	1.27	1.10
	Total	47	2.47	1.65
Control Group	High ability	9	4.11	2.42
	Medium ability	27	2.41	1.65
	Low ability	10	.80	.63
	Total	46	2.39	1.96
Total	High ability	18	3.83	2.09
	Medium ability	54	2.50	1.58
	Low ability	21	1.05	.92
	Total	93	2.43	1.80

Table 8 shows a two- way ANOVA, which aims to determine whether there is a statistically significant interaction between the students' groups and the students' abilities in terms of their pretest scores. First, data shows that there is no significant difference between the experimental and the control group in their performance on the pretest, F (1, 87) = .009, p = .93. However, there is a significant difference between the 3 levels of student ability, F (2, 87) = 15.11, $p \leq .001$. Finally there is no statistically significant interaction between student group and student ability F (2, 87) = .55, p = .58

Table 8: Two- way ANOVA for Pretest Total Score based on Student Abilities

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	78.87	5	15.77	6.24	.000
Intercept	445.91	1	445.91	176.39	.000
StGrp	.022	1	.02	.009	.93
AB	76.41	2	38.20	15.11	.000
StGrp * AB	2.76	2	1.38	.55	.58
Error	219.93	87	2.53		
Total	848.00	93			
Corrected Total	298.80	92			

Since there is a significant difference among participants in the pretest based on their abilities, a Tukey HSD post- hoc comparison test is run. Results of the post-hoc test, which are presented in table 9, show that the mean differences among all ability groups are significant. Particularly, the highest significance is observed for the mean difference between the high ability group and the low ability group (MD = 2.79, $p \leq .001$), followed by the mean difference between the medium ability and the low ability groups (MD = 1.45, p = .002), to conclude with the mean difference between the high ability and the medium ability groups (MD = 1.33, p = .008).

Table 9: Post Hoc Tests for Pretest Total Score based on Student Abilities

(I) Ability of student	(J) Ability of student	Mean Difference (I-J)	Std. Error	Sig.
High ability	Medium ability	1.33	.43	.008
	Low ability	2.79	.51	.000
Medium ability	High ability	-1.33	.43	.008
	Low ability	1.45	.41	.002
Low ability	High ability	-2.79	.51	.000
	Medium ability	-1.45	.41	.002

4.3 Comparison of Posttest Results

In order to assess the impact of computer simulations on Physics learning, data collected from the posttest is divided into 3 parts:

4.3.1 Comparing posttest total score of the experimental group to the posttest total score of the control group: In order to compare the performance of the experimental group to that of the control group in the posttest, a one- way analysis of variance (one- way ANOVA) is used.

Table 10 features the descriptive statistics that compare the experimental group to the control group in terms of their performance in the posttest. The experimental group has a higher mean score

(M = 21.21) than the control group (M = 18.70). In addition, the distribution of scores around the mean is slightly higher in the control group (SD = 5.21 and SE = .77) compared to the experimental group (SD = 4.08 and SE = .59).

Table 10: Descriptive Statistics for the Posttest Total Score

	N	Mean	Std. Deviation	Std. Error
Experimental Group	47	21.21	4.08	.59
Control Group	46	18.70	5.21	.77
Total	93	19.97	4.82	.50

Results from a one- way ANOVA presented in table 11 show that the difference between the mean score of the experimental group and that of the control group is statistically significant,

F (1, 91) = 6.74, p = .011.

Table 11: One- Way ANOVA for Posttest Total Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	147.29	1	147.29	6.74	.011
Within Groups	1987.61	91	21.84		
Total	2134.90	92			

4.3.2 Comparing the posttest total scores of the experimental and the control groups in terms of student abilities: This part focuses on investigating the interaction between the student groups (including the experimental and the control groups) from one side, and the students' abilities (including high, medium and low abilities) from the other side regarding the posttest total score. For this purpose, a univariate Analysis of Variance (two- way ANOVA) is conducted; in which students' scores on the posttest represent the dependent variable. In addition, a paired samples t- test is conducted to further investigate the impact of the intervention on different student abilities. This part of the study aims at addressing the fourth research question, which converges on the impact of computer simulations on students' achievements in Physics based on their ability groupings.

Table 12 shows that the experimental group (*M* = 21.21, *SD* = 4.08) performed better than the control group (*M* = 18.70, *SD* = 5.21) in terms of total score on the posttest. More specifically, high ability students from the experimental group (*M* = 25.89, *SD* = 2.09) slightly outscored high ability students from the control group (*M* = 25.44, *SD* = 1.88). However, the gap between medium ability students from the experimental group (*M* = 22.00, *SD* = 1.84) and medium ability students from the control group (*M* = 18.78, *SD* = 3.70) is greater than the one observed for high ability students. The latter result is also observed when comparing low ability students from the experimental group (*M* = 15.45, *SD* = 2.50) to low ability students from the control group (*M* = 12.40, *SD* = 1.90).

Table 12: Descriptive Statistics of Posttest Total Score Based on Student Abilities

Student Group	Ability of student	N	Mean	Std. Deviation
Experimental Group	High ability	9	25.89	2.09
	Medium ability	27	22.00	1.84
	Low ability	11	15.45	2.50
	Total	47	21.21	4.08
Control Group	High ability	9	25.44	1.88
	Medium ability	27	18.78	3.70
	Low ability	10	12.40	1.90
	Total	46	18.70	5.21
Total	High ability	18	25.67	1.94
	Medium ability	54	20.39	3.32
	Low ability	21	14.00	2.68
	Total	93	19.97	4.82

To determine whether there is a statistically significant interaction between students' groups and students' abilities in their performance at the posttest, a multivariate analysis (two- way ANOVA) is conducted as shown in table 13. First, results show that there is a significant difference between the experimental and the control group in their performance on the posttest, F (1, 87) = 13.38, $p \leq .001$, partial $\eta^2 = .13$. There is a significant difference among the 3 levels of student ability, F (2, 87) = 98.03, $p \leq .001$, partial $\eta^2 = .69$. Finally there is no statistically significant interaction between student group and student ability in the posttest results, F (2, 87) = 1.96, $p = .15$, partial $\eta^2 = .04$.

Table 13: Two- way ANOVA for Posttest Total Score based on Student Abilities

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared (η^2)
Corrected Model	1532.00[a]	5	306.40	44.21	.000	.72
Intercept	29539.41	1	29539.41	4262.58	.000	.98
StGrp	92.72	1	92.72	13.38	.000	.13
AB	1358.66	2	679.33	98.03	.000	.69
StGrp * AB	27.17	2	13.58	1.96	.15	.04
Error	602.91	87	6.93			
Total	39215.00	93				
Corrected Total	2134.90	92				

The fact that there are significant differences among ability groupings of students ($p \leq .001$) with a high effect size (partial η^2 = .69) in the posttest scores requires to develop a Tukey HSD post hoc test to identify which pairs of ability groups have the most significant difference. As shown in table 14, the mean differences among all ability groups are significant. Particularly, the highest mean difference is observed between the high ability group and the low ability group (*MD* = 11.67), followed by the mean difference between the medium ability and the low ability groups (*MD*= 6.39), to conclude with the mean difference between the high ability and the medium ability groups (*MD* = 5.28).

Table 14: Post Hoc Tests for Posttest Total Score based on Student Abilities

(I) Ability of student	(J) Ability of student	Mean Difference (I-J)	Std. Error	Sig.
High ability	Medium ability	5.28	.72	.000
	Low ability	11.67	.85	.000
Medium ability	High ability	-5.28	.72	.000
	Low ability	6.39	.68	.000
Low ability	High ability	-11.67	.85	.000
	Medium ability	-6.39	.68	.000

To further investigate the impact of computer simulations on students of different abilities, a paired samples T- test is conducted between the following pairs of variables:

- High ability students from the experimental group (ExpHL) and high ability students from the control group (ContHL)
- Medium ability students from the experimental group (ExpML) and medium ability students from the control group (ContML)
- Low ability students from the experimental group (ExpLL) and low ability students from the control group (ContLL)

Table 15 presents descriptive statistics comparing the performances of students from the experimental group and the control group for each ability level. Regarding high ability students, those of the experimental group (M = 25.89, SD = 2.09) outscored those of the controlled group (M = 25.44, SD = 1.88). Also, medium ability students of the experimental group (M = 22.00, SD = 1.84) scored higher than their peers of the control group (M = 18.78, SD = 3.70). Similar results were obtained for low ability students, as those from the experimental group (*M* = 15.20, *SD* = 2.49) outperformed those of the control group (*M* = 12.40, *SD* = 1.90).

Table 15: Paired Samples Descriptive Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ExpHL	25.89	9	2.09	.70
	ContHL	25.44	9	1.88	.63
Pair 2	ExpML	22.00	27	1.84	.35
	ContML	18.78	27	3.70	.71
Pair 3	ExpLL	15.20	10	2.49	.79
	ContLL	12.40	10	1.90	.60

Note. ExpHL = High Level students of the Experimental group. ContHL = High Level students of the Control group. ExpML = Medium Level students of the Experimental group. ContML = Medium Level students of the Control group. ExpLL = Low Level students of the Experimental group.
ContLL = Low Level students of the Control group

Table 16 features results of a paired- samples test, showing that the mean difference between the experimental and the control groups for students of high ability (*M* = .44, *SD* = 2.70, *SEM* = .90) is not significant (*p* = .634). However, the mean difference between medium ability students of the experimental group and their peers from the control group (*M* = 3.22, *SD* = 2.99, *SEM* = .77) is significant (*p* ≤ .001). Regarding low ability students, the mean difference between the experimental and the control group (*M* = 2.80, *SD* = 2.57, *SEM* = .81) is also significant (*p* = .007).

Table 16: Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	ExpHL - ContHL	.44	2.70	.90	.49	8	.634
Pair 2	ExpML - ContML	3.22	3.99	.77	4.19	26	.000
Pair 3	ExpLL - ContLL	2.80	2.57	.81	3.44	9	.007

Note. ExpHL = High Level students of the Experimental group. ContHL = High Level students of the Control group. ExpML = Medium Level students of the Experimental group. ContML = Medium Level students of the Control group. ExpLL = Low Level students of the Experimental group. ContLL = Low Level students of the Control group

4.3.3 Comparing between the posttest scores of the experimental and the control groups based on knowledge dimensions and students' abilities: This part of the study is intended to identify significant interactions between student groups and student abilities in the posttest. More specifically, its purpose is to investigate whether there are significant differences between the experimental and the control groups in the posttest, taking into consideration the performances of students of different ability levels in each of the 3 knowledge dimensions (factual, conceptual and procedural). To address those issues, a multi-analysis of variance (two- way MANOVA) is employed. Analysis drawn from this section aims to address the first 3 questions of the study, which focus on determining the impact of computer simulations on students' achievement in factual, conceptual and procedural questions.

Table 17 shows that for the posttest factual score, there is a slight advantage for the experimental group (M = 4.70, SD = 1.28) over the control group (M = 4.22, *SD* = 1.49). However, students of high ability from the control group (*M* = 5.89, *SD* = .33) have a slight advantage over those of the same ability from the experimental group (*M* = 5.67, *SD* = .71). Regarding students from the experimental group of both medium (*M* = 5.07, *SD* = .73) and low abilities (*M* = 3.00, *SD* = 1.18), they slightly outscored their peers of the same respective levels from the control group (*M* = 4.30, *SD* = 1.10) and (*M* = 2.50, *SD* = 1.18) respectively.

Table 17: Descriptive Statistics for Posttest based on Factual Knowledge and Student Abilities

	Student Group	Ability of student	N	Mean	Std. Deviation
Posttest Factual Score	Experimental Group	High ability	9	5.67	.71
		Medium ability	27	5.07	.73
		Low ability	11	3.00	1.18
		Total	47	4.70	1.28
	Control Group	High ability	9	5.89	.33
		Medium ability	27	4.30	1.10
		Low ability	10	2.50	1.18
		Total	46	4.22	1.49
	Total	High ability	18	5.78	.55
		Medium ability	54	4.69	1.01
		Low ability	21	2.76	1.18
		Total	93	4.46	1.40

Table 18 also features a slight gap between the experimental (*M* = 5.15, *SD* = 1.47) and the control (*M* = 4.63, *SD* = 1.95) groups for the posttest conceptual score, in favor of the experimental group. Among ability groupings, high ability students from the experimental group (*M* = 6.67, *SD* = .87) slightly bested their peers of the same ability from the control group (*M* = 6.56, *SD* = 1.51). The same outcome is observed between medium ability students of the experimental group (*M* = 5.30, *SD* = 1.14) and their peers from the control group (*M* = 4.63, *SD* = 1.64), as well as between low ability students from the experimental group (*M* = 3.55, *SD* = 1.04) and their peers from the control group (*M* = 2.90, *SD* = 1.45).

Table 18: Descriptive Statistics for Posttest based on Conceptual Knowledge and Student Abilities

	Student Group	Ability of student	N	Mean	Std. Deviation
Posttest Conceptual Score	Experimental Group	High ability	9	6.67	.87
		Medium ability	27	5.30	1.14
		Low ability	11	3.55	1.04
		Total	47	5.15	1.47
	Control Group	High ability	9	6.56	1.51
		Medium ability	27	4.63	1.64
		Low ability	10	2.90	1.45
		Total	46	4.63	1.95
	Total	High ability	18	6.61	1.20
		Medium ability	54	4.96	1.44
		Low ability	21	3.24	1.26
		Total	93	4.89	1.73

Table 19 presents data collected from students' achievements in the posttest procedural score. It is noticed in this table that the gap between the experimental (M = 11.36, SD = 2.18) and the control (M = 9.85, SD = 2.76) groups is greater than the ones observed for both the factual and conceptual posttest scores. The largest difference resides between medium ability students of the experimental group (M = 11.63, SD = 1.62) and their peers from the control group (M = 9.85, SD = 2.16), followed by the difference between low ability students from the experimental group

(*M* =8.91, *SD* = 1.64) and their peers from the control group (*M* = 7.00, *SD* = 2.21). The least difference is observed between the high ability students of the experimental group (*M* = 13.56, *SD* = 1.24) and their peers from the control group (*M* = 13.00, *SD* = .87).

Table 19: Descriptive Statistics for Posttest based on Procedural Knowledge and Student Abilities

	Student Group	Ability of student	N	Mean	Std. Deviation
Posttest Procedural Score	Experimental Group	High ability	9	13.56	1.24
		Medium ability	27	11.63	1.62
		Low ability	11	8.91	1.64
		Total	47	11.36	2.18
	Control Group	High ability	9	13.00	.87
		Medium ability	27	9.85	2.16
		Low ability	10	7.00	2.21
		Total	46	9.85	2.76
	Total	High ability	18	13.28	1.07
		Medium ability	54	10.74	2.09
		Low ability	21	8.00	2.12
		Total	93	10.61	2.58

Table 20 features a two- way MANOVA analysis, showing that the Wilk's Lambda of .86 for student group is significant, F (3, 85) = 4.71, p = .004, partial η^2 = .14. This means that we can reject the hypothesis that the population means are the same for the experimental and the control groups. The table also shows that the Wilk's Lambda of .29 for student abilities is significant, F (6, 170) = 24.72, $p \leq .001$, partial η^2 = .47, indicating that we can reject the hypothesis that the population means are the same among students of high, medium and low abilities. Regarding the interaction between student group and student ability, Wilk's Lambda of .94 reflects no statistical significance, F (6, 170) = .87, p = .518, partial η^2 = .03, which signifies that the 2 independent variables have no impact on one another.

Table 20: Two- way MANOVA for Posttest based on Knowledge Dimensions and Student Abilities

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared (η^2)
Intercept	Pillai's Trace	.98	1438.80	3.00	85.00	.000	.98
	Wilks' Lambda	.02	1438.80	3.00	85.00	.000	.98
	Hotelling's Trace	50.78	1438.80	3.00	85.00	.000	.98
	Roy's Largest Root	50.78	1438.80	3.00	85.00	.000	.98
StGrp	Pillai's Trace	.14	4.71	3.00	85.00	.004	.14
	Wilks' Lambda	.86	4.71	3.00	85.00	.004	.14
	Hotelling's Trace	.17	4.71	3.00	85.00	.004	.14
	Roy's Largest Root	.17	4.71	3.00	85.00	.004	.14
AB	Pillai's Trace	.73	16.59	6.00	172.00	.000	.37
	Wilks' Lambda	.29	24.72	6.00	170.00	.000	.47
	Hotelling's Trace	2.44	34.19	6.00	168.00	.000	.55
	Roy's Largest Root	2.42	69.24	3.00	86.00	.000	.71
StGrp * AB	Pillai's Trace	.06	.87	6.00	172.00	.519	.03
	Wilks' Lambda	.94	.87	6.00	170.00	.518	.03
	Hotelling's Trace	.06	.87	6.00	168.00	.518	.03
	Roy's Largest Root	.06	1.71	3.00	86.00	.172	.06

Table 21 features an ANOVA test of between- subjects effects, in order to investigate in which types of questions (factual, conceptual or procedural) there are significant differences among student groups (experimental and control groups) and student abilities (high, medium and low abilities). The table shows no significant difference between student groups (experimental and control) regarding their scores on posttest factual questions, F (1, 87) = 2.59, p = .11, partial η^2 = .03. No significant difference was also observed between the 2 groups regarding their scores on posttest conceptual questions, F (1, 87) = 2.29, p = .13, partial η^2 = .03. In contrast, a highly significant difference is noted between the 2 groups in their scores on posttest procedural questions, F (1, 87) = 11.53, p = .001, partial η^2 = .12.

On the other hand, table 21 shows significant differences among students of high, medium, and low abilities in their scores on posttest factual questions (F (2, 87) = 53.91, $p \leq .001$, partial η^2 = .55), posttest conceptual questions (F (2, 87) = 30.84, $p \leq .001$, partial η^2 = .42), and posttest procedural questions (F (2, 87) = 43.18, $p \leq .001$, partial η^2 = .50)

Table 21: Tests of Between-Subjects Effects for Posttest based on Knowledge Dimensions and Student Abilities

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared (η^2)
Corrected Model	Posttest Factual Score	104.25	5	20.85	23.60	.000	.58
	Posttest Conceptual Score	119.15	5	23.83	13.14	.000	.43
	Posttest Procedural Score	335.23	5	67.05	20.92	.000	.55
Intercept	Posttest Factual Score	1433.34	1	1433.34	1622.22	.000	.95
	Posttest Conceptual Score	1797.56	1	1797.56	991.21	.000	.92
	Posttest Procedural Score	8392.99	1	8392.99	2618.72	.000	.97
StGrp	Posttest Factual Score	2.29	1	2.29	2.59	.111	.03
	Posttest Conceptual Score	4.16	1	4.16	2.29	.134	.03
	Posttest Procedural Score	36.94	1	36.94	11.53	.001	.12
AB	Posttest Factual Score	95.26	2	47.63	53.91	.000	.55
	Posttest Conceptual Score	111.85	2	55.93	30.84	.000	.42
	Posttest Procedural Score	276.77	2	138.39	43.18	.000	.50
StGrp * AB	Posttest Factual Score	3.38	2	1.69	1.91	.154	.04
	Posttest Conceptual Score	1.10	2	.55	.30	.740	.01

	Posttest Procedural Score	5.82	2	2.91	.91	.407	.02
Error	Posttest Factual Score	76.87	87	.89			
	Posttest Conceptual Score	157.78	87	1.81			
	Posttest Procedural Score	278.84	87	3.21			
Total	Posttest Factual Score	2033.00	93				
	Posttest Conceptual Score	2503.00	93				
	Posttest Procedural Score	11089.00	93				
Corrected Total	Posttest Factual Score	181.12	92				
	Posttest Conceptual Score	276.93	92				
	Posttest Procedural Score	614.07	92				

Note. StGrp = Student Group. AB = Ability

The significant differences among student ability groups in the posttest require a Tukey HSD post- Hoc comparison test, which is presented in table 22. Results show that the mean differences among all ability groups are significant. Particularly, the top 3 mean differences are observed between the high ability group and the low ability group in the procedural score ($MD = 5.28$, $p \leq .001$), followed by the mean difference between the high ability and the low ability groups in the conceptual score ($MD = 3.37$, $p \leq .001$), and then by the mean difference between the high ability group and the low ability group in the factual score ($MD = 3.02$, $p \leq .001$).

Table 22: Post Hoc Tests for Posttest based on Knowledge Dimensions and Student Abilities

Dependent Variable	(I) Ability of student	(J) Ability of student	Mean Difference (I-J)	Std. Error	Sig.
Posttest Factual Score	High ability	Medium ability	1.09	.26	.000
		Low ability	3.02	.30	.000
	Medium ability	High ability	-1.09	.26	.000
		Low ability	1.92	.24	.000
	Low ability	High ability	-3.02	.30	.000
		Medium ability	-1.92	.24	.000
Posttest Conceptual Score	High ability	Medium ability	1.65	.37	.000
		Low ability	3.37	.43	.000
	Medium ability	High ability	-1.65	.37	.000
		Low ability	1.72	.35	.000
	Low ability	High ability	-3.37	.43	.000
		Medium ability	-1.72	.35	.000
Posttest Procedural Score	High ability	Medium ability	2.54	.49	.000
		Low ability	5.28	.58	.000
	Medium ability	High ability	-2.54	.49	.000
		Low ability	2.74	.46	.000
	Low ability	High ability	-5.28	.58	.000
		Medium ability	-2.74	.46	.000

4.4 Summary of Results

This chapter focused on reporting the findings of the study. First, results showed that there were no significant differences between the performance of the experimental group and that of the control group in the pretest. However, there were significant differences among students of different abilities in the pretest. Moving on to the posttest, significant differences were particularly noticed between students of the experimental and control groups, for medium and low ability students. Also, when comparing the performance of the experimental and the control groups based on knowledge dimensions, only questions that tackled procedural knowledge reflected a significant difference in favor of the experimental group. Finally, it was noted that no significant interaction existed between student groups and student abilities.

Chapter 5: Discussion

5.1 Chapter Overview

The purpose of this study is to explore the impact of using computer simulations as a teaching method for developing factual, conceptual and procedural knowledge related to the Physics topic of "Uniform Circular Motion" in Al Ain, UAE. The study also aims to investigate the impact of these simulations on the performance of students of different abilities. The aim of this chapter is to discuss the data presented in chapter 4. It also presents comparisons of the results obtained from this study with the ones presented from previous research studies as reported in literature. The findings of the study are then discussed in relation to the research questions. Finally, the chapter concludes with suggestions and recommendations for further research.

5.2 Students' Scores in the Pretest and Posttest based on Student Groupings

The data presented in chapter 4 were based on the achievement of students on a 29- item content test administered twice, first as a pre-test and then after the implementation of the intervention as a post-test. Results from the pre-test showed that there was no statistically significant difference between the performance of the experimental group and that of the control group in terms of the total score on the test (p = .839). This shows that prior to the intervention, both groups were homogenous in terms of understanding of the tested content.

Data related to the post-test, which took place after implementation of the intervention with the experimental group was then presented. The comparison between the experimental and the control groups' performances on the post-test showed that the experimental group achieved a higher mean score than the control group on the test total score. A one- way analysis of variance analysis was found to be statistically significant (p = .011). It can be depicted from these results that the intervention of computer simulation had a positive impact on students' achievement in Physics, specifically in the topic of "Uniform Circular Motion". This positive impact may be due to the high interactivity of computer simulations. In fact, even though Physics videos and animations that were used with the control group provided students with animated Physics concepts and processes that could help students understand abstract ideas related to Physics topics, they were still passive resources. The interaction level of students with videos and animations was limited to observing the events presented. On the other hand, a computer simulation allows students to control the initial conditions of the Physics phenomena presented in this simulation. As a result, the student is not limited to only observing a ready- made animation, but he can expand his interaction with this technology to investigating different outcomes that result from different settings that he/she have control of. Consequently, the student would understand the Physics concept or process presented in the simulation from different perspectives and different angles, resulting in a more profound understanding of concepts and a higher mastery of processes.

Based on literature review, many studies reported similar impact for simulations on students' learning of Physics, such as Podolefsky, Perkins and Adams (2010). In this study, the success of simulations in enhancing students' learning was attributed to the "engaged exploration" offered by the simulation, as students were able to use the simulations to explore the topic of "Wave Interference" in ways that were similar to how scientists explore Physics phenomena. Another factor that contributed to the success of simulations in this study was the high level of interactivity with dynamic and immediate feedback to the students.

Also, Adams et al. (2008) reported positive impact of simulations that were used in their study to teach students about “Sound Waves”. In this study, the authors related the positive impact of simulations to enabling students to see an animated motion instantly change as it was responding to their self-directed interaction with the simulation, resulting in the formation of new ideas and in making connections between the information provided by the simulations and their previous knowledge.

McKagan et al. (2008) have also reported positive impact of computer simulations on students’ learning of “Quantum Mechanics”. In their study, they conveyed that impact on the high interactivity of the simulations, allowing students to adjust controls and observe animated response. This helped students establish cause- and- effect relationships, and construct understanding and intuition for abstract quantum phenomena. Another factor that made simulations effective in this study was their capability to quickly perform complex calculations. This feature relieved students from spending time and effort on calculations, and let them focus more on understanding the concepts without digging into math.

5.3 Students’ Performance in the Pretest and Posttest based on Ability Groupings

When students’ scores on the pretest were compared among their different ability levels, a two- way analysis of variance showed that there are significant differences among all ability levels ($p \leq .001$) with no significant interaction between student groups (experimental and control) and student abilities (high, medium and low). More specifically, a post- hoc test showed that the highest significance is observed between the high and low ability groups ($p \leq .001$), followed by the one between the medium and the low ability groups ($p = .008$) and then by the one between the high and the medium ability groups (*p* = .002). These results can be considered as normal, because high ability students are expected to perform at a higher level than their peers of the medium and low abilities, even in a pretest, which usually assesses students' prior knowledge about the subject or the topic to be taught.

Students' scores based on their abilities was also reported for the posttest. Descriptive statistics showed that high ability students from the experimental group had a higher score than their peers from the control group. Students of medium ability from the experimental group have also outscored their peers from the control group. Moreover, low ability students of the experimental group also had higher mean scores than their peers from the control group.

The difference between the performances of the experimental and the control group on the posttest was proven to be significant ($p \leq .001$) for all ability groupings upon performing a two- way Analysis of Variance. This shows that simulations had a greater impact on students' learning than videos and animations for all ability groupings. The analysis also reflected a significant difference among the 3 levels of student ability ($p \leq .001$) and no statistically significant interaction between student group and student ability in the posttest results ($p = .15$). This result may be considered as normal because it is expected to have a difference between the performance of students from different abilities regardless of the methods of teaching and learning. Further analysis was done to investigate which ability grouping had the greatest gain from the intervention. A paired samples t- test revealed statistically non- significant gain for high ability students ($p = .634$), and statistically significant gains for medium ability students ($p \leq .001$) and low ability students ($p = .007$).

The fact that high ability students did not have a significant gain from simulations may be explained by the capability of those students to build their knowledge and understanding by either using videos and animations, or by using simulations as assistive technology. This type of students has intrinsic motivation to learn, and high cognitive abilities that allow them to relate to any kind of technology, and use it to develop their knowledge. On the other hand, medium and low ability students may have profited more from simulations than videos and animations because they were engaged by the high interactivity of simulations, which offered them a technological platform where they had full control of the outcomes, and where they had the freedom to learn at their own pace by repeating the simulations as much as they wanted and receiving immediate feedback to build their knowledge. For students who used videos and animations, they were limited to observing animated Physics phenomena that provided no feedback, and may have limited response to their queries because they presented concepts in a one- dimensional way.

The results presented in this study regarding the impact of simulations on students of different abilities were similar to other studies reported in literature. Yildiz and Atkins (1996) found that the same simulation could have different impact on students of different genders and prior achievement levels. In their study, medium ability students showed great improvement upon using simulations when learning about “Energy”. Yildiz and Atkins explained these results by claiming that these students took advantage of the possibility to repeat the same experiment many times to build confidence in their understanding. However, in the same study, high achieving students showed less promising results after using the same simulations. This was attributed to the fact that the lack of challenge in using computer simulations might have caused boredom and loss of concentration for these students. Moving on to students with low prior achievement, the findings presented in this study contradicted those of the study conducted by Yildiz and Atkins (1996). In the latter study, students of low ability struggled in using the simulations, which was attributed to its incapability to provide them with clear learning objectives and immediate feedback.

Also, Adegoke and Chukwunenye (2013) reported similar results to the study presented in this paper. It focused on investigating the effect of computer simulations on students' achievement in practical Physics, taking into consideration their levels of mathematical reasoning abilities. The study employed 3 experimental groups, as the first group used computer- simulated experiments only, the second group used hands- on experiments only, and the third group used both simulated and hands- on experiments. Results showed that the third group performed the best among the 3 groups, and students of moderate mathematical reasoning ability showed more improvement from the pretest to the posttest than those of high mathematical reasoning ability.

However, Chang, Chen, Lin and Sung (2008) conducted a study that presented outcomes that are different from those presented in the present study. Their study focused on the impact of learning support on simulation-based learning in three learning models: experiment prompting, a hypothesis menu, and step guidance. Also, the study took into consideration the different levels of abstract reasoning of students. Results showed that students with higher abstract reasoning level benefited from the simulations more than their peers of lower abstract reasoning level.

5.4 Students' Performance in the Posttest based on Ability Groupings and Knowledge Dimensions

The achievement test administered in the study included 29 questions that consisted of 3 knowledge dimensions as follows:

- 6 factual knowledge questions
- 8 conceptual knowledge questions
- 15 procedural knowledge questions

To analyze the impact of simulations on students' performance based on knowledge dimensions and student abilities, a two- way MANOVA was used. Primary results from the analysis showed that there is a significant difference between the experimental and the control group (p = .004) and a significant difference among student abilities ($p \leq .001$). However, there was no significant interaction between student groups and student abilities (p = .518).

Further analysis was conducted to inspect the statistically significant differences regarding student groups, which lead to the use of ANOVA analysis. The ANOVA test showed that the difference in the performances between students of the experimental and the control groups for factual knowledge questions was not statistically significant (p = .11). It was also found that there was no statistically significant differences between the experimental and the control group regarding their performances in conceptual knowledge questions (p = .13). The only statistically significant difference between the 2 groups was noted for procedural knowledge questions (p = .001).

Finally, a Tukey HSD post Hoc test showed that the differences among student ability groupings were all significant, and across all knowledge dimensions ($p \leq .001$).

Regarding the performance of students of different abilities, the statistically significant differences among them are fair and acceptable, as it is normal to have students of high ability outperform those of medium and low abilities. These differences were not attributed to the intervention, as they were observed in the pretest and the posttest results as well.

The fact that computer simulations had no significant impact on factual and conceptual knowledge may be due to the use of technology for both the experimental and control groups. In fact, while most of the studies in literature used traditional methods with the control group, this study employed videos and animations during the instruction of the control group, because the use of technology was part of the settings of the school at which the study was conducted. Consequently, students of the control group benefited from the videos and animations because they present complex Physics phenomena and facts in an easy and interactive way, and because they offer a multimedia platform, which uses animated images and sounds, to simplify Physics concepts. These factors make videos and animations an effective tool that enhances factual and conceptual knowledge.

On the other hand, computer simulations used with the experimental group gave students, in addition to all the features offered by videos and animations, the opportunity to control variables, to manipulate initial conditions of a given situation, and then observe the outcome of their input. These features develop procedural knowledge within the students, because they focus on methods of inquiry, which are key elements of procedural knowledge. For those reasons, results of this study showed that the experimental group had more gains in procedural knowledge than the control group.

The effect of computer simulations in developing different types of knowledge has been reported in many studies in literature. Some of these studies had similar results as the findings of the present study.

Eylon, Ronen, and Ganiel (1996) studied the impact of the RAY computer simulations on understanding the concept of “Optics”. They divided their study in 2 parts. In the first part, the experimental group used one computer in the classroom to observe the simulations, which was used to investigate “Optics” phenomena, to understand concepts, to analyze experiments and to represent theoretical problems. The control group integrated the same type of activities as the experimental group, but in a traditional learning environment. Results reported from this study showed that the simulations impacted problem- solving skills only, with limited gain for conceptual understanding. However, when the same simulations were used individually by the experimental group of the second part of the study, gains were observed for both problem solving and conceptual understanding. Eylon, Ronen, and Ganiel (1996) interpreted these results by claiming that the simulations promoted exploration and provided students immediate feedback while they are solving problems. Also, they explained that the design of the tasks that were adjacent to the simulation addressed directly the learning difficulties of students, and that students were given the chance to reflect on the solution of problems and to reformulate knowledge thanks to the use of the simulation.

Finkelstein et al. (2005) conducted a study that assessed the effectiveness of computer simulations in promoting conceptual knowledge and procedural knowledge about electric circuits. The control group was taught using lab equipment, while the experimental group was taught using computer simulations. The instruments used in the study to collect data included a conceptual survey and to performance- based task consisting of assembling real circuits and describing how they worked. The group of students who used the computer simulations performed better than the other group in both the conceptual survey and in the hands- on tasks, showing that simulations helped students acquire both conceptual and procedural knowledge.

A study, conducted by Sierra- Fernandez and Perales- Palacios (2003), showed that, similar to what was reported in the present study, computer simulations have no significant effect on conceptual knowledge. In fact, upon administering a concept test and an attitude test for the experimental and the control groups regarding Newtonians mechanics, Sierra- Fernandez and Perales- Palacios commented that simulations did not have systemization in the confirmation of hypotheses, leading students to wrong conclusions. They also added that the space- time and velocity- time graphs were hard to interpret. This led them to conclude that students, regardless of the instructional approach they received, needed additional help such as immediate feedbacks.

5.5 Summary of the Discussion

5.5.1 How much can computer simulations help students acquire factual knowledge?

Results of this study showed that even though computer simulations did help students learn factual knowledge, they did not show an advantage over other technologies used with the control group.

5.5.2 How much can computer simulations help students acquire conceptual knowledge?

Results of this study also showed that videos and animations have similar impact as computer simulations in terms of promoting conceptual knowledge.

5.5.3 How much can computer simulations help students acquire procedural knowledge?

Computer simulations reflected their greatest positive impact on procedural knowledge, as the difference between the mean scores of the experimental and control groups for procedural knowledge questions was significant.

5.5.4 What impact do computer simulations have on students achievement based on their ability grouping?

The study showed that students of high ability scored nearly the same in the posttest, while students of medium and low abilities from the experimental group scored significantly higher than their respective peers from the control groups, showing that computer simulations impacted medium and low ability students more than high ability students.

These findings were discussed in the context of previous research findings such as those reported by Podolefsky, Perkins and Adams (2010), Adams, Reid, LeMaster, McKagan, Perkins, Dubson, and Wieman (2008), McKagan, Perkins, Dubson, Malley, Reid, LeMaster, and Wieman (2008), Adegoke & Chukwunenye (2013), Eylon, Ronen, and Ganiel (1996), Sierra- Fernandez and Perales- Palacios (2003).

5.6 Recommendations and Suggestions for Further Research

Many studies have proved the effectiveness of computer simulations in learning physics. One of the main aspects of physics in which simulations play an effective role is the lab work. Studies showed that simulations could be as effective, or even more effective than working with lab equipment to understand the practical part of physics. In the light of those facts, the following recommendations and suggestions may be put in place:

- **Teachers may use computer simulations to introduce students to a lab experiment before taking them to the lab:** This allows students to understand the laws and theories that underlie the phenomena observed during the experiment. In this way, teachers would help students link their observations in the lab to what they have learned in class, thus benefitting from the lab to the maximum.
- **Develop lab manual software, in which every experiment is associated with a convenient simulation:** This simulation should be provided to students prior to executing the experiment to introduce them to the objectives of the experiment, as well as the procedure that they need to follow when they would work on it. Most importantly, the simulation would explain the scientific concepts that underlie every outcome of the experiment, in an animated and interactive way. In this way, students would be able to conduct the experiment by themselves, with minimal help from the teacher, and they would understand all the Physics concepts that are relevant to what they observe in the lab. The result would be a rich learning experience that involves students with conceptual modeling, procedural knowledge, independent learning, and methods of inquiry.
- **Develop courses, or training sessions, that show teachers how to design a computer simulation by themselves:** One of the main challenges that prevent teachers from using simulations frequently in their classes is that these simulations may not be convenient to the learning environment. For example, sometimes a teacher struggles to find simulations

that describe exactly the concept he/ she wants to teach his/ her students. Another obstacle that can be faced by a teacher is when the material presented in a simulation is too hard or too easy compared to the level of his/ her students. Hence, teachers should be taught to design and implement a simulation in their classes based on the topic they are supposed to teach and based on the level of students that are expected to use the simulation. Despite the fact that it would be challenging for the teachers to learn computer programming in order to develop simulations, but there is no denial that current teachers need to be technology- savvy because they are expected to mentor students who will be part of a world that is becoming increasingly dependent on technology.

- **Integrate multiple types of technology when delivering a Physics lesson:** The results drawn from the current study showed that in addition to simulations, which promote procedural knowledge, videos and animations are also effective technological tools that promote understanding of Physics concepts. This shows that the key to reach optimum results with students is to use multiple technologies in class.
- **Allow students to reflect on their experience with simulations:** Since the purpose of integrating any kind of technology in education is to enhance the learning experience whether by facilitating material or by promoting students' engagement, it is necessary for teachers to let students reflect on their interaction with simulations. This reflection may focus on:
- how much computer simulations help students understand physics concepts
- how much computer simulations help students use the information learned in the simulations to solve problems in different contexts

- whether the use of simulations is simple enough to let students focus more on learning physics than on learning how to use simulations
- whether simulations motivated students to learn about physics phenomena by following methods of science inquiry

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Appendix A- Achievement Test

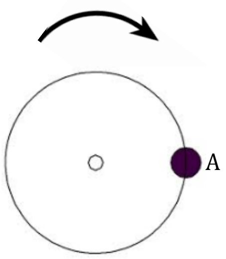
Achievement Test

Lesson: Uniform Circular Motion

1. Uniform circular motion is:
   a. The motion of an object along a circular path under the influence of gravity
   b. The motion of an object along a circular path due to a constant force
   c. The motion of an object along a circular path at constant speed
   d. The motion of an object along a circular path at constant velocity
   e. The motion of an object along a circular path with a constant acceleration

2. An object that has a uniform circular motion accelerates because it has a:
   a. constant velocity
   b. constant speed
   c. velocity that increases
   d. velocity that decreases
   e. velocity that changes its direction

3. Mansour is swinging a ball attached to a rope in a vertical plane as the following diagram shows (Clockwise). If the rope is cut at position "A" how will the ball continue its motion as soon as it is released?



   a. downward because of gravity
   b. downward because the velocity is tangent to the circular path at every position
   c. left because it is submitted to a centripetal force
   d. right because as the rope is cut, the ball is not submitted to a centripetal force anymore
   e. upward because of air resistance

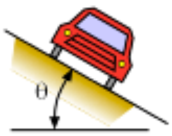
4.
   A. A clown in a circus act swings a 2.7 kg metal ball attached to a 72.0 cm nylon string in a horizontal circle above his head, making one revolution in 0.98 s. What is the centripetal force acting on the metal ball?
   a. 3.8 N
   b. 80 N
   c. 92 N
   d. 100 N
   e. 3000 N

B. The agent that supplies the centripetal force which keeps the metal ball along the circular path is the:
   a. friction force
   b. tension force
   c. gravitational force
   d. force exerted by the clown's hand
   e. normal force

5. In order to have a uniform circular motion, an object should:
   a. be submitted to a net constant force
   b. have a constant velocity
   c. be submitted to the gravitational force only
   d. have a constant acceleration
   e. be submitted to a net force that is always directed towards a fixed point

6. Consider an object that is moving along a uniform circular motion. If its speed is doubled while its mass and the radius of its trajectory remain constant, then the centripetal force acting on it will:
   a. be quadrupled
   b. be doubled
   c. be halved
   d. be divided by 4
   e. remain the same

7. A racecar enters a banked curve with a constant speed. Which of the following factors ensures the centripetal force that allows the car to enter the curve at high speed?



   a. Normal force
   b. Force of gravity
   c. Force of the engine
   d. Resultant of the normal force and force of gravity
   e. Resultant of the normal force and the force of the engine

8. A dragonfly is sitting on a merry- go- round 2.8 m from the center. If the tangential velocity of the ride has a magnitude of 0.89 m/s, what is the centripetal acceleration of the dragonfly?
   a. 0.11 m/s^2
   b. 0.28 m/s^2
   c. 0.32 m/s^2
   d. 2.2 m/s^2
   e. 3.45 m/s^2

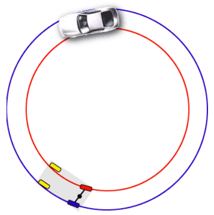
9. The force exerted by a 2 m massless string on a 0.82 kg object being swung in a horizontal circle is 4.0 N. What is the tangential velocity of the object?

a. 2.8 m/s
b. 3.1 m/s
c. 4.9 m/s
d. 9.8 m/s
e. 11.2 m/s

10.

A. A 1000 kg car enters an 80 m- radius curve at 20 m/s. The magnitude of the centripetal force is:
   a. 5 N
   b. 250 N
   c. 1000 N
   d. 1200 N
   e. 5000 N

B. The agent that supplies that centripetal force and prevents the car from skidding is the:

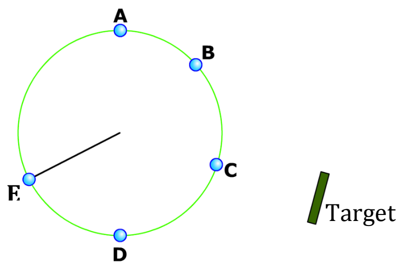


   a. friction force
   b. tension force
   c. gravitational force
   d. force developed by the engine
   e. normal force

11.

A. In the following diagram, where should you release the ball to hit the target if it was rotating clockwise?

a. Point A
b. Point B
c. Point C
d. Point D
e. Point E

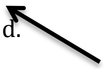


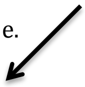
B. Which of the following would be the correct direction of the net acceleration at point (D) if the ball rotates counterclockwise at constant speed?

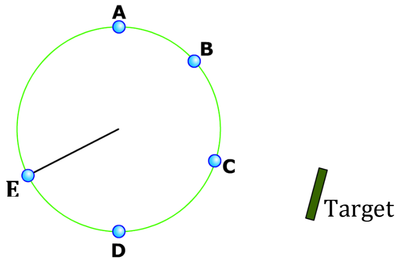
a. 

b. 

c. 

d. 

e. 



12. In track and field sports, the hammer throw event involves spinning a 4 kg weight at the end of a wire and releasing it at maximum speed. Calculate the length of the rope if the tension on the wire is 2100 N and the highest speed is 25 m/s.

a. 1.19 m
b. 10.19 m
c. 13.44 m
d. 3281.25 m
e. 328125 m

13. A test pilot is strapped into a large centrifuge machine for training. The machine spins rapidly to simulate increased gravitational forces on the body. If the machine spins the pilot in a circle with a 9.9 m radius, what should be the period of rotation so that the pilot experiences a centripetal force equal to twice his body weight? (Weight = m. g)

a. 4.42 s
b. 6.25 s
c. 10.34 s
d. 19.54 s
e. 27.96 s

14. A ball is attached to the end of a cord of length 1.4 m. The ball is whirled along a circular path, in a horizontal plane. The cord can withstand a tension, which produces a maximum acceleration of 126.7 m/s^2 before it breaks. What is the maximum speed the ball can have without the cord breaking?

a. 0.075 m/s
b. 4.28 m/s
c. 7.05 m/s
d. 13.32 m/s
e. 177.42 m/s

15. How far does an object in uniform circular motion travel during one period?

a. $m.\,v^2/R$
b. v^2/R
c. $2\pi\sqrt{R/ac}$
d. πR^2
e. $2\pi R$

16. An object in uniform circular motion has an acceleration that is____.

a. along a direction tangential to the circle
b. directed away from the center of the circle
c. directed towards the center of the circle
d. directed along the direction of motion
e. zero

17. A 0.150 kg rubber stopper is attached to the end of a 1.00 m string and is swung in a circle.
If the stopper makes 3 revolutions in 3.53 s, what force does the string exert on the stopper?

a. 0.23 N
b. 2.07 N
c. 4.28 N
d. 10.82 N
e. 26.19 N

18. If we consider the circular motion of a satellite around Earth, what agent provides the centripetal force, which keeps the satellite rotating around Earth?

a. The friction force
b. The tension force
c. The normal force
d. The force developed by the engine
e. The gravitational force

19. Objects A and B are in uniform circular motion and both have a tangential velocity of 11.5 m/s.

A. If the period of Object A is 2.4 s and the period of Object B is 1.2 s, what is the ratio of the radius of Object A's motion to the radius of Object B's motion?
   a. ¼
   b. ½
   c. 1
   d. 2
   e. 4

B. If the radius of Object A's motion is 4.0 m and the radius of Object B's motion is 1.0 m, what is the ratio of Object A's acceleration to Object B's acceleration?
   a. ¼
   b. ½
   c. 1
   d. 2
   e. 4

20. A ventilation fan has blades 0.25 m long rotating at 20 rpm (20 revolutions per minute). What is the centripetal acceleration of a point on the outer tip of a blade?

a. 0.23 m/s^2
b. 1.1 m/s^2
c. 2.3 m/s^2
d. 4.6 m/s^2
e. 6.0 m/s^2

21. A yoyo is attached to a 15 cm rope, and rotates at a frequency of 2 Hz. The centripetal acceleration of the yoyo is equal to:
a. 23.69 m/s^2
b. 35.16 m/s^2
c. 47.26 m/s^2
d. 51.49 m/s^2
e. 68.02 m/s^2

22. Consider a point on a bicycle tire that is momentarily in contact with the ground as the bicycle rolls across the ground with constant speed. The direction for the acceleration for this point at that moment is:
a. upward
b. down towards the ground
c. forward
d. opposite to the motion
e. at that moment the acceleration is zero

23. Is it possible for an object to have a uniform circular motion, with zero acceleration?

a. Yes, because the velocity of this object has the same direction at any point during the motion
b. No, because the velocity of this object is constant
c. Yes, because the speed of this object is constant
d. No, because the speed of this object changes
e. No, because the direction of velocity of this object changes during the motion

24. An object swings in a horizontal circle at a constant speed, attached to a 1.8 m string. What is the period of the resulting uniform circular motion, if the object has a centripetal acceleration of 14.68 m/s^2?

a. 0.48 s
b. 1.63 s
c. 2.20 s
d. 5.78 s
e. 6.41 s

25. Is it possible for an object moving along a circular path at constant speed, to have a constant acceleration?

a. No, because the direction of the velocity changes during the motion
b. Yes, because the direction of the acceleration is always directed towards the center of the motion
c. Yes, because the centripetal force has a constant magnitude
d. No, because the direction of the acceleration changes during the motion
e. Yes, because since the speed is constant, then the acceleration is constant

Appendix B- Letter of Consent from the School

Date: April, 2015

Dear _________________________________,

I, Mohamad Fadi Aoude, am a student at the United Arab Emirates University, and I am currently preparing for my Master of Education Thesis, under the supervision of Dr. Hassan Tairab. The purpose of this letter is to ask for a permission to conduct a study at ____________________________ for students of Grade 11 in Al Ain, as part of my thesis.

The aim of the study is to investigate the effectiveness of using computer simulations on students' understanding of Physics concepts.
The study follows the procedure shown below:

1. First students are pretested to allow the teacher to have an idea on students' background knowledge about the topic to be taught, and gives students a glimpse on the main ideas of the lesson.
2. Some classes (experimental group) receive instruction using computer simulations, and other classes (control group) learn by using other technologies (such as real- life videos and animations).
3. At the end of the lesson, students are post tested.

Data collected from the pretest and the posttest allows the researcher to identify in which knowledge dimensions students benefit the most from computer simulations (factual, conceptual or procedural knowledge).

The implementations of this study could be very beneficial in terms of integrating the right technology to enhance students' acquisition of a specific type of knowledge, and in terms of applying differentiated instruction to cater for students' needs.

The study requires no special arrangement, and produces no intrusion on students, the staff, or the instructional pace. Also, the confidentiality of individual participants is assured, and the results of the pretest and the posttest do not affect students' grades, as they are both used as worksheets, not as formal school assessments.

On behalf of ______________________________, I _____________________________,
have no objection for conducting this study in ______________________________.

Name:	Name:
Signature:	Signature:

Appendix C- Letter of Cooperation for Data Collection in Schools

UAEU College of Education

جامعة الإمارات العربية المتحدة
United Arab Emirates University

Letter of Cooperation for Data Collection in Schools

Sunday, May 10, 2015

To Whom It My Concern:

Mohamad Fadi Aoude is requesting permission to collect research data from your school to complete his study at the College of Education master's program. The research entitled (The Impact of Integrating Computer Simulation Software on the Achievement of Grade 11 Students in Mechanics in Al Ain). You will be informed of the purposes of the study and the nature of the research procedures by the researcher. You will be also been given an opportunity to ask questions of the researcher.

As a Master's program coordinator at the College of Education at the UAEU, I hope that you can grant Mohamad permission to collect the necessary data from your school. Your support is greatly appreciated.

If you have any questions, please contact me at (halae@uaeu.ac.ae)

Thanks for your cooperation

Sincerely,

Improving The Academic Advising in al Jaheli institute

Hala Elhowe

Hala Elhoweris

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Appendix D- Lesson Plan: Uniform Circular Motion

Content objectives	• Define uniform circular motion (UCM) • Investigate why an object in uniform circular motion accelerates • Investigate the force causing uniform circular motion • Sketch a diagram of velocity and acceleration vectors for a particle in uniform circular motion • Relate the radius of the circle and the tangential speed of the particle to the magnitude of the centripetal acceleration • Determine the speed at any instant during uniform circular motion in terms of the radius of the trajectory and the period of motion • Determine the acceleration at any instant during uniform circular motion in terms of the radius of the trajectory and the period of motion • Derive Newton's second law for uniform circular motion • Determine the centripetal force at any instant during uniform circular motion in terms of the radius of the trajectory and the period of motion • Analyze real- life examples of objects undergoing uniform circular motion
Introduction	Prior knowledge: • Difference between scalar and vector • Difference between speed and velocity • Acceleration • Newton's second law and the relation between force and acceleration

I- Definition of uniform circular motion	Group activity: Give students real- life examples of uniform circular motion in order to help them define it. Class discussion: Discuss the answers provided by students Feedback: Comment on students' answers and provide them with the definition of uniform circular motion.	
II- Velocity in uniform circular motion	Experimental group • Use "*Alien Invasion*" simulation to investigate about the direction of velocity in uniform circular motion. • Assessment: Draw the direction of the velocity vector at different points in a uniform circular motion	Control group • Use "*Velocity of an object in a circle*" video to investigate about the direction of velocity in uniform circular motion. • Assessment: Draw the direction of the velocity vector at different points in a uniform circular motion

III- Force and acceleration in uniform circular motion	Experimental group • Use "*Gravity and orbits*" simulation to investigate about the direction of acceleration and force in uniform circular motion. • Assessment: Draw the directions of the velocity, acceleration and force vectors at different points in a uniform circular motion	Control group • Use "*Centripetal force demo*" video to investigate about the direction of acceleration and force in uniform circular motion. • Assessment: Draw the directions of the velocity, acceleration and force vectors at different points in a uniform circular motion

IV- Examples of centripetal force	Experimental group Expose students to real- life examples of uniform circular motion and ask them to identify the centripetal force acting on the moving object: • Circular motion of a ball attached to a string • Motion of Earth around the sun • A car taking a turn • Banked curve: Use the "*Interactive: Banked Curve*" simulation to investigate about the centripetal force in banked curves.	Control group Expose students to real- life examples of uniform circular motion and ask them to identify the centripetal force acting on the moving object: • Circular motion of a ball attached to a string • Motion of Earth around the sun • A car taking a turn • Banked curve: Use the "*m16 1*" video to investigate about the centripetal force in banked curves

V- Magnitude of centripetal acceleration and centripetal force	Experimental group • Use "*Gravity and orbits*" and "*Ladybug revolution*" simulations to investigate about the relation between force, mass, speed, acceleration and radius in uniform circular motion. • Use inductive reasoning and mathematical approach to issue the formulae of centripetal force and centripetal acceleration.	Control group • Use "*How to Find the Centripetal Force With the Radius, Mass & Constant Speed*" video to investigate about the relation between force, mass, speed, acceleration and radius in uniform circular motion. • Use inductive reasoning and mathematical approach to issue the formulae of centripetal force and acceleration.

	• Assessment: Practice problems where students calculate the centripetal force, centripetal acceleration, mass, speed and radius in uniform circular motion.	• Assessment: Practice problems where students calculate the centripetal force, centripetal acceleration, mass, speed and radius in uniform circular motion.
VI- Period and frequency	Experimental group • Use "*Gravity and orbits*" and "*Ladybug revolution*" simulations to investigate about the period and frequency in uniform circular motion. • Use inductive reasoning and mathematical approach to issue the formulae of period and frequency. • Use mathematical approach to derive formulae of speed and acceleration in uniform circular motion in terms of period and frequency. • Assessment: Practice problems where students use period and frequency to find different quantities in uniform circular motion.	Control group • Use "*Period and Frequency for circular motion*" video to investigate about the period and frequency in uniform circular motion. • Use inductive reasoning and mathematical approach to issue the formulae of period and frequency. • Use mathematical approach to derive formulae of speed and acceleration in uniform circular motion in terms of period and frequency. • Assessment: Practice problems where students use period and frequency to find different quantities in uniform circular motion.
Conclusion	Provide students with a summary of the lesson, focusing on the following concepts: • Speed and velocity in uniform circular motion • Directions of velocity, acceleration and force in uniform circular motion • Examples of centripetal force	

	• Formulae relating force, speed, mass and acceleration in uniform circular motion • Period and frequency in uniform circular motion • Formulae of speed and acceleration in terms of period and frequency in uniform circular motion