MAPPING THE RELATIONSHIP BETWEEN CURRICULUM, PEDAGOGY AND DIGITAL TECHNOLOGY TO DEVELOP A PREDICTIVE MODEL FOR THE IMPROVEMENT IN STUDENTS' ATTAINMENT

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Signature:..

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THE SOOTHING (Ash-Sharh) *Al Quran Al Kareem verse 94.*

In the Name of God, the Most Gracious, the Most Merciful:

> *"Did We not soothe your heart? And lift from you your burden. Which weighed down your back? And raised for you your reputation? With hardship comes ease. With hardship comes ease. When your work is done, turn to devotion. And to your Lord turn for everything".*

I greatly thank God for granting me the ability to finish this work.

The Prophet, peace and blessings be upon him, said: "*He has not thanked Allah who has not thanked people*".

I would state that this work would not have been finished without the marvellous and precious support of great people, I owe them forever.

I would like to express my sincere gratitude and appreciation to my supervisors Dr Ruth Richards and Dr Andrew Clapham. Thank you both for your great support, guidance and constructive feedback during the development stages of this thesis. This will always be remembered and highly appreciated. Besides my supervisors, I would like to thank Dr Gren Ireson and Dr Mark Crowley. And very special gratitude to my wife, who supported me throughout this long journey.

Thanks for all your encouragement. God bless you all.

DEDICATION

This work is dedicated to all those who struggle and strive in order to change, develop and inspire.

God bless all of you.

ABSTRACT

The relationship between learning, pedagogy and technology is a complex area of injury. Working with, and analysing data generated by, twenty teachers and two hundred seventy-eight students from the Institute of Applied Technology (IAT) in the United Arab Emirates, I was able to drill down into the complex interactions between curriculum, pedagogy and technology. From this work, I developed an original predictive model, which outlines the improvement in students' attainment due to the complex interactions of three critical elements - curriculum (C), pedagogy (P), and digital technology (T), what I call the CPT model. My analysis indicated that digital technology impacted positively on students' attainment when it was used with science subjects but less so when it was used with humanities subjects.

Based on the literature review, the relationship between C, P and T had been widely investigated (see, for example, Mishra and Koehler (2006; 2013), Archambault and Barnett (2010), Angeli and Valanides (2009), Voogt et al. (2012)). However, none of the researchers dealt with this relationship and its impact on students' learning and attainment quantitatively or using a mathematical perspective. This study aims to highlight how the CPT model can predict the improvement in students' attainment as an outcome of using educational technology (the impact factor) and locate the most effective strategies of learning.

This research fills the knowledge gap by developing a new model that explores the C, P, T correlations using three-dimensional equations that I have developed. As such, the study makes a significant contribution to educational technology literature through exploring the C, P, T impact on students' attainment. The research offers educators, policymakers and curriculum developers opportunities to leverage digital technology as a mean for enhancing attainment. Understanding the CPT relationship enables the development of focussed digital technology-supported curricular for students regardless of their academic level. I concluded this by arguing that the CPT model can guide both teachers and policymakers to locate the most effective strategy of learning to maximise the impact of digital technology on students' attainment.

This PhD study contributes to knowledge by a new educational term called Tranology, which is a combination of two main types of learning, traditional and digital technology-based learning, please refer to sections 2.9 and 8.4. Furthermore, this study suggests the application of the vector space concept to organise the relationship between the elements C, P and T. In turn, this implies that these elements overlap over three-dimensional space, which is addressed in this study as the CPT space, rather than, overlapping over two-dimensional plane as demonstrated by Mishra and Koehler (2005; 2006; 2008), please refer to chapter 5.

In terms of future scientific understanding and theoretical insights, the CPT model can be transformed from three-dimensional model (C, P and T) to four-dimensional model (4-D) that comprises the three dimensions of curriculum, pedagogy and digital technology (C, P and T) and the one dimension of a student's attitude towards learning (S) to produce 4-D model called the CPT-S curvatures. Please refer to section 8.6.

Keywords: **digital technology; attainment; impact factor.**

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LIST OF ABBREVIATIONS

CPT model: curriculum (C), pedagogy (P), and digital technology (T) model.

CPT-S model: four-dimensional model (4-D) that comprises the three dimensions of curriculum, pedagogy and digital technology (C, P and T) and the one dimension of a student's attitude towards learning (S).

Cnc, Pnp, Tnt: CPT strategy

SMT: science male teacher

SFT: science female teacher

HMT: humanities male teacher

HFT: humanities female teacher

Numbers 1-20: the sequence of distributing the questionnaires. For instance, SMT1, SMT2 and SMT3.

PNP based learning: paper *and pen-based learning.*

Tranology: a combination of two main kinds of learning, traditional and digital technology-based learning.

D2L-LMS: desire to learn - learning management system.

|CPT|: the magnitude of the CPT vector, which locates students' learning strategy in the CPT space, i.e., digital technology-based learning.

$|CPT_0|$: the magnitude of the CPT_0 vector, which locates students' learning strategy in the CPT_0 space, without using educational technology, i.e., nondigital technology-based learning.

Cnc represents how many types of curriculum are applied to implement each learning objective. Cnc takes integer values from 1 to 3; this thesis suggested three kinds of curriculum theoretical, interactive and practical.

Pnp represents how many pedagogical dimensions are applied to implement each learning objective, Pnp takes integer values from 1 to 4; this thesis suggested four pedagogical dimensions: direct teaching, collaborative, cognitive and constructive learning.

Tnt represents the percentage of the learning objectives integrated with digital technology. Tnt takes one of the following values, as suggested in this thesis; 20 %, 40 %, 60 %, 80 %, 100 %.

R_0: the threshold impact factor.

R: the impact factor, which is defined in this thesis as the percentage of improvement in students’ attainment due to the use of educational technology.

CLL: Collaborative learning

CL: Competitive learning

CHAPTER ONE –

Introduction to the Thesis

1 INTRODUCTION TO THE THESIS

INTRODUCTION

Research into the impact of modern technology, such as pocket computers, tablets and smartphones, on learning is relatively new (de Jong, et al., 2010; Looi, et al., 2010; Wong, et al., 2010) involving the mobility and connectivity of mobile devices may lead to innovation in learning across different environments, as it promotes the pedagogical design and content of the curriculum (Chee, et al., 2011; Deaney, et al., 2003). For instance, it has been shown that mobile phones are increasingly used to improve both knowledge (content) and communication skills (Zhang, et al., 2011). Looi et al. (2010), and Tai (2012) stated in their studies that the evolution in digital technology has led to significant growth in the communication sector, which is reflected in the learning process. Hence, learning has been converted into a lifelong activity rather than short-term limited activities.

The innovation of digital technology-based learning continues to challenge educators to develop new teaching and learning pedagogies, which leads to continuous development in the content knowledge shape (Chilton & McCracken, 2017), since content knowledge can be shaped into different forms, such as theoretical, practical and interactive content (Farah, et al., 2016). According to Berger (2003), the integration of education and digital technology has changed many aspects of learning, such as the methods of teaching (pedagogy), the delivery systems using virtual learning platforms, and the content of the curricula. These changes have contributed to developing the society and human progress through positive interaction between members of the community and the new technologies.

According to Higgins (2003), the use of digital technology in the learning process offers learners and educators a gate for many external resources and communication platforms that can lead to effective learning. Juniu (2006), Burnage and Persaud (2012) endorse these ideas regarding the role of digital technology in advancing the use of diverse virtual learning platforms, such as learning management systems and social media sites, which facilitate the engagement of learners with those from other countries, as it enables them to exchange experience, ideas and knowledge. Therefore, the use of digital technology could expand learning, as it becomes a lifelong process that takes place inside and outside the classroom and at any convenient time for a student (Aldhafeeri, et al., 2006).

Lucey (2005) and Turner (2003) claimed that digital technology has a significant impact on society's members, including teachers and students. Kimmel and Deek (1995), Roschelle et al. (2000) argued that digital technology has a positive effect on education if it is used effectively. Wise et al. (2006) stated that mobile technology devices can be easily adapted to aid learning and can have a positive impact on students' learning. Thus, Sharma (2009) confirmed that using digital technology is an essential element in developing learning.

Walker (2003) explored the significance of digital technology in learning and stated that digital technology is a critical factor for students, teachers and the entire learning process including the delivered content and the pedagogy used to implement learning. However, according to Walker (2003), the use of educational technology on its own is not enough to achieve successful learning, as there are other critical factors related to teachers, students and policymakers, such as the preparation process for the lesson and student's attitude towards learning and towards the teacher.

Tutty and White (2006) claimed that new technologies have a significant impact on education, as the effective use of digital technology has contributed substantially to moving learning from the traditional approach, where a teacher is the centre of learning and learners are mere listeners, i.e., passive learners, to the modern style of teaching and learning where a teacher and students are both at the centre of the learning process. Thus, they can be considered as partners in this process, or active learners in one group, since all of them can learn from each other (Wang, et al., 2009). This agrees with Whitworth and Berson (2003, p. 483) who stated that "the computer continues to serve the primary function of facilitating students' access to content and remain somewhat relegated to being an appendage to traditional classroom materials".

With the aid of new technologies, lessons are more interactive. As such, visual and audio styles of learning can replace the traditional methods and tools of learning (Ghavifekr, et al., 2016). Jacob and Issac (2008), Ghavifekr and Rosdy (2015) claimed that a radical change had taken place in the classrooms in recent years using new technologies. For instance, computers and iPads have replaced textbooks and notebooks;

smart whiteboards have replaced the traditional boards, smart-pens are used instead of chalk and iBooks instead of the paper-based books. Hence, learning itself is no longer restricted to the classroom, as digital technology grants students the opportunity to share and learn with others at any time or any place (Kalz, 2014). Tutty and White (2006) considered distance learning as evidence that new technologies facilitate the mechanism of learning.

Digital technology has made communication between the members of the learning process, such as students, teachers and curriculum developers, easier and more convenient (Costley, 2014), which impacts positively the subject delivery (content and pedagogy) especially in schools that rely substantially on the use of digital technology, I would suggest calling such schools the paperless schools. In such cases, the delivery of content can be implemented using digital technology, so the delivery process is no longer face-to-face only or based on the teacher alone (Musawi, 2011). Adzharuddin and Ling (2013) suggested that teachers could use a virtual learning platform, such as a learning management system to communicate, deliver the content, evaluate, and examine students at any time and any place. Pachler et al. (2011), Adzharuddin and Ling (2013) stated that mobile technology devices offer learners access to extra sources of knowledge and social interaction through virtual platforms, such as a learning management system or a social media site, and many other applications that are assigned and created for this purpose, enabling learners to respond to each other, exchanging experiences and ideas.

The effective use of new technologies makes learning possible, achievable and accessible at any time and any place. In other words, digital technology can create sufficient opportunities for learning to take place (Groth, et al., 2009).

1.1 THE RATIONALE FOR SELECTING THIS RESEARCH AREA AND THE GAPS IN THE KNOWLEDGE

A survey of the literature suggests that there are positive effects of integrating digital technology and education. For instance, O’Donnell and Sharp (2012) claim that the use of digital technology has a positive impact on students’ learning, as it enhances their experience and engagement with the taught subject. Which agrees with Al-Hariri and Al-Hattami (2017, p. 1) who claimed that there is “a significant relationship between students’ use of digital technology and their achievements”.

In line with Al-Hariri and Al-Hattami, Eyyam and Yaratan (2014, p. 31) claimed:

> The mathematics post-test results of the students who were instructed using technology were significantly higher than the post-test results of the groups who were instructed without technology. Results showed that students had a positive attitude towards technology use. (Eyyam & Yaratan, 2014, p. 31)

Many other researchers investigated the impact of digital technology on learning in general, and the relationship between content knowledge (C), pedagogy (P) and digital technology (T) in particular, such as Mishra and Koehler (2006), Voogt et al. (2012) and Graham (2011). However, none of these researchers dealt with this relationship and its impact on students’ learning and attainment quantitatively, i.e. using a predictive mathematical perspective to measure in advance the improvement in students’ attainment as an outcome of the complex interaction between C, P and T. Therefore, I conducted this research to fill this knowledge gap by developing a new model that consists of three dimensional (3D) equations that deal with the above elements mathematically or quantitatively. Thus, it can predict the improvement in students’ attainment due to the use of educational technology (digital technology), which is referred to in this study as the impact factor (see section 5.2).

Based on the findings of this research, I would state that the significance of dealing with the relationship between C, P and T mathematically will be reflected positively in the curriculum planning. Teachers and curriculum developers will be able to design the curriculum in the most effective strategy (CPT strategy) that can maximise the learning outcomes. Refer to the conclusions and contributions to knowledge, chapters 8 and 9 in this thesis.

1.1.1 A Brief Description of the Developed Model of This Study (the CPT Model)

The pilot study findings led the researcher to form the relationship between the three factors (C, P and T) using the concept of vector space, for the purpose of this thesis, the vector space is identified as a three-dimensional vector formed of three components:

X, Y and Z. The idea of vector space was applied to the findings of this study to be developed and redefined using three different components C, P and T to be considered as the components of the new vector (the CPT vector), i.e. C, P and T replaced X, Y and Z. This thesis assumed that these new components are vectors and perpendicular to each other (the angle between any two components is equal to 90^o).

A Content, Pedagogy and digital Technology (CPT) model approach to the TPACK model (refer to section 2.8). The CPT model deals with the TPACK area (the common area between technology, pedagogy and content knowledge) as a space to be called the CPT space, which is formed of an infinite number of points or vectors. i.e. the common area between technology, pedagogy and content knowledge or what is known as TPACK, is no longer considered as an area or a plane (2D) but as suggested by the CPT model, it is a CPT space (3D) full of 3D vectors that represent the CPT strategies of learning.

Three key factors represent each point in the CPT space: digital technology, pedagogy and curriculum. In other words, C, P and T form a 3D vector in this space since the relationship between these three elements was formed using the concept of the vector space, as shown in Figure 1. The magnitude of each CPT vector can be calculated using the developed CPT equations (refer to section 5.2). Thus, the findings of this study assist educators and curriculum developers in locating the best point in the CPT space, i.e., the most effective strategy of integration between C, P and T, that enhances learning, maximises the learning outcomes and improves students' attainment.

The CPT model components

As shown in Figure 1, four pedagogical dimensions (P1 to P4) have been considered in this model: direct teaching, cognitive learning, constructive learning and social (collaborative) learning (Lin, et al., 2012), similarly three kinds of curriculum (C1, C2 and C3) have been suggested by the researcher: theoretical, practical and interactive (Farah, et al., 2016). As regards to the digital technology dimension (axis) is divided into five levels of integration, starting from level one (T1) to level five (T5) or (20% to 100%). I suggest these levels to represent the amount of the content integrated with digital technology.

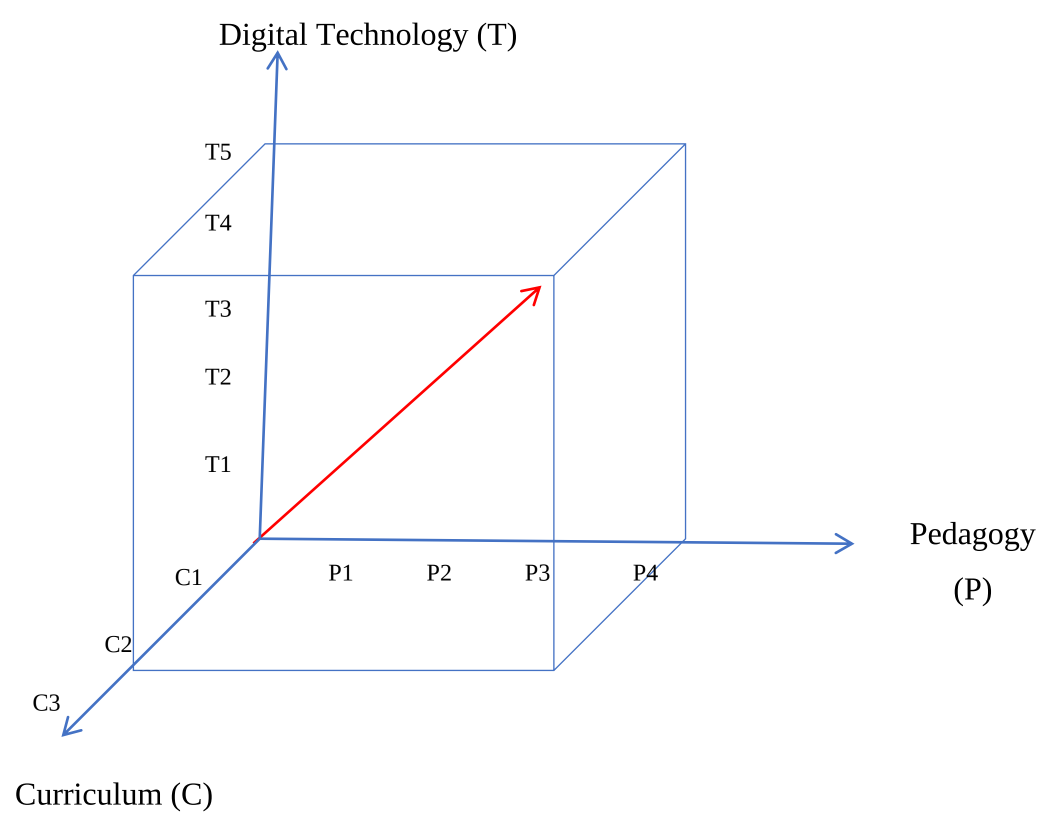


Figure 1. A CPT vector shows the point (2, 4, 1), which is interpreted according to the CPT model as (C2, P4, T5).

For more details about the CPT model components, refer to section 5.2

1.2 RESEARCH OBJECTIVES AND APPROACHES

The essential goal of this research is to explore the impact of educational technology (digital) on students' attainment and investigate the relationship between three factors: digital technology, the content of the curriculum and pedagogy. Hence, an original predictive model can be developed. As anticipated, the developed model (CPT model) outlines the improvement in students' attainment due to the complex interaction of these critical factors, i.e. measures the impact factor.

This study aims to investigate the qualitative impact of educational (digital) technology on students' attainment (if it has a positive or negative impact). As such, students' attainment without digital technology and with digital technology to be compared using the Pearson correlation factor and the effect size.

This study aims to investigate the quantitative impact of educational technology on students' attainment and to check the validity of the CPT model. Therefore, the observed improvement in students' attainment, as an outcome of using educational technology in different subjects related to science and humanities, were measured and compared with the predicted improvements that were calculated using the equations of the CPT model. A range of statistical functions (refer to Appendix 1 – Statistical Functions), such as the chi-square test, T-test and the P-value were used to achieve this goal. Thus, the null hypothesis of this study, the validity of the CPT model and its equations could be checked, i.e. the quantitative impact of educational technology on students' attainment could be measured.

The findings of this study guide teachers to locate the most effective strategies of teaching and learning humanities and science subjects; this goal could be achieved by comparing the observed improvements when applying different CPT strategies. Refer to the conclusions and contributions to knowledge, chapters 8 and 9.

1.3 THE NULL HYPOTHESIS (H_0) OF THIS STUDY

The null hypothesis (H_0) of this study states that there is no significant difference between the means of the predicted and observed impact factors, which implies that the CPT model is a valid and reliable tool as a predictive model for the improvement in students' attainment as an outcome of using educational technology.

The data analysis of this study showed that there is no significant difference between the means of the predicted and observed impact factors, which suggests that the CPT model can be considered as a valid predictive tool for the improvement in students' attainment. Hence, the null hypothesis of this study could not be rejected. Refer to the data analysis chapter, sections 6.1 and 6.2.

1.4 RESEARCH QUESTIONS

The findings of this study are utilised to answer the following questions:

1. Is there any relationship between the use of educational technology and students’ attainment?
2. If there is a relationship between educational technology (digital) and students’ attainment, then does it have a positive or a negative effect on students’ attainment?
3. Is there any relationship between the content of the curriculum, digital technology and pedagogy? If the answer is yes, can a mathematical model represent this relationship?
4. Can this model be a reliable tool to be used as a predictive model to measure in advance the improvement in students’ attainment due to the use of educational technology (digital)?
5. What are the implications of using the predictive tool for curriculum planning?

1.5 STRUCTURE OF THE THESIS

The thesis consists of nine chapters, followed by a bibliography and appendices. The first chapter presents an abstract and introduction that provide an outline of the thesis and the primary interests of this research. Moreover, research objectives, the rationale for selecting this research area and knowledge gaps are discussed in this chapter. The second chapter presents the literature review where several areas related to the research questions and the CPT model have been discussed, such as learning theories, digital technology, the content of the curriculum, pedagogy, it also includes a description of the term, learning management systems, the portable devices as tools for education, traditional and digital technology-based learning. The third chapter of the thesis describes the methodologies and the theoretical research framework directing the study. This includes a description of the methods implemented for data collection in this research, sampling, the data collection procedures, validity, reliability, ethical issues. It also includes the stages of building and developing the CPT model. Chapter four is assigned for the data analysis and discussion of the pilot study findings. Chapter five demonstrates the development of the CPT model. Chapter six discusses the findings of the main study, followed by chapter seven which describes the limitations of this study and its findings. Chapter eight presents the contributions of this study to knowledge and future studies. Finally, chapter nine shows the conclusions of this study, including suggested answers for the research questions based on the findings of this study.

1.6 SUMMARY

This chapter has provided an introduction to the study and its areas of interest. The potential impact of the findings of this research on educators and curriculum developers has been demonstrated. For more details, see section 8.2 and chapter 9. Moreover, this chapter described the theoretical framework of the CPT model, as shown in Figure 1. The rationale for choosing this research area and the significance of the study was described as well, to be discussed in more detail in the methodology and the data analysis chapters. Research objectives and questions have also been presented in this chapter. Finally, the structure of the thesis has been described. The next chapter will focus on the literature reviews that are related to this study.

CHAPTER TWO –

Literature Review

2 LITERATURE REVIEW

2.1 THE DEFINITION OF LEARNING

The principle of learning can explain our everyday behaviour. Some of our innate behaviours are involuntary, such as breathing, eating, and coughing. However, learning can possibly modify even these biologically programmed responses and actions. People can learn and gain new ways of behaving from their interaction with the surrounding environment and practices in their own lives. For example, developing breathing techniques to allow free divers to hold their breaths for extended periods of time underwater. Thus, one of the main things that makes us different from any other creature is our ability and flexibility to learn very complex behaviour, and our ability to develop those that already exist.

Elias (2011) defined learning as a product of the interaction between many factors, such as teachers, students and curricula. Depending on the epistemology underlying the learning design, learners interact with tutors, content and other learners. Elias claimed that this kind of interaction is an essential part of learning. As such students can learn from each other. This idea leads one to consider learning as a process of teamwork in which everyone can participate and be a productive member. This suggests that the roles in the learning process, such as transmitting and receiving knowledge, tasks and resources are to be shared among the members, and each is responsible for exchanging the experiences and the newly gained knowledge with other members.

Some researchers believe that there is a connection between learning and behaviour; therefore, their definitions of learning include the modification of behaviour. For instance, in 1977 Gagne defined learning as “a change in human disposition or capability which persists over a period of time, and which is not simply ascribable to process of growth”, cited in (Shachak, et al., 2005, p. 200). According to Gagne, learning must be associated with some modifications in behaviour. Mayer (1982) showed alignment with Gagne’s definition, stating that learning is a relatively permanent change in a person’s knowledge and behaviour due to experience. Mayer’s definition can be divided into three components:

i) The change is long-term rather than short-term, which is stated in the definition as a relatively permanent change.

ii) It is mentioned in the definition that the change includes learner’s knowledge (the content) and behaviour, which shows clearly that learning is associated with the behaviour’s modifications.

iii) Learner’s knowledge (the content) and behaviour can only be changed when learner’s experience in the environment is changed, which is more effective than any other tool, “rather than fatigue, motivation, drugs, physical condition or physiologic intervention” (Mayer, 1982, p. 1040). This agrees with Ambrose et al. (2010, p. 3) who stated that learning is “a process that leads to change, which occurs as a result of experience and increases the potential of improved performance and future learning”. In the year 2000, Driscoll defined learning by considering the relationship between learning, experiences and performance “a persisting change in human performance or performance potential which must come about as a result of the learner’s experience and interaction with the world”, cited in (Khatibi & Fouladchang, 2015, p. 85). Based on these definitions of learning, one can conclude that learning should improve the way we experience the environment, which leads to an improvement in the performance.

Clark and Mayer (2003) believe that the change in human performance and experience takes place when learning involves reinforcing the correct responses, weakening the incorrect responses and consists in acquiring a new knowledge that will be added to learner’s memories. Therefore, learning involves making sense of freshly acquired knowledge by reorganising it and connecting it with what is already known.

The previous definitions of learning are very close to a theory of education referred to as the Behaviourist Theory (refer to section 2.3.4). While the following definitions of learning show alignment with an alternative theory, different from that of behaviourism, which is referred to as Constructivist Theory (refer to section 2.3.5).

Bingham et al. (2010) defined learning as the transformative process of taking in new knowledge, which interacts with the previous knowledge or experience. The produced mixture changes the existing knowledge and builds new modified knowledge. This definition shows alignment with the Constructivist theory of learning, as it is based on three components: i) the input knowledge, ii) the interaction process, which leads to new knowledge. The result of this interaction process between the old and the new knowledge leads to a modifying of the existing knowledge, by developing a new primary form of experience and understanding. Finally, iii) the unique combination of knowledge that was produced, in the previous component, constructs an entirely new experience.

It seems evident that learning cannot be given one precise definition, nor seen from one perspective. However, according to Smith (1982), learning itself can be visualised as a container that has multiple uses, purposes and satisfies a variety of needs. This container can have different shapes depending on the needs and goals of educators, learners and the learning process itself. For instance, in terms of needs/purposes, learning can be defined as:

i) Acquiring knowledge: learning is the acquisition and mastery of what is already known about something (Smith, 1982). “Learning is focused on connecting specialised information sets, and the connections that enable us to learn more are more important than our current state of knowing” (Siemens, 2005, p. 6).

ii) Innovations: Learning is the extension and clarification of the meaning of one’s experience that promotes creativity (Smith, 1982).

iii) The analysis of ideas: learning is an organised, intentional process of testing ideas relevant to problems (Smith, 1982). This was echoed by Brown et al. (2014), who stated that learning involves acquiring knowledge and expertise and having them promptly available from memory, which assists a learner in solving new problems and dealing with new situations.

In other words, the definition of learning could be used to describe a product, a process or a function (Smith, 1982).

It seems clear that most of the definitions that showed alignment with both perspectives of behaviourism and constructivism agree that the essential point of learning is acquiring something new to modify the existing knowledge and behaviour.

2.1.1 Learning Perspectives

For the purpose of this thesis, learning is to be defined as acquiring new knowledge that is constructed by overwriting the old knowledge, which will be modified as a result of gaining new experience. The interaction between the old and new knowledge should form an entirely new understanding (current knowledge) until the learner adjusts it by acquiring newer knowledge.

Before relating the above definition of learning, which is offered by this thesis, to learning perspectives, it is essential to describe three different perspectives of learning: associationist, cognitive and situative (Greeno, et al., 1996).

Behaviourists, such as Tolman (1932), Guthrie (1935), Skinner (1938), and Hull (1943), cited in (Greeno, et al., 1996), developed the associationist perspective. According to Jessel (2013), this perspective places an increased emphasis on the idea of association and repetition. The associationist perspective shapes learning as the gradual process of building patterns, associations and skill elements (Beetham & Sharpe, 2007).

In this perspective, learning takes place by linking behavioural units through a series of activities followed by immediate feedback. Associationist approach requires the subject material to be analysed as particular associations, displayed as behavioural objectives; this type of analysis was suggested by Gagné (1985). Based on the task's analysis, units of knowledge need to be sequenced in terms of complexity, simpler components as prerequisites for the more complicated tasks (Koedinger, et al., 2012).

Gagné (1985) described the principle of Instructional Systems Design (ISD) as a recursive breakdown of knowledge and skills into small units. The fundamental principle of ISD states that the complex tasks need to be built step by step, starting from more simplistic units of knowledge. According to Gagné (1985), cited in (Mayes & Freitas, 2007, p. 15), ISD comprises three steps:

i. "Analyse the domain into a hierarchy of small units.

ii. Sequence the units so that a combination of units is not taught until its component units are grasped individually.
iii. Design an instructional approach for each unit in the sequence."

Gagne's approach "was reflected in the technology of the time: teaching machines were developed that were based upon learning principles such as simple repetition, feedback and reinforcement through external reward. The assumption was that learning was a matter of building on earlier behaviours" (Jessel, 2013, p. 16). The repetition of the simple units to those of increasing complexity, bottom-up fashion, reshape student's behaviour gradually. Joining this fashion with immediate feedback provides students with various paths to a successful completion where each learner is given access to the next problem contingent on their answer to the former one, "this process is suited to automation through simple technology" (Mayes & Freitas, 2007, p. 16).

Many researchers criticised the associationist perspective, see, for example, Nunes & McPherson, (2003) as it does not promote higher-order thinking skills. This claim is backed by Jessel (2013, p. 16), who stated that this pedagogy is "essentially didactic with the learner regarded as passive recipient of knowledge that is transmitted". Thus, there was a need to move to a new view of learning, cognitive perspective, which focuses on the mechanism of processing and constructing the knowledge rather than being delivered and memorised. In other words, it encourages higher-order thinking skills. According to the cognitive perspective, knowledge acquisition is regarded as the adjustment of current schema, including concepts and understanding. Such development arises from active interaction of new experiences and the existing schemes (Jessel, 2013).

While cognitive theory suggested by Piaget is concerned with the individual's development and achievement, Vygotsky (1978; 1934/1986) shifts the emphasis towards a social context where individuals work together to build their knowledge (Cole, 1991). Vygotsky's contribution goes in line with the sociocultural theory, which reveals how a community contributes to an individual's growth, the interaction between a learner and the culture is addressed in this theory as well. In the cognitive perspective, students need to be active participants in learning, emphasise understanding, analysing and application of critical thinking rather than memorisation and repetition. These claims are supported by Jessel (2013, p. 17), who stated that “ a cognitive perspective is concerned with inner mental functioning of a higher order such as thinking and reasoning and representation in memory”.

This perspective of learning allows students to develop current schemes by constructing new knowledge. Schallert and Martin (2003) suggested that teachers, in this perspective, are no longer considered the only providers of knowledge, but facilitators for students’ learning. According to this perspective, students learn through mental activities, such as reasoning and challenging tasks, rather than being offered the knowledge through instruction (Jessel, 2013; Brown, et al., 1989).

The possibility of building new knowledge through activities led to the development of a new approach, the constructivist perspective (Brown, et al., 1989). Learners are encouraged to develop their understanding “through self-directed activities, including problem-solving and experimentation” (Jessel, 2013, p. 17). Such developments require learners to interact with environments related to real-life applications. Constructivism promotes higher-order thinking skills. For instance, learners raise questions, look for answers by building a reasonable hypothesis, test their hypothesis and based on their findings; learners draw conclusions. For further information about constructivism, please refer to section 2.3.5

Finally, situated learning is an instructional method promoted by Jean Lave and Etienne Wenger in the early 1990s (Heick, 2019). This perspective follows the work of Vygotsky, who stated that students are more willing to learn through experience (Clancey, 1995). Stein (1998) stated that situated learning is related to creating an experience from authentic contexts or activities linked to real-world. According to Jessel (2013), since situated learning occurs in an authentic setting, it can be contradicted with other approaches to learning that are based on abstract principles isolated from a context of use.

Situated learning proposes that learning occurs through social relationships between learners, previous knowledge and authentic environment (Besar, 2018). According to Mayes and Freitas (2007, p. 19), "There are perhaps three levels at which it is useful to think of learning being situated". The first level represents the cultural perspective that highlights the necessity to learn in order to accomplish the desired participation in a broader community. The second level of situatedness is related to the learning group. At this level, learning is experienced in a social context, such as students in the classroom or students enrolled in a virtual learning platform computer-mediated communication. In such groups, students are keen to participate as active members. Finally, learning through individual relationships. This level emphasises that learning is mediated through the relationships with different members of a community. Fowler and Mayes (1999) stated that these relationships vary according to the characteristics of the community, the circumstances within which individuals work and the strength of the relationships.

The definition of learning offered by this thesis, strongly agrees with the cognitive constructivism and social constructivism perspectives, that are based on the work of Jean Piaget and Lev Vygotsky, as well as the situated learning. Constructing new knowledge and adjusting the old schemes through the interaction with the environment are critical elements in the presented definition of learning.

The definition of learning offered by the thesis is formed of three interrelated elements:

Firstly, acquiring new knowledge. The analysis of this element shows that it consists of the first part of the adaptation process (refer to section 2.3.5), which is the assimilation process (Ginsburg & Opper, 2016). Piaget explained the assimilation process as the process where a person uses existing schemes to interpret the newly gained knowledge (Littlefield Cook & Cook, 2005).

The interaction between organisms and the environment forms (assimilates) new knowledge or behaviour. The assimilated knowledge has to be discussed internally (internal mind) to check its compatibility with the existing set of behaviours and schemes. If these schemes fail to understand the external examples or the newly acquired knowledge, then new schemes need to be developed through the second phase of constructivism, the accommodation process, see the second element below.

Secondly, overwriting the old knowledge through the interaction between the old and new knowledge to form an entirely new understanding, after which it will be considered current knowledge.

The term overwriting indicates that an old item disappears and new emerges (Oxford dictionaries, 2005, p. 1085). This statement leads to connect this element with the second part of the adaptation process, which is the accommodation process. The accommodation takes place when the previous knowledge or schemes do not work or are insufficient to understand the external examples, which causes cognitive disequilibrium. In this case, the existing schemes must be overwritten and modified to be compatible with the newly gained experience. This implies that there will be an interaction between the external elements, those that can be seen externally (the environment), and the existing experience (AIU, 2018; vonGlasersfeld, 1982). As such, the newly formed schemes are sufficient to understand the new experience. In other words, new schemes will be developed; previous schemes are overwritten. Consequentially, new knowledge will be accommodated. Therefore, cognitive equilibrium is back again.

Finally, adjusting the current knowledge by acquiring newer experience (the current knowledge being re-challenged).

Reading through this element, show that it is linked with the second primary phase of the intellectual growth; the organisation process. Ginsburg and Opper (2016, p. 57) defined this process by "the tendency to form increasingly coherent and integrated structures". In other words, it is the process of seeking the perfect equilibrium (perfect understanding), which will never be fully achieved, as always there are new ideas to examine. Because of this tendency, people are never satisfied with the current equilibrium as they are looking for a deeper understanding of the known "We stretch and extend our cognitive structures by assimilating new and challenging information" (Ginsburg & Opper, 2016, p. 57). Piaget claimed, “the normal state of mind is one of disequilibrium—or rather a state of ‘moving equilibrium” (Beilin, 1994, cited in (Ginsburg & Opper, 2016, p. 58).

The newly accommodated knowledge will be considered as learner's current knowledge until new assimilation (experience) re-challenges the last formed schemes (the current ones) (AIU, 2018; Littlefield Cook & Cook, 2005). Hence, the process of constructivism, including all stages; assimilation, adaptation and organisation, will be repeated to form again another current knowledge, including the cognitive equilibrium. Therefore, using the constructivist approach, *I would summarise my definition of learning by stating, it is the dynamic interaction between the old and new knowledge to form the current knowledge*.

I would argue that the offered definition of learning by this thesis is also related to Vygotsky’s perspective of constructivism, the social constructivism, and situated learning as well. The presented definition stated, constructing new knowledge and adjusting the old schemes will be achieved through the interaction with the environment. However, the definition did not specify if this knowledge will be constructed individually, as Piaget suggested, or in a social context, where individual's work together to build their knowledge, as suggested by Vygotsky.

Moreover, the presented definition of learning did not specify the nature of the environment, if it is an authentic or merely abstract principle isolated from the context of use. This might be considered as limitations in the offered definition. Even though the above elements discussed the proposed definition in relation to Piaget's view only, considering the collaboration and scaffolding between students to build new knowledge in an authentic environment, creates the connection between the offered definition of learning and both perspectives, the social constructivism, and situated learning.

Lave and Wenger (1991) claimed that situated learning promotes collaboration between students in an authentic setting. Besar (2018) claimed that situated learning occurs through social relationships between learners, participation, previous knowledge and authentic environment. Thus, including the social context and an authentic environment in the offered definition by this thesis would support my argument that this definition is related to both perspectives, social constructivism of Vygotsky and situated learning, in addition to the cognitive constructivism of Piaget.

2.2 THE NOTION OF TECHNOLOGY AND THE ENTRANCE TO EDUCATIONAL TECHNOLOGY

In the nineteenth century, the term technology was defined as the organised knowledge of the practical arts (Schatzberg, 2006). The roots of this definition go back to the work of Johann Beckmann, a professor at the University of Göttingen who published Anleitung Zur Technologie translated into English as the Guide to technology in 1777 (Schatzberg, 2006). In this publication, technology was defined as "the science that teaches the processing of natural products or the knowledge of handicrafts" (Schatzberg, 2006, p. 490). This definition formed the beginning of technology to be regarded as an academic subject in German-speaking countries (Tietz, 2015). In 1855, George Wilson, a professor of technology at Edinburgh University, defined technology as “the Science of the Arts, or, as generally restricted, the Science of the Useful Arts” (Schatzberg, 2006, p. 490). Likewise, in 1911, the Century Dictionary, which was published in New York, addressed technology as “that branch of knowledge which deals with the various industrial arts; the science or systematic knowledge of the industrial arts and crafts, as in textile manufacture, metallurgy, etc.” (Fernando, 2019).

Over time, various technologies have been developed and introduced to serve societies. Thus, different perceptions of the characteristics and functions of technology emerged.

Technology mediates both realities, physical and virtual:

> …technology absorbs people in a virtual reality. It deadens them to those who are actually nearby. The resulting social autism adds to the ongoing list of unintended human consequences of the continuing invasion of technology into our daily lives. Goleman, 2006, cited in (Clapham, 2011, p. 16).

Technology also possesses an element of “checks and balances” (Clapham, 2011, p. 16) :

> Technology offers the potential to make life easier and more enjoyable; each new technology provides increased benefits. At the same time, added complexities arise to increase our difficulty and frustration. Norman, 1999, p. 31, cited in (Clapham, 2011, p. 16)

Cuban *et al.* (2001, p. 813) argued that the practitioners of educational technology view it as possessing determinism fastened to it, which mediates a positive consequence to the project in which it is used:

> Most policymakers, corporate executives, practitioners and parents assume that wiring schools, buying hardware and software, and distributing the equipment throughout will lead to abundant classroom use by teachers and students and improved teaching and learning. (Cuban, et al., 2001, p. 813)

To some extent, Bill Gates echoes Cuban et al.'s opinion: "Technology is just a tool. In terms of getting the kids working together and motivating them, the teacher is the most important". Gates, 1997, cited in (Clapham, 2011, p. 16)

Technology is a set of tools that manage power:

> Machines are worshipped because they are beautiful, and valued because they confer power; they are hated because they are hideous, and loathed because they impose slavery. (Russell, 1928, p. 28)

Koehler and Mishra (2009, p. 64) claimed that any definition of technology "is in danger of becoming outdated by the time this text has been published". In line with their publication in 2006, Mishra et al. (2009) confirmed again that the term technology exists in a state of flux due to the rapid development of the technology field. "This makes defining and acquiring it notoriously difficult" (Harris, et al., 2009, p. 397).

Burgelman et al. (1996) defined technology as theoretical and practical knowledge, which includes skills, and artefacts that can be employed to enhance products, services and knowledge delivery systems. Technology is also embodied in people, materials, cognitive and physical processes, facilities, machines and tools (Lin, 2003).

Based on these various perceptions of technology, it is essential to be precise as to what technology means and to draw some of the pertinent characteristics within such seemingly different definitions.

> Technology consist of a basic purpose or function, materials, energy source, artefacts/hardware, layout, procedures (programs, software), knowledge, skills, qualified people, work, organisations, management techniques, organisational structure, cost/capital, industry structure (suppliers, users, promoters), location, social relations and culture. (Fleck & Howells, 2001, p. 525)

In an educational context, Clapham (2011) argues that:

> Technology in school encompasses a broad church of sometimes not apparently interlinked elements. Technology can be both physical and abstract. A ruler is a technology, so too a book or a room - technology can be a norm, system, or a tool used to accomplish a task. (Clapham, 2011, p. 17)

Interpreting artefacts as educational technologies, or learning technologies, implies variation context in which these technologies are established:

> ...artefacts that mediate the encounters of *deliberate* learning can be termed educational technologies or learning technologies. Here, we prefer the latter phrase. It is less familiar, but therefore it comes with fewer connotations. Educational technology risks limiting discussion to those institutionalised versions of deliberate learning that make up schooling, whereas here we are keen to explore technology-mediated continuities between in-school and out-of-school experience. (Crook & Lewthwaite, 2010, p. 437)

Selwyn (2010) likewise addressed educational technology as those technologies that mediate the arrangements of education. In line with Selwyn (2010), Clapham (2011, p. 17) regarded educational technology “ as any technologies – computer or otherwise - that mediate teachers’ formal and institutionalised activities". For instance, teachers’ activities can be mediated using mobile technology, such as a laptop or tablet.

Katic (2008) suggested that investigating educational technology requires researchers to study how teachers reflect on and employ technology in their teaching. Katic's suggestion is backed by Zaho et al. (2001), who believe that educational technology needs to be viewed in terms of teachers’ experience.

> Such conceptions are important as the expectations of those designing, manufacturing and selling educational technologies might not be reflected in teachers own conceptions as to what activities these technologies can, and cannot, successfully mediate. (Clapham, 2011, p. 18)

Educational technology advances schools and with it an enhancement of learning and sequentially education (BECTA, 2009a), cited in (Clapham, 2011). Bigum and Kenway (1998) argued that educational technology is “characterised by an unswerving faith in the technology’s capacity to improve education and most other things in society, often coupled with a sense of inevitability concerning the growth and use of computer technology”, cited in (Selwyn, 2010, pp. 12-13). Such development is reflected in a positive culture (Goodson, et al., 2002). Although technology guided educational innovation being accomplished, as Crook (2001, p. 19) claimed, "much more slowly than innovators themselves predict". For more details, about the term educational technology, please refer to section 2.5.

Clapham (2011) and MacKenzie and Wajcman (1999) justified the contradiction between the technological accomplishment in reality, and that anticipated by innovators, using the interrelationship between technology, community, culture and political philosophy, which influence the actual achievement of technology in the innovation context. Therefore, some researchers, see for example, Tepstra and David (1985) and Lin (2003), viewed educational technology in terms of a socio-cultural system that considers the relationships between people and their environment.

Smaldino et al. (2005) claimed that many technologists consider broad conceptions of the term technology, as it comprises not only physical equipment but also the processes and programs used to solve problems. Thus, Koehler and Mishra claimed that technology is a set of “tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfil needs, or satisfy wants” (2008, p. 5). In contemporary educational contexts, the term technology involves the ability to use digital technologies in the learning process. Also, it “covers the ability to adapt to and learn new technologies” (Koehler, et al., 2013, p. 3). These claims were backed by Graham (2011), who claimed that technology refers to a user’s ability to use technological tools to manipulate products related to software and hardware. In turn, this implies that anyone, at any age, in any field of employment, can possess technology knowledge.

Koehler and Mishra (2006, p. 1027) defined Technology as: “knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video. This involves the skills required to operate particular technologies”. However, in 2009, they modified their definition to be compatible with the notion of Fluency of Information Technology (FITness), which was suggested by the National Research Council (NRC, 1999) (Koehler & Mishra, 2009). The new version of the definition stated:

> …persons understand information technology broadly enough to apply it productively at work and in their everyday lives, to recognise when information technology can assist or impede the achievement of a goal, and to continually adapt to changes in information technology. (Koehler & Mishra, 2009, p. 64).

To some extent, Cox (2008) agreed with Mishra and Koehler (2008; Koehler & Mishra, 2008), as Cox divided technology into transparent and emerging technologies. Transparent technologies comprise tools like pencil, chalkboard and book. Emerging technologies include digital tools applied to a learning environment, such as laptops, tablets and virtual learning platforms. The analysis of Cox's definition leads to a result that the transparent technologies were involved within Shulman's conception of PCK while the emerging technologies are encompassed within the new TPACK framework, refer to section 2.8. However, Cox stated that TPACK researchers continue to interpret technology broadly without a clear distinction between technological tools. Therefore, to make the distinction between TPACK and PCK, Cox (2008, p. 73) stated that "technological knowledge is defined as knowledge of how to use emerging technologies" since transparent technology includes traditional tools, such as books, pen and chalkboard.

Shulman (1986) defined curricular knowledge as teachers' knowledge of educational tools and materials, including visual materials and films. Thus, technology was implied though not plainly expressed in Shulman's conception of PCK. This was supported by Angeli and Valanides (2009, p. 156) who claimed that Shulman intended to include technology in his PCK framework but "did not explicitly discuss technology and its relationship to content, pedagogy, and learners, and thus PCK in its original form does not specifically explain how teachers use the affordances of technology to transform content and pedagogy for learners".

Mishra and Koehler (2006, p. 1023) stated that "until recently, most technologies used in classrooms had been rendered 'transparent', or in other words, they had become commonplace and were not even regarded as technologies". In line with Mishra and Koehler (2006), Cox (2008) argued that the investigation of the term technology is not limited by digital technologies exclusively, but also it includes what Mishra and Koehler (2006) refer to as standard technologies. This includes tools that had been used in the classroom, and no longer are considered technologies, such as pencil, chalkboard, and face-to-face communication.

Based on the broad perspectives of defining technology, every teaching process requires the use of technology since no teacher can typically teach without using some of these tools. These arguments of defining technology led to establishing new concepts related to digitalisation, such as digital technology, which will be discussed in the next section.

2.2.1 The Concepts of Digitalisation

Several concepts are adopted to express digitalisation, such as digital technology, information technology (IT), information and communication technology (ICT), technology, and educational technology (Salavati, 2016).

These concepts are used in literature interchangeably, as there is no clear distinction between them. For instance, Grönlund (2014, cited in (Salavati, 2016)) used IT and the term technology interchangeably. Other researchers, such as Fleisher (2013, cited in (Salavati, 2016)); and Tallvid (2014) used IT and ICT; digitalisation and digital tools interchangeably. Likewise, Wikramanayake (2005) used the terms technology, digital technology and the acronym ICT interchangeably.

The acronyms used to describe digitalisation vary between *IT* and *ICT*. In articles published in some European countries, such as Sweden, the acronym IT is frequently used, while ICT is used frequently in England (Ministry of Enterprise, Energy and Communications, 2011). The last digital agenda of the UAE (FGCCC, 2016), where this study took place, considered the term technology, while other webpages related to the government of the UAE considered the acronym ICT, such as smart Dubai-2021 webpage (Smart Dubai, 2019).

In English publications, the acronyms and concepts used to express digitalisation vary. For instance, the British Educational Suppliers Association (BESA, 2015) used the acronym *ICT*. Mishra and Koehler (2006) and Bates (2015) used the term *technology*. In addition to IT and ICT, other terminologies, such as *educational technology are* used as well (Bates, 2015).

Cox (1999) claims that there is substantial confusion between Information Technology (IT) and Information and Communication Technology (ICT). According to Cox (1999), the acronym IT referred to a separate subject in schools, whereas ICT comprises digital tools, software and hardware, employed in a broader range of teaching and learning processes. Likewise, Kumar (2008, p. 1) describes ICT as an umbrella that includes a variety of digital devices and software programs, such as “digital television, radio, internet, network hardware and software, videoconferencing, and distance learning”. However, Lever-Duffy et al. (2005, pp. 4-5), state that some “educators may take a narrower view” and predominantly “confine educational technology [ICTs] primarily to computers, computer peripherals and related software used for teaching and learning”.

In educational settings, digital technologies, such as laptops and portable devices, are becoming essential tools in creating new opportunities for learning to take place. One of the critical features that can distinguish digital technologies, afforded by web 2.0, from other technologies, such as those afforded by web 1, is the two-way connectivity. This can be reflected in different sectors of the society in general, and the education sector, in particular. Facilitating the communication between the members of the learning process provides new opportunities for lifelong collaborative, constructive and interactive learning (Jessel, 2013).

Digital technologies enable learners to move between different virtual learning platforms, such as social platforms. Thus, students can exchange and share their knowledge (Chasse, et al., 2017; Faizi, et al., 2013). This implies that learning is no longer restricted by a specific place or time, as digital technologies offer learners continuous connectivity with diverse sources of knowledge and facilitate the communication between learners themselves (Pureta, 2015).

"The introduction of digital technologies has changed the methods and techniques of acquiring, representing, and manipulating knowledge in almost all disciplines, from mathematics to music, astronomy, and archaeology" (Kereluik, et al., 2013, p. 132). Jessel (2013) stated that the use of digital technology tools could enhance learning. However, there is no guarantee that the mere availability of these tools leads to effective learning since the method of use is more significant than possessing it (Jessel, 2013).

This thesis considers the terms educational technology and digital technology to express the new technologies that were used to implement the teaching and learning during the study, such as laptops, iPads, Internet, software programs, simulations, digital videos, smart boards, projectors, and the learning management system. In some places in this thesis, the terms digital technology and educational technology might be used interchangeably. However, I confirm that what is meant by the use of any of these terms is the new technologies, i.e., digital technologies.

2.3 LEARNING THEORIES

Learning can be implemented using several learning theories or what is called the pedagogical dimensions (Lin, et al., 2012). For the purpose of this thesis, the author's definition of the term pedagogy is to be the method and practice of teaching or how a teacher teaches a subject matter.

Lin et al. (2012), Farah et al. (2016) and Beattie et al. (1997) suggested that the pedagogical dimensions can be divided into the following categories:

i) Self-learning.

ii) Collaborative learning.

iii) Competitive learning.

iv) Behaviourism.

v) Cognitive and social constructivism.

vi) Deeper and surface learning.

2.3.1 Self Learning

Self-learning is also called independent learning or student-centred learning (Froyd & Simpson, 2010). In this kind of education, learners must rely on themselves to build their own knowledge. In other words, learners are in charge of managing their learning processes. This can be called the ownership of learning since students are in charge of the majority of their learning (University of Kent, 2017) and only a small part in the form of supporting, checking and directing the learners is left to the teacher. During the self-learning process, the educator's role is to track learners to make sure that the learning process is moving along the correct path. This means that self-learning itself might include a sort of collaborative learning between learners and educators.

Chee et al. (2011) believe that digital technology has a substantial role in promoting self-learning as it facilitates students' research process to build their knowledge. This seems to suggest that digital technology promotes the cognitive and constructive aspects of self-learning, which may lead to building a new model of knowledge independently (Chee, et al., 2011).

Self-directed learners show a remarkable capacity to produce meaningful learning and monitor their knowledge (Garrison, 1997). Taylor (1995) claimed that these learners are curious and enthusiastic to investigate new matters since they see obstacles and difficulties as chances to gain new knowledge (Taylor, 1995). Taylor also observed that self-learning has many benefits for learners, such as raising their motivation level and their level of confidence, as it expands their horizons, leading them to have a greater awareness.

Dziewulski (2012) claimed that self-learning has a positive impact on student's learning. It is expected that while a student works independently, new knowledge emerges. The student might understand the gained knowledge alone, or might need external support to grasp it. Therefore, in order to discuss and clarify ideas, students have to communicate with each other. Therefore, one can conclude that self-learning includes a positive effect on students and educators as well, since educators have to keep developing their knowledge and academic level in order to meet their students' expectations every time they are experienced.

One of the previous studies about self-learning was conducted in Thomas Telford School in the United Kingdom. This school was the first state-funded school to record 100% of students gaining A–C scores in at least five GCSE exams (exams that are typically taken at the age of 16 years old). According to the school, this success is a result of developing self- and independent- learning skills across the whole school. These results give some evidence that independent learning can improve student's learning (Meyer, et al., 2008).

Meyer (2010) stated that independent learning might have a positive effect on students' learning. However, according to Meyer, this kind of learning needs to be organised with strategies, boundaries and rules. For instance, students should be aware of the research area they have to investigate and which task or assignment they have to work on; otherwise, students might get lost, and their efforts will not be concentrated in one distinct area, but instead, it will be scattered with no clear strategy to make connections. According to Meyer (2010) scattering the efforts is considered one of the risks with independent learning. Nor and Saeednia (2009) argued that learners' efforts need to be steered in the correct direction; as such, the learning outcomes meet the expectations. Based on the claim made by Nor and Saeednia (2009), one can conclude that independent learning can be a useful learning technique in the case of remedial sessions, researching and writing essays.

According to Meyer et al. (2008), self-learners have higher self-esteem than other learners, as they believe in themselves more, may feel stronger academically and might feel that they have their own space that is full of innovations and their own achievements. These privileges can motivate and attract other learners, especially those who are sufficiently developed to access this area of learning. As such, the newcomers (the new students in this area) can experience pride and feelings of self-worth that are derived from achieving something independently.

MacBeath (1993) and Meyer et al. (2008) have confirmed that the teacher must always record and track the progress which has been achieved, provide continuous feedback and recommend resources, references, plans and instructions to be used by the learner during the learning process. In other words, the teacher's role is shifted from the leading knowledge provider to that of monitor or director, giving advice and guidance when it is needed, as well as highlighting objectives and expectations.

The literature proposes that the essential components of independent learning may include internal and external factors. The external characteristics are the construction of a robust relationship between educators and students and the establishment of a suitable environment for learners (MacBeath, 1993), while the internal characteristics of independent learning are related to learner's skills, such as the cognitive skills, comprising the memory, in addition to the effective skills, including those related to feelings and emotions (Meyer, 2010).

Meyer et al. (2008) suggested that self-learning moves learning from being teacher-centred to student-centred, though this does not mean that students should work alone all the time. Students are required to keep their teachers updated on their progress so that teachers can be aware of their students' progress and can intervene in the time of need. Thus, independent learning implies a shared responsibility between learner, educator and the institution, each of which plays a different role. In line with Meyer et al., Krause and Coates (2008) claimed that the independent learning process consists of learners, teachers, school management or policymakers, each of which must have a specific role to implement. For example, teachers provide students with adequate resources, guidance and advice whenever it is needed.

On the other hand, the school management has an important role to play, supporting both learners and teachers at the same time. The school has to provide learners with sufficient, reliable and robust resources and tools, which include software and hardware that can help students to implement their independent learning. The school management supports teachers as well by improving their academic and technical skills through the provision of continuous development sessions and workshops or other courses related to educational technology and independent learning.

Meyer et al. (2008) believed that school management plays a considerable role in reinforcing and sustaining the relationships between educators and students and between students themselves in order to maintain more effective communication, since sharing the useful resources of learning between them benefits the independent learning process. Meyer's et al. claim agrees with Mistry and Sood (2017, p. 128) who stated that "developing good relationships lies at the heart of good leadership development and how individuals take control of their own learning or through working closely with others".

In line with Mistry and Sood, Krause and Coates (2008) suggested that:

> The concept of engagement embraces a specific understanding of the relationship between students and institutions. Institutions are responsible for creating environments that make learning possible, and that afford opportunities to learn. The final responsibility for learning, however, rests with students. (Krause & Coates, 2008, p. 2)

Based on perceptions proposed by Meyer et al. (2008), Meyer (2010) and Krause and Coates (2008), self-learning consists of three stages. Firstly, the planning stage to address the learning outcomes and expectations, which should be a shared responsibility between a teacher and learner. Secondly, the conducted research and self-monitoring stage, which should be the learner's responsibility. Finally, the evaluation stage, which is a shared responsibility between teacher, student and the school management, whether the student feels satisfied or not can be considered as a kind of evaluation. Therefore, it seems evident that the self-learning process incorporates some aspects of collaborative learning.

2.3.2 Collaborative Learning (CLL)

At the end of the 18th century, the concept of collaborative learning (CLL) was applied at the University of Glasgow by George Jardine (Gaillet, 1994). Afterwards, an American researcher John Dewey developed the idea of CLL and endorsed the concept of collaboration as a primary procedure to implement learning. Therefore, it became an essential part of their way of teaching and learning (Smith & MacGregor, 1992).

CLL is a personal philosophy, not just a classroom technique or an abstract mechanism (Panitz, 1999) as it needs an internal belief in it from the members of the learning process, including learners, educators, curriculum designers and management. The CLL process consists of two main features: creating and sharing. Each member participates in developing and exchanging with others what was created and developed. These two features form the idea of collaboration (Laal & Laal, 2011). Thus, the term collaboration leads to another phase of education, which is organising or distributing the responsibilities and tasks to be shared between the group members (Smith & MacGregor, 1992; Tinzmann, et al., 1990).

Between 1960 and the 1980's many researchers, such as Slavin (1983), Johnson and Johnson (1989) supported the idea of CLL and agreed that this kind of learning could lead to solving the psychological problems that face learners. Slavin (1983) claimed that collaboration between students encourages them to work harder since collaborative learning has a positive impact on students' behaviour, learning and efficiency regardless of their ages (Slavin, 1983; 1990). Millis (2002) claimed that CLL impacts students' learning positively as it reinforces the social interaction between students, sustains their personalities and increases their trust and belief in themselves, and grants students the opportunities to learn more by asking more and checking more resources related to the case they are studying. According to Smith and MacGregor (1992), collaborative work gives the members the possibility to share and exchange their knowledge. Thus, feedback will be received from other members in the group, which improves students' learning, as they aim to meet the expectations of others (teacher and other students).

Johnson and Johnson (1991), and Johnson et al. (1991) defined collaborative learning as the use of small groups in educational activities to maximise students' learning and improve their academic performance and engagement, as students share their experience and ideas. Johnson et al. (1991) stated that collaborative learning needs the effective participation of all members to achieve the best outcome. For instance, two or more learners collaborate to create a shared understanding of a concept, discipline or area of practice that was not known previously, such as building a new model or developing new knowledge that none of them possessed before. According to Gerlach (1994), the definition of collaborative learning must be built on the idea of defining learning as a social activity where participants talk and chat among themselves. In other words, learning takes place collaboratively through the interaction between learners.

Dillenbourg (1999) claimed that CLL is a kind of learning that takes place when two or more people attempt to acquire new knowledge together through some learning activities. Dillenbourg's definition can be divided into three components. Firstly, the number of participants. There must be two or more learners which can be considered as a pair or a small group (3-5 students) or a full class (more than 15 students). Secondly, the acquisition of new knowledge, which can be interpreted as learning activities, such as writing an essay or a problem-solving activity. Finally, the term together, which might be interpreted as the interaction between learners, face-to-face interaction or distance-based learning using the communication tools, such as the social media websites (Smith & MacGregor, 1992).

However, for the purpose of this study, I would define collaborative learning as a set of educational activities that are conducted to implement teaching and learning. These activities require the participation of groups of students who collaborate to solve problems, complete tasks, create and grasp new concepts.

Williams and Eberechukwu (2015) claimed that the use of digital technology could promote collaborative learning. Chandrasekaran et al. (2016) suggested that the CLL does not require the members to be in the same place physically, nor does it require a specific time. It is particularly relevant these days with the presence of electronic communication and social media; learners from America can collaborate with learners from another continent, such as Europe or Asia. Hence, learning is no longer restricted to the classroom, as it takes place inside or outside the school at any convenient time for learners.

Laal and Ghodsi (2012) stated several significant advantages of CLL. Firstly, Social benefits; as CLL develops learning communities and supports the social interaction between learners. Hence, all members of the learning process, including students and teachers, can learn from each other. Secondly, Academic benefits; CLL Promotes learner's critical thinking. Thirdly, Psychological benefits. Finally, CLL can be applied on a minor scale inside the classroom and a major scale likewise outside the school.

Educators can collaborate as well to improve their skills and to build new knowledge (Mistry & Sood, 2012). Hence, these educators will stay up to date and capable of meeting the expectations of the learning process. They are likely to be organised and always looking for further development through collaboration and exchanging ideas. Indeed, Laal and Ghodsi (2012) suggested that the use of CLL ensures that both students and educators perform successfully in the learning process.

In line with Burgelman et al. (1996), Lave and Wenger (1991) believed that CLL should not be limited to students only, but it should be between students and their teachers and between teachers themselves in the form of communities. Furthermore, Lave and Wenger suggested that working as a community and using digital technology throughout the school for this purpose would offer a more significant benefit for the school and might lead to developing teachers’ skills related to educational technology. Putnam and Borko (2000) stated that any improvement in the teacher’s academic level would not happen unless teachers had the opportunity to interact with other teachers and experts in the professional community. Sachs (2003) argued that if teachers have no social interaction or are isolated, their work will become dull routines without any progress and these teachers will avoid or not benefit from any new challenges and opportunities that might improve their skills.

In CLL, learners are working in groups, where each group consists of two or more learners. Their main target is to explore specific concepts or phenomena and look for new knowledge and models (Gleeson, et al., 2004). This leads to conclude that collaborative learning can serve many educational approaches, one of the most important of which is concentrated on learners’ exploration of the topics they study.

Collaborative learning as a learning method helps to move learning from traditional teaching, which is known as the teacher-centred approach, towards a modern learning style, which is more concentrated on the positive interaction between learners and educator. This kind of learning is known as student-centred learning, where the emphasis is on student's ownership of learning and of responsibility for learning (Lowman, 1987; Smith & MacGregor, 1992). Since the modern learning style is based on the positive interaction between teachers and students, I would suggest that this style of learning should be called teacher-student centred learning, which emphasises the shared or joint responsibility of the teacher and student.

It seems likely that when using CLL, students are more engaged in learning (Laal & Ghodsi, 2012). Teacher's role is kept in the learning process, but not as the only knowledge provider. However, using the collaborative learning method, the teacher's role can be described as the role of the organiser or tasks' distributor, but no longer as the transmitter or the only source of knowledge. This claim is supported by Abdu et al. (2012), who argue that for teachers using this method it is sufficient to distribute the tasks to the group's members, to direct them, to keep monitoring at a distance and intervene in the time of need. However, the use of collaborative learning does not mean that the teaching activities will disappear entirely, such as lecturing, listening and note-taking process, but these activities can run parallel to the process of collaboration between learners themselves and between learners and educators (Smith & MacGregor, 1992).

With regard to the teacher's role in CLL, Rae et al. (2006) and Laal and Ghodsi (2012) believed that the use of CLL would reinforce the sense that the teachers who rely substantially on the use of collaboration to implement learning tend to think of themselves less expert as transmitters of knowledge to students, and more expert as designers of intellectual experiences for students. Abdu et al. (2012) confirmed in their study that the teacher who applies collaborative learning serves less like an agent for the transmission of knowledge and more as a moderator. I would claim that this is an ordinary sense, as long as these teachers are not transmitters anymore, they are just directing the learning process from a distance; however, teachers are requested to keep developing their academic level to be capable of interfering and supporting whenever learners need help. In other words, there should not be any connection between the experience as a transmitter and the teacher's academic level and skills of the taught subject.

Dillenbourg (1999), Smith and MacGregor (1992) believed that collaborative learning is addressed and evaluated from a developmental perspective, as a biological and cultural process, which occurs over the years. Therefore, teachers may use many rubrics to judge the achieved progress and to decide if learning took place or not. For instance, the rubrics can be based on the quality of the gained knowledge or by the achieved progress in the problem-solving area, the overall performance, the improvement in dealing with the application, analysis and evaluation of problems.

Like any other method of learning, CLL requires an appropriate environment for learning to take place. Creating a positive collaborative learning environment can be achieved by dividing learners into groups, distributing tasks between the groups, which reinforces the social interaction between learners as well as enabling them to exchange their knowledge, experience and thoughts (Lowyck & Poysa, 2001; Brindley, et al., 2009). Students from different academic levels including high achievers and low achievers have to be seated in the same group, so that weaker students may benefit from the contact with stronger students, proper instructions have to be distributed by the teacher. Webb (1982) confirmed the effectiveness of the heterogeneous pattern of distribution for both high and low achievers. Webb stated that when high achievers were distributed homogeneously, they interacted less efficiently as they expected that every student in the group should have grasped the content, unlike the situation of heterogeneous distribution. Cheng et al. (2008) claimed that the rules and guidelines must be distributed to learners in advance, so learners stay on the correct path towards achieving the target of the collaborative learning process.

Laal and Ghodsi (2012) suggest that CLL can be divided into two types. Firstly, internal CLL if it takes place inside the classroom. This kind of learning mode requires students to be divided into groups. Students in each group should be seated at round tables so that the conversations, discussions, creation and exchanging of ideas can take place. In this mode of learning, all students should participate effectively, as all in one and one in all. Secondly, external CLL, if it takes place outside the classroom. In this case, learners have to communicate using a virtual learning platform, such as the social media websites, a telecommunications application like Skype, or a learning management system, such as the desire to learn (D2L).

Based on the discussed perceptions of the CLL, I would describe the term collaborative learning as a trick or a trap (positive trap). While the teacher’s goal is to teach students, unfortunately, often the students' goal is to escape from the traditional time of the lesson, which they have to spend inside the classroom. Very often, students tend to chat with each other. CLL grants them this opportunity, but with the condition that the teacher chooses for them the topic to chat about. In other words, the teacher enables students to waste class time efficiently. The selected topic for students should be related to the lesson with some ordering of the ideas, instructions, structures, and competitions between the members must be arranged. As such, the response level towards learning from learners will be higher and quicker. Thus, learners can be shifted from passive to active learners, as they will be able to create, invent and overcome the challenges more effectively.

2.3.2.1 Collaborative or Cooperative Learning?

Both terms collaborative and cooperative are very close in meaning, so as to be considered as having the same definition, especially for non- native speakers. These two expressions agree about an essential point that both terms require working together as a group to achieve a common goal. This kind of learning is known by various names: collaborative learning, cooperative learning and collective learning. However, the main point here is that the term collaboration is not precisely the same as the term cooperation (Panitz, 1999).

Cooperation and collaboration seem to overlap, but in the cooperative model of learning the teacher still controls most of what is going on in the class (Ahmed, 2017), even though students are working in groups. In other words, the teacher remains in the centre of the learning process. On the other hand, in collaborative learning, the teacher can be considered as a member of each group and students are taking almost full responsibility for working together, sharing the ideas and building a new knowledge together (Panitz, 1999).

Lane (2016) stated that in collaborative learning, there should be shared goals since students learn from the teacher and each other. In contrast, in cooperative learning, the teacher stays in control of everything in the class (is the centre of the process). Theroux (2001) argued that collaborative learning has many common areas with cooperative learning, but it differs from cooperative learning by being more student-centred learning than teacher-centred learning. In the case of collaborative learning, students are in charge of their own learning, including the learning outcomes and building their own knowledge, as shown in Table 1. Panitz supported this idea:

> Cooperative learning is defined by a set of processes which help people interact together in order to accomplish a specific goal or develop an end product, which is usually content specific. It is more directive than a collaborative system of governance and closely controlled by the teacher. (Panitz, 1999, p. 5)

In general, teachers who rely on either a collaborative or cooperative learning method in their teaching have continuous development. They are involved with the learners, working with them individually or in groups. Their engagement with the students should include distributing the tasks, offering help in the time of need, observing, supplying students with extra resources and giving hints on how to reach the targets.

	Teacher	**Student**
Collaborative learning	Member in the learning process.	The centre of the learning process (student-centred learning)
Cooperative learning	The centre (controller) of the learning process (teacher-centred learning)	A controlled member in the learning process by the teacher.

Table 1. Distinctions between collaborative and cooperative learning, based on the research projects of (Panitz, 1999), Theroux (2001) and Lane (2016).

2.3.3 Competitive Learning (CL):

Akinbobola (2006) stated that our current educational system is based upon competition among learners for grades, social recognition, scholarship and admission to top schools. Hilk (2013) defined competitive learning as a learning structure that emphasises negative interdependence between students. Individual students or small groups of students strive to outperform the others to achieve the same goal. Hence, in the CL, the learner typically works alone to compete with others or works as part of a group to compete with other groups.

Markussen et al. (2014) claimed that CL leads a specific section of students to expand their horizon and encourage them to achieve more. According to Kolawole (2008) competition fosters and sustains the sense of a win-lose situation, and it is most likely that the smarter students will have most of the rewards and the low achieving students will not be able to achieve the rewards.

Johnson and Johnson (1989), Markussen et al. (2014) stated that CL is based on the individual efforts of a student. However, it can be run between groups by dividing students into groups and encouraging competition between them. This was echoed by Johnson and Johnson, (2013), who claimed that CL could be interpersonal (between individuals) or inter-group (between groups).

Johnson and Johnson (1991) and Markussen et al. (2014) claimed that CL, as a team-based activity, promotes the collaboration aspects of learning. When students formulate their own terms and rules of the contest, giving them ownership of the activity. In other words, applying CL to the activities will lead students within the same group to apply the concept of collaboration, since, everyone is working towards the same goal (to outperform other groups and win the competition). Tingstrom et al. (2006) suggested using team-based competitions to motivate students and modify their behaviour and performance since these students are engaged with other students and stay involved in many activities.

Walters (2000) cited in (Mall-Amiri & Navid Adham, 2013) listed the following factors as the ones that must be considered when applying CL. Firstly, it should be used with students who enjoy competing against each other. Secondly, activities should be prepared to allow most students to have approximately the same chance of winning. Thirdly, it is better to teach students how to compete against themselves rather than competing against each other, which promotes collaborative learning in addition to competitive learning and finally, rewards must be provided for the winners to motivate other participants.

According to Good and Brophy (2008), the competitive activities in the learning process can be productive if most students can win. This can be achieved through team-based competition rather than individual competition. As it offers weaker students an opportunity to be successful, so by varying the teams, one can ensure that in every new competitive activity, new students win or lose. In general, competition might create interest and passion for tasks or topics that otherwise could be perceived as boring or lacking in interest to students. Thus, intergroup competitions allow students to learn effectively and raise their level of enjoyment, fun and engagement.

Good and Brophy (2008) argued that competition in the classroom would prepare students for competition in their lives beyond school, such as the workplace. One of the drawbacks with CL is that the students might take competition as a way of dealing with life outside the classroom, which might affect their social networking negatively. The necessity for someone to lose, so someone else can win is essential in any competitive activity, which might impact losers' attitudes negatively, especially if they lose over and over despite their efforts. Therefore, there is a need to vary the applied learning theories that are used inside the classrooms. In other words, not all assignments or tasks should be delivered using competitive learning so as to ensure that a student will not become selfish and push others away. At the same time, all of the assignments or tasks should not be delivered using a collaborative style of learning as students, free riders, could depend on their classmates to implement the tasks and the assignments (Markussen, et al., 2014). It is advisable to have a variety of learning pedagogies to support and fulfil the learning objectives (Good & Brophy, 2008).

Deutsch (1962), Johnson and Johnson (1989) and Lin (1997) claimed that CL could create a negative atmosphere among students as competitive situations are often where students work against each other to achieve a goal that only one or a few can attain. Therefore, in competition, there is a negative interdependence among goal achievers since students perceive that they can obtain their goals if, and only if, other students in the class fail to accomplish their goals.

As a summary of the literature discussed in this section, the following factors need to be considered when applying CL strategy:

The first factor: the competitors' academic level must be similar or close to each other, so the higher achieving students will compete together and subsequently, the low achieving students will compete among themselves. This is because if the competition between a strong and a weak student(s), then a teacher can anticipate the result in advance; the active student may not put in an extra effort, and the weak student will not be motivated to prepare well for the competition, because the result is estimated in advance.

For example, students in a class should be arranged in one of four ability groups, where group A has the highest ability and Group D the lowest. Group A should not be placed to compete with group D but should compete with group B, and accordingly, group D can compete with group C. As such, students' level in group D might be improved even if they lost the competition, due to the interaction with students in group C they potentially could gain some further knowledge. If this process is repeated many times, then students' level in group D might be improved, so they will be shifted to end up in C. Therefore, they will be qualified to compete with B. After the same repeated process, the students will be qualified to compete with the students in group A. This example demonstrates an advantage of competitive learning in helping make students' levels more homogeneous.

The second factor: CL should not be used frequently, to prevent losing its value from the students' perspective. Furthermore, having numerous competitions between students can create a negative atmosphere, since it is recognised that a friendly atmosphere is required for successful learning.

The third factor: students must be provided with adequate tools, proper content knowledge, appropriate technology equipment (software and the hardware) and reliable resources and references to be eligible and qualified to enhance CL.

2.3.4 Behaviourism

One of the oldest styles of teaching and learning is the traditional or direct method of teaching. Lin et al. (2012) and Novak (1998) claimed that in this style of education, students are guided in acquiring knowledge, and the teacher is the controller of the learning process. The teacher has the power, and main responsibilities inside the classroom, i.e. the teacher is the decision-maker with regard to the content knowledge, learning outcomes and providing the knowledge, which students should memorise. This process of teaching considers students as empty vessels to be filled with knowledge (Poonam, 2017).

The disadvantage of this learning theory is that it does not encourage students to be active learners (Novak, 1998). As students, during traditional teaching methodology, are requested to be listeners only and to remain silent, which leads them to be copiers and memorisers, which does not serve the purpose of learning (ibid). Wenger (2003, p. 80) stated, students are “born of learning, but they can also learn not to learn”.

“Traditional teaching methodology, which relies primarily on lectures, note-taking, chapter reviews and the regurgitation of facts on tests. The teaching style is strongly teacher-directed” (Lin, et al., 2012, p. 102). Traditional learning is rooted in the theory of behaviourism (elearning, 2017; NCSU, 2018). For more information about traditional teaching, please refer to section 2.9.1. According to the behaviourists, learning should be defined from the perspective of the modification in the behavioural tendency (Gagne, 1985). This was echoed by Plotkin (2003), who suggested that learning is related to behaviour that is formed as a result of monitoring the culture and environment.

Lampridis and Papastylianou (2014) suggested that the term behaviour is related to the term tendency or the willingness to move in a specific direction since the term behavioural tendency is an inclination to move along a particular path or act in a particular manner. The habits and natural movements in life can be seen as a behavioural tendency. These habitual actions generate a tendency, for example, the tendency to read a book or a journal before going to bed. With time, this desire becomes a need; later, this habit might be known as a behaviour because it becomes habitual, which means it is permanent.

Behaviourists believe that tendency and behaviour can be affected by reward and punishment, which plays a vital role in managing the teaching-learning process. For instance, distributing some gifts to the students who scored above 90 % in the quiz will reinforce positive behaviour while giving extra assignments for the students who failed to score above 90 % will encourage them to behave differently and to study (Baumgartner, et al., 2003). Therefore, teachers need to impact in such a way that the learner would be impressed, convinced and willing to start walking along the drawn and planned path, which leads to modification in students’ behaviour. However, if a student is not convinced of the idea or the need to change, then neither response nor any alteration in the behaviour will appear, i.e., learning did not take place (Morrison, et al., 2004).

According to Mayer (1982) and Gagne (1985), the modification in behaviour can take place at any time and any place, therefore learning is not restricted by a specific timeline (like childhood) or an exact location (like the classroom), i.e. behaviour can be modified at any time and any place through experience and practice (Weegar & Pacis, 2012). For the purpose of this thesis, behaviourism is defined as a learning theory in which a student's learning (behaviour) can be controlled and modified through punishments or rewards. Hence, learning takes place.

2.3.4.1 The Behavioural Learning Theory

Watson published the Behavioural Learning Theory in 1913 (Moore, 2011). Watson's publication was an investigation of the relationship between the organisms and their environment (Overskeid, 2008). Pavlov's findings on animals' responses to stimuli were used in Watson's publication; indeed, Watson considered these findings as the foundations for his research. Pavlov used to ring the bell to notify his dog of the feeding time. Eventually, the sound of the bell ringing made the dog start salivating without seeing the food. According to Pavlov, the dog learned a new behaviour, associating the bell with food; the sound of the bell was enough to make it salivate as it anticipated food. Pavlov believed that this theory could be applied to humans (Moore, 2011). Pavlov's idea was supported by Watson, who stated that people could also be conditioned to respond to such stimuli. Watson applied Pavlov's experiment to a young boy, who was conditioned to be afraid of a white rabbit paired with the sound of a metal bar (in what today would be considered an unethical experiment!). By repeating this process continuously, the boy started to fear everything white and furry, even the face of Santa Claus (Moore, 2011).

Watson's idea was reinforced by Birzer (2003), who considered the human as a machine that can be switched on and off. Zimmer (1999) claimed that the human is an animal that has been adapted to the environment and is formed by external conditions. This idea was supported by Crow and Tian (2006) as they argued that the process of learning occurs because our learning is associated with a condition, and that condition is the environment. The essential claim for the behaviourists is based on the premise that if the animal can learn so the human can do as well (Stables & Gough, 2006).

In an effort to reinforce Pavlov and Watson's findings, Skinner conducted several studies on animals' behaviour (Webb J. L., 2007). He had invented a box, known now as Skinner's box, in which rats were placed. In order to get food, they had to press a lever. As rats learned to do this, their behaviour supported the idea of behaviourism (Webb J. L., 2007).

The concept of behaviourism and educational technology started with the development by Skinner in 1958 of a teaching machine that mimics today's software. Skinner's teaching machine and its principles can be described as follows: when students use the device in order to answer the question, they have to press one of the buttons, which corresponds to one of the choices (multiple choices test). If the student's answer is correct then the machine will move to the second item, but if the student's answer is wrong then the device will stay on the same question, and the student should keep trying until he/she finds the correct answer. Skinner's experiment can be considered as a starting point for digital learning, which is applied nowadays using the available digital technology (Weegar & Pacis, 2012).

McDonald et al. (2005) claimed that behaviourism, as a theory, assumes that there is no relationship between the mind and learning. These behaviourists defined learning as the acquisition of new skills and behaviours. According to Skinner, the change in behaviour is the only standard or indicator for the learning outcome. Thus, behaviourists monitor the behaviour, not the mental activities. Behaviourism can affect people's behaviour and move them towards positive behaviour. According to this theory, the human has to focus on their surroundings to acquire new behaviour; as such learning takes place (Dawning, et al., 2005).

Watson argues that the human can be remanufactured and converted to any profession: doctor, lecturer, and a thief using one of the powerful external emotions, such as loving the reward or fearing the punishment. This theory formed the basis for an educational approach where teachers believe in the traditional approach of rewards and punishments as a motivator for students to acquire new knowledge or modify a current behaviour (Weegar & Pacis, 2012).

Eischens (1998) stated that the disadvantage of behaviourism is the ignorance or the absence of the human mind in learning. Behaviourists are interested in the behavioural responses only, disregarding what is occurring in the brain. Skinner explores these responses and argues that the mind has nothing to do with people's behaviours (Gregory, 1987). However, behaviourism fails to explain and justify complex human behaviours adequately, as the complex behaviours of the human cannot be explained by running some studies on animals. This was echoed by Naik (1998), who claimed that behaviourism could cure or deal with the symptoms only; therefore, the theory of behaviourism is not a reliable theory for active learning. However, this does not mean that behaviourism has no usefulness at all. In reality, nobody can ignore the effect of the environment on human behaviour, but with different perceptions. That is to say that the environment affects human behaviour to some extent, but in no way, can it be considered as the only factor in shaping human behaviour.

2.3.5 Constructivism

Knowledge construction has been strongly affected by the development of technological equipment, such as video discs, CD-ROMs, simulation software as well as telecommunication tools, including e-mail and social media websites (Eady & Lockyer, 2013). The growth in educational technology could create an active engagement of students in learning using various strategies, such as talking instead of only listening, writing instead of only reading, positive interaction, problem-solving instead of copying and memorising, and other active engagements (Tam, 2000). Therefore, there has been a move from the behaviourist theory where students are listeners and copiers to a new approach called the constructivist theory in learning where students are active members of the learning process (Weegar & Pacis, 2012; Ertmer & Timothy, 1993). The use of digital technology enables students and teachers to share ideas and exchange their experience; likewise, it offers students the opportunity to check the thoughts of their peers in different places or countries about the same topic, which expands their horizons, i.e. students are involved more in their learning. Therefore, students can construct their own knowledge (Burnage & Persaud, 2012).

Baker et al. (2007) claimed that the constructivist theory of learning has become widely used and is a prevalent theory since researchers, educators and authors are actively engaged in supporting constructivist principles for designing and implementing new learning environments to improve learning. Windschitl (1999) considered constructivism as a set of beliefs, thoughts, and practices rather than a set of strategies or merely steps to be followed in order. Therefore, the essential idea of constructivism is the belief that students can invent, understand, accommodate and organise new knowledge.

The constructivist theory of learning was developed by Piaget (1896-1980), Vygotsky (1896-1934) and Bruner (1915-2016). Jean Piaget is considered as the founder of cognitive constructivism, Bruner and Vygotsky are the founders of social constructivism (Amineh & Asl, 2015). The term constructivism has many different meanings and is used in various areas, such as education, science and engineering. In education, it is used to describe learning and teaching, as well as the curriculum and assessment (Ertmer & Timothy, 1993). The concern of this thesis is constructivism in education and particularly in learning and teaching.

Baker et al. (2007) investigated the concept of constructivism. Their study was built on a simple question concerning constructivism as a theory of learning – The construction of what? The answer to this question as they stated could be one of the following:

Constructing: i) our knowledge about the world as children construct their knowledge about their surroundings; ii) the shared and accepted scientific knowledge about the world as it exists in established science, which implies that scientific knowledge is socially constructed and iii) the world itself. Since the world is socially constructed as well, i.e. the knowledge about the world can be constructed due to the social interaction between learners and the environment (their own world) (Baker, et al., 2007).

Lefoe (1998) demonstrated that there are several views on what the term constructivism means; however, these views tend to share the same beliefs about constructivism, as it was considered an active process of constructing knowledge rather than acquiring knowledge. Duffy and Cunningham (1996) suggested that constructivism is a framework or the structure of creating, reasoning, understanding and interpreting the interaction with the environment so that learners can construct their knowledge. As such, it is a framework for understanding (interpreting) any learning environment, as well as a framework for designing instruction.

Christie (2005) claimed that constructivism is a learning theory in which learners actively create their knowledge. Christie explained it as a process, which occurs among a community of learners that emphasises hands-on and real-life experiences. According to Christie, constructivism is an educational approach that involves collaboration between teachers, parents, students, local and global communities so that new knowledge can be created and constructed. Taber (2006) claimed that constructivism in one sense is personal and individual, as a student construct new knowledge through the interaction with the physical world or the environment, but at the same time, it can be seen as collaborative in social settings and a cultural environment.

Giesen (2006) argued that people build their knowledge of the world by experiencing real life, which will be reflected in their own experiences and level of understanding. This suggests that constructivism is an opportunity to shift the emphasis from teaching to learning and help students to develop the processes, skills and attitudes towards the construction of useful knowledge. Wilson (1996) stated that a constructivist learning environment requires students to work together and support each other as they use many tools and resources to build their knowledge, achieve the learning outcomes and objectives, and to do problem-solving activities. This is an environment where students have more control in learning, and the teacher takes on the role of a monitor, coach and facilitator.

For the purpose of this thesis, the term constructivism is identified as the process of modifying the previously existing models to accommodate new models and knowledge. Student's knowledge and ideas about specific phenomena or a topic might be inaccurate, uncertain or not compatible with the new knowledge, which is more deeply rooted and well developed. Therefore, there should be a modification in the existed knowledge. As a result of the learner's interaction with the environment, new models and schemes will be developed and considered as current knowledge. In general, constructivism focuses on learners and how they develop and construct their knowledge, which means that an active learner actively constructs knowledge, not passively receives it from the outside, i.e. constructivism requires a learner to be active rather than passive.

2.3.5.1 Piaget and Constructivism

Jean Piaget (1896 – 1980) was a Swiss psychologist and epistemologist, who at the age of 21 was awarded a PhD in biology. His research focused on how organisms are adapted to their environment. Piaget was one of the most influential researchers in developmental psychology during the twentieth century (Chapman, 1988). However, his primary research target remained the same throughout his career: What is the nature of knowledge? How does it grow and develop?

According to Piaget, the nature of knowledge should be studied empirically to monitor how and where it is constructed and developed. Piaget stated that these questions could be answered either through the historical development of knowledge, as it is found in well-established sciences, in particular, physics and mathematics, or it may be studied in the growth and development of an individual (Baker, et al., 2007). Piaget's developmental theory of learning and constructivism is based on discovery and interaction with the environment. In accordance with his constructivist approach, children/learners should be allowed to construct knowledge that is meaningful for them. Piaget believed that a constructivist classroom must provide a variety of activities to challenge students, increase their readiness to learn, discover new ideas and enable them to construct their knowledge (McLeod, 2015).

Piaget's theory of cognitive constructivism claims that the active interaction between experience and environment is the primary factor in building the individual's new understanding and experience. For instance, Piaget believed that children's understanding was formed through the interaction between what is already known and what they discover in their environment. As a result, they will develop ideas compatible with the newly obtained knowledge (Ultan, 2012).

Amineh and Asl (2015) argued that the constructivist theory of learning leads learners to discover new knowledge and improve their own skills and experience by migrating previous and current experiences. This argument leads one to conclude that constructing knowledge in the constructivist theory depends on the dynamic interaction (continuous and uniform interaction) between former and current knowledge to produce new knowledge, which is different from the traditional technique of learning that focuses on memorising, repeating and stating the facts. The constructivist theory of learning context provides an opportunity for solid knowledge and concrete experience, which can be supported by discovering, inventing and sharing ideas, and checking these ideas' validity to construct new knowledge.

Clark (2000) and Dougiamas (1998) suggested that the teacher's role in the case of applying the constructivist theory should be more critical and significant even though it might seem that it demands less work and involvement. Teachers must provide learners with suitable resources to use in their research. Moreover, teachers need to be central in providing connections between the previous and the current knowledge, since they need to create a suitable professional environment, helping students explore, discover and establish a relationship between new and existing knowledge. Individual interpretation of the experience is essential, and the teaching approach emphasises the student-centred context.

2.3.5.2 The Development of Intelligence

Piaget suggested two processes, adaptation and organisation, to be the basis of the learning process. In accordance with the theory of constructivism, human beings have inherited the tendency to adapt and organise the gained knowledge (Ginsburg & Opper, 2016).

Mainemelis et al. (2002) defined the adaptation process as the equilibrium between the action of the organism and the environment and vice versa. “Piaget believed that organisms are self-regulating in their choices of ways to adapt to the environment and that intelligence develops through an organism’s adaptation to the environment” (Southwell, 1998, p. 2). Piaget argued that this stage includes creating schemes or psychological models as a consequence of the interaction with the environment (Littlefield Cook & Cook, 2005).

According to Piaget, the adaptation process consists of two parts: assimilation and accommodation (Ginsburg & Opper, 2016). VonGlasersfeld (1982) stated that assimilation and accommodation processes are complementary, as one cannot exist without the other. Simatwa (2010) stated that the assimilation is the process of intellectual growth so that the previously existing behaviours can be described as a set of organised behaviours or cognitive structures that are considered as previous knowledge. The interaction between organisms and the environment will form (assimilate) new knowledge or behaviours, which will be discussed internally (internal mind) to check its compatibility with the previously existing set of behaviours and schemes. If these schemes fail to understand the external examples or the newly gained knowledge, then new schemes will be developed. In other words, the new knowledge will be accommodated; new schemes will be formed, which will be considered later as current knowledge.

Piaget explained the assimilation process as the process where a person uses existing schemes to interpret newly gained knowledge or real external examples from practical life (Littlefield Cook & Cook, 2005). This implies that there will be integration between the external elements, those that can be seen externally (the environment) and the existing experience. (vonGlasersfeld, 1982; AIU, 2018). The second part of the adaptation process is the accommodation process, which has been defined as the process of acquiring new knowledge from the environment. The accommodation takes place when the previous knowledge or schemes do not work or are insufficient to understand the external examples, which cause cognitive disequilibrium; in this case, the existing schemes must be modified to be compatible with the new situations. Therefore, new schemes will be formed, which brings cognitive equilibrium again. As such, the newly formed schemes are sufficient to understand the new experience, until new assimilation (experience) rechallenges the scheme. (AIU, 2018; Littlefield Cook & Cook, 2005).

Bada (2015) claimed that the accommodation stage is an essential process as it explains how a human can stay up to date by adjusting the previous schemes. For instance, without accommodation, the child’s thoughts and views of the environment could never be developed.

Simatwa (2010) demonstrated that the assimilation process occurs without any change in the cognitive structure, unlike the accommodation process that ends up changing the cognitive architecture. For example, a child can have some experience of geometrical shapes (square, rectangular, pentagonal, hexagonal), later on; they can see a new geometrical shape, which implies that a new piece of knowledge will be assimilated. At this point, there has still not been any change in the cognitive structure, but when the child adds the new knowledge to the previously existing knowledge to interact with each other; a change in the cognitive structure takes place. Therefore, it can be said that after accommodating the new knowledge, a change in the cognitive structure takes place.

Regarding the organisation process, it is considered the second primary phase of intellectual growth. The significance of the organisation is to allow the integration between assimilation and accommodation, so newly formed knowledge will be organised as current knowledge (Bhattacharjee, 2015).

The organisation process is "the tendency to form increasingly coherent and integrated structures" (Ginsburg & Opper, 2016, p. 57). In other words, it is the process of seeking the perfect equilibrium (perfect understanding) which will never be fully achieved, as always there are new ideas to examine. Because of this tendency, people are never satisfied with the current equilibrium as they are looking for a deeper understanding of the known "We stretch and extend our cognitive structures by assimilating new and challenging information" (Ginsburg & Opper, 2016, p. 57). Piaget claimed, “the normal state of mind is one of disequilibrium—or rather a state of ‘moving equilibrium” (Beilin, 1994, cited in (Ginsburg & Opper, 2016, p. 58).

According to Piaget, adaptation and organisation are interdependent factors complementing each other in developing human intelligence. In other words, one cannot be found without the other. “It is by adapting to things that thought organises itself, and it is by organising itself that it structures things” (Piaget, 1952, p. 8).

Based on the discussion of the two processes, adaptation and organisation, it can be suggested that there are three interrelated stages of cognitive development. Firstly, the discovery of new knowledge due to the interaction with the environment. Secondly, checking the new knowledge in light of the old schemes. Finally, the modification or adjustment of the cognitive structure to create a new cognitive structure, which will be organised as current knowledge. These three steps form the adaptation and organisation stages. Table 2 and Table 3 show a summary of these processes.

Adaptation process	
Assimilation process	**Accommodation process**
The human uses the existing schemes to interpret the newly gained knowledge	The human adjusts the previous schemes to develop new schemes after discovering that the current schemes are inadequate

Table 2. The Adaptation Process.

Organisation process
The organisation process is consonant with the learner’s natural tendency to organise knowledge into well-connected structures (schemes). The significance of the organisation process is to allow the integration between assimilation and accommodation (Bhattacharjee, 2015)

Table 3. The Organisation process.

2.3.5.3 Stages of Cognitive Development

Piaget explored four sequential stages of the psychological development of the young learner and believed that teachers should be aware of these stages: i) sensory-motor stage (before the age of 2), ii) pre-operational stage (from age 2 to age 7), iii) concrete operational stage (from age 7 to age 11) and iv) formal operational stage (after 11 years of age). Piaget declared these stages to be common standards to be applied to all children. As such, they can experience their environment and reach full intellectual development (Pulaski, 1980).

The first stage is the sensory-motor. Piaget believed that this stage takes place during the first two years of the child's life. In this stage, the cognitive structures will be built using the child's sensory, feelings, and their initial schemes (the basic blocks of thinking that allow the child to think about the objects and events). The initial schemes and thoughts of a baby will be the basis for the cognitive structures, which will change continuously due to the continuous interaction with the surroundings. The experiences that will be formed in this stage will qualify the baby to move to the next step, the pre-operational stage (Woolfolk, et al., 2009).

The second stage is the pre-operational stage that starts from the age of two years old and lasts to seven years of age. During this stage, the child's language will be developed until it achieves the fluency in its mother tongue. Besides, the child's ability to use symbols (words, gestures, and images) to represent actions or objects is a significant achievement of this stage (Woolfolk, et al., 2009). Furthermore, the child's ability to imitate an object or action will be developed as well. Since the child at this stage tries to copy the previous behaviour accurately, imitation is primarily an accommodation (Wadsworth, 2004).

Bada (2015) argued that during this stage, the child's behaviours and thinking might be described as selfish or self-centred. Egocentrism can even be noticed in the child's speech. Piaget has called this the collective monologue. However, egocentric thinking is essential for the initial use of any newly acquired cognitive development because the child needs to be egocentric with his thoughts before he can bring them under control.

Woolfolk et al. (2009) claimed that logical thinking at this stage is limited to one direction only, and the child lacks the ability of reversible thinking. For example, the relationships such as A<B<C (A is less than B is less than C) are difficult to handle at this stage. Moreover, the child is not able to understand the principle of conservation (that some characteristics remain the same despite changes in appearance). Becker et al. (1975) claimed that at this stage, the mental operations could be described as operations of great imagination. It is the moment of cognitive development when a child relies

strongly on the imagination. However, they are still far from operational and logical thinking, which will start to be developed in the next cognitive stage.

The third stage is the concrete operations stage that starts from the age of seven and continues to the age of eleven years. Piaget described this stage as hands-on thinking (Woolfolk, et al., 2009). In this stage, the child starts to deal with reasons and symbols and might understand the concept of conservation. Besides, children master the operation of classification that helps the child in categorising objects. Likewise, in this stage, the child can develop a logical system of thinking that allows the child to construct logical relationships and deal with symbols. For example, the child will be able to deal with a relationship as of A<B<C to be interpreted in the child's thinking so that B can be greater than A but still less than C.

Piaget claimed that knowledge results from actions. For instance, to know an object means to experience and act upon it, and to assimilate reality into structures of transformation (Piaget, 1970 cited in Pulaski, (1980). According to Piaget, children in this stage still cannot manage complete mental operations. Piaget believed that children have to be active learners and not passive ones in order to actualise their experience (Pulaski, 1980).

Wadsworth (2004) stated that at the end of this stage, the child should be able to deal with logical operations, for example, reversibility and classification. These logical operations can only be applied to concrete objects and events in the present and not to hypothetical, purely verbal or abstract problems. At the end of this stage, the child theoretically should be ready to access the fourth stage.

The fourth stage (last stage) is called the formal operations stage. It starts at the age of eleven and continues to adulthood. During this stage, abstract thinking begins as the learner begins thinking about probabilities, associations and analogies. The child can develop formal patterns of logical reasoning, rationale and intellectual strategies that allow him or her to identify the factors affecting the problem and then deduce and systematically evaluate different solutions (Woolfolk, et al., 2009). This ability helps in terms of the formal propositions of symbolic logic and mathematics (Becker, et al., 1975).

2.3.5.4 Social Constructivism

The theory of social constructivism was established by Vygotsky (1896-1934), who argued that knowledge is developed through social interaction (Amineh & Asl, 2015). For instance, a learner's skills in a specific language can be improved via communication with people. The social construction of knowledge grants students the opportunity to be exposed to other ideas, cultures and forums on global issues. Students can work on collaborative projects, which may come in the form of a networked writing project or the building of separate phases of an engineering project that enables them to receive and give instant responses or feedback (The Fountain Magazine, 2004).

Vygotsky developed a new concept called the Zone of Proximal Development (ZPD) or what a learner can do with help, as shown in Figure 2 (The Open University, 2018). The ZPD indicates the difference between what a student can achieve with and without help or the difference between the actual development level without receiving any assistance, and the level of potential development in the case of receiving support from peers (DeMara, et al., 2016; Jessel, 2013). Vygotsky claimed that the concept of ZPD helps to fill the gap between the known ideas and what can be known. The latter believed that effective learning and the most rooted academic growth take place in the ZPD (VDocuments, 2017).

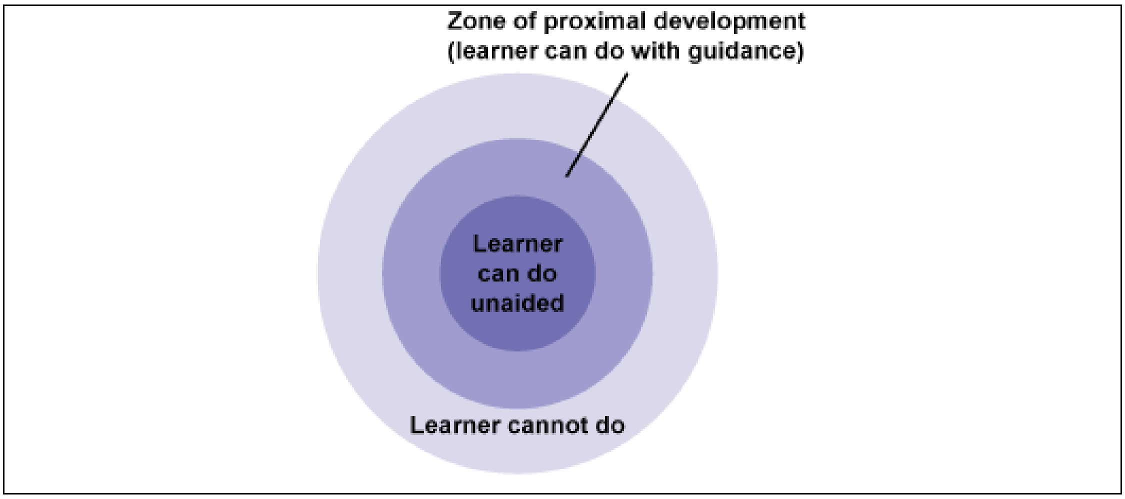


Figure 2. The theory of a Zone of Proximal Development (ZPD) (The Open University, 2018). © TheOpenUniversity, CC by-NC-SA 4.0

Vygotsky's theory states that students have to be active learners, collaborating and interacting with each other and with their teacher, so they can build their knowledge and produce new ideas, rather than the traditional approach of teaching where a teacher delivers and dictates the ideas to learners for future examination (Hausfather, 1996). Social constructivism requires a well-prepared classroom with several groups, each of which consists of 4 or 5 students. Shared attention, activities and problem solving are necessary to create a process of cognitive and effective interaction (Driscoll, 1994).

Bruner (1986) believed that learning is directly associated with social development, i.e., the assistance of other individuals. To achieve effective social development, Hausfather (1996) suggested that the instructions and guidelines of social constructivism should be prepared by the teacher and designed in a specific way that guarantees the effective interaction between learners and gives equal opportunities for every member in the group to participate, taking into consideration if one partner dominates, then the interaction is less successful. Slavin (1983; 1990) claimed that successful interaction and collaboration lead students to a higher academic level than their current level.

Vygotsky believed differently from Piaget that children would not achieve significant progress if they were left alone to discover and explore the surroundings on their own (Vygotsky, 1978). Piaget believed that the development is an initiative process and should be completed by children based on their own efforts.

Vygotsky thought that students' intelligence could not be determined by what they knew, but instead on their ability to sort out problems and deal with new ideas independently. Vygotsky raised a question: If two students at the same age (8 years old) and academic level (for example, could achieve the same score in the same exam), do they have the same level of mental development? The latter concluded that they do not have the same level of development or the same ability to solve new problems, "as the first child can deal with problems up to a twelve-year-old's level, the second up to a nine-year-old's" (Vygotsky, 1978, p. 86):

> This difference between twelve and eight, or between nine and eight, is what we call the zone of proximal development. It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers. (Vygotsky, 1978, p. 86)

Vygotsky’s argument implies that even though both students have the same score, it might be that one of them relied on memorisation to answer the questions of the exam, and the other one used his critical thinking and the analysis ability to solve the problems. Therefore, the students’ development levels are not necessarily the same even if they have the same score; since memorising and critical thinking are entirely different fields.

2.3.5.5 Bruner’s Theory of Constructivism

Following the constructivist theory, as learners grow up, they gain new ways allowing them to develop their level of understanding and represent their environment (Ultan, 2012). According to Bruner (1957), the learning outcomes are not only the concepts and problem solving, but should also include the capability to invent and develop new forms of their existing knowledge. Bruner claimed that the student’s level of understanding and their cognitive academic growth would be developed as an outcome of the interaction between human’s basic abilities and other factors, such as environment and technological tools that serve and reinforce constructivism. Bruner, in his research about the cognitive development of children (1966), stated that the goal of education is to create confident learners, and he proposed three modes of representation. Firstly, enactive representation (action-based). Secondly, iconic representation (image-based). Finally, symbolic representation (language-based).

Bruner's Modes of Representation

Bruner argued that the learner’s modes of representation should be defined using the way in which knowledge is stored and manipulated in the memory, unlike Piaget, who identified phases of development using age-related stages (GTCE, 2006).

Enactive mode (0 - 1 year): This mode of representation involves the information that is based on the actions that will be stored in the memory; for example, babies can remember the voice of their mother and respond to it (McLeod, 2008).

Iconic mode (1 - 6 years): In this mode of representation, the knowledge will be stored visually in the form of pictures, which is why for many students it is helpful to have some diagrams or visual aids for a new subject (Tomic & Kingma, 1996; McLeod, 2008).

Symbolic mode (7 years onwards): This is the last mode of representation where the information will be stored in the form of symbols or codes, for instance, language, dealing with digital technology software and the skill of solving mathematical problems (Tomic & Kingma, 1996). This mode of representation consists of the previous modes (the Enactive and Iconic) as it combines the action and image. Bruner believed that human beings are active learners, can create the connections between images, actions and symbols so that they can build their knowledge. In other words, learners can reach the level of symbolic thinking.

For Bruner, the only way to develop symbolic thinking is by discovering and looking for knowledge instead of waiting for the teacher to introduce it. Bruner called this the concept of discovery learning, which is inquiry-based learning that takes place through problem-solving activities where learners use their own experience and current knowledge to discover new concepts and relationships. Hence, learners can build their knowledge (Clabaugh, 2010).

Bruner's constructivist theory proposed the idea of constructivism by the progression or the transition from the enactive to iconic and finally to symbolic modes of representation. According to Bruner, these modes of representation apply to all learners (GTCE, 2006).

Bruner asserted that the learner in general, and the very young learner and adults in particular, could learn any material since the content was organised and clear instructions were provided (Bruner, 1960; Cherry, 2004). Bruner applied his theory to the creation of the Spiral curriculum, which has three levels. At level one, the material must be introduced with straightforward ideas to learners. At level two, the content must be reviewed with additional ideas about the taught topic; and eventually, at level three, the material must be introduced to learners at a range of levels of complexities (Cherry, 2004; McLeod, 2008). These ideas were evident in Bruner's published article, The Process of Education, in which he emphasised that students are active learners, capable of building their knowledge and learning any new material (Bruner, 1960). Bruner's ideas form a very sharp contrast to the ideas that were suggested by Piaget since Piaget claimed that students must be taught the new content only when the teacher thinks that the student has reached the required level of maturity based on the age-related stages (Pulaski, 1980; McLeod, 2008).

Bruner and Vygotsky agreed that adult students could participate in the child's learning and in developing their skills. This process of aiding the learner is called scaffolding and is regarded as a part of social constructivism. Wood, Bruner and Ross use this term to describe how tutors interacted with children to help them to solve a block reconstruction problem (Wood, et al., 1976). Faryadi (2007) claimed that the concept of scaffolding identifies the importance of providing students with sufficient support in the initial stages of learning a new subject. Wood et al. (1976, p. 90) asserted that the scaffolding process "enables a child or novice to solve a task or achieve a goal that would be beyond his unassisted efforts".

> The role of social context in individual development has been attributed to those such as Vygotsky where a more experienced other play a 'scaffolding' role in supporting someone less experienced. (Jessel, 2014, p. 913)

Scaffolding ensures that students are not left on their own to understand the new content. For instance, to have a student capable of solving the mathematical problems, this student must observe his/her teacher or a small group of students working through the task step by step. Hence, the student should be able to attempt it on his own, i.e., I do you do. The supports or the scaffold will be removed when a student is ready, like the scaffold, which is used in the construction of a building, will be removed when the building is completed and can stand on its own (McLeod, 2018). Table 4, Table 5 and Table 6 show a summary of the main ideas of Piaget, Bruner and Vygotsky.

Note: Table 4, Table 5 and Table 6 are based on Piaget, Vygotsky and Bruner's perspectives of the constructivist theory.

Common areas between Piaget and Bruner	**Conflict areas between Piaget and Bruner**
Children, by nature, are curious, adapted to learn, and active learners can build their knowledge.	Development is a continuous process (Bruner) not a series of age-related stages (Piaget).
Child's cognitive level will be developed until they become capable of dealing with the symbols.	According to Piaget, students must be taught the new material when the teacher thinks that the student has reached the required level of maturity (age-related), unlike Bruner's suggestion that any student at any age is capable of learning any topic. "Any subject can be taught effectively in some intellectually honest form to any child at any stage of development". (Bruner, 1960, p. 33).

Table 4. Common and conflict areas between Piaget and Bruner.

Piaget	Vygotsky
The idea of constructivism built on assimilation, accommodation and organisation.	The idea of constructivism relies on scaffolding and social interactions.
The student is an active learner who can build his/her knowledge alone. Not necessary to have scaffolding and social interactions.	The student is an active learner but needs scaffolding and social interactions.
The teacher must provide a suitable environment and encourage students to move forward.	The teacher needs to manage social activities and provide scaffolding for students when it is needed.

Table 5. Comparisons between Piaget and Vygotsky.

Common areas between Vygotsky and Bruner	Conflict areas between Vygotsky and Bruner
Children learn effectively through social activities. Learners cannot gain knowledge independently (100%). Vygotsky and Bruner discovered that effective learning takes place through social interaction. “Both Bruner and Vygotsky emphasise a child's environment, especially the social environment, more than Piaget did” (McLeod, 2008).	No significant difference between Vygotsky and Bruner, but Bruner believed that students learn better when they learn independently and receive a little support (scaffold) when they need it. On the other hand, Vygotsky feels that learners need continuing support.
Children’s cognitive level will be developed by supporting them when they need.	

Table 6. Common and Conflict areas between Vygotsky and Bruner.

2.3.5.6 The Effect of Constructivism on Learning

Adopting constructivism as one of the pedagogical dimensions can help in designing a curriculum effectively so that it meets students’ needs and expectations (Farah, et al., 2016). Applying the constructivist theory encourages teachers to look for various activities and tools to deliver knowledge and motivate students to analyse, interpret and seek new knowledge. This was echoed by Pandey and Ameta (2017), who claimed that constructivist teaching could create a positive change in teachers' and students' attitudes towards teaching and learning, respectively.

Dev (2016) claimed that students who were taught using constructivist approaches were observed to possess a deeper understanding of the explained topic and, as a consequence, those students became more critical and active than those in traditional classes. Using the constructivist approach, learning relies substantially on open-ended cases (problems require an extensive research process to be solved and which might accept many answers or many views, such as the problems related to qualitative areas); therefore teachers need to encourage students to search for solutions for the suspended cases (Williams, et al., 2010). This might lead to developing new strategies for the assessments since students will no longer be assessed according to what they memorise, but according to their ability to solve problems using their critical thinking, existing knowledge and initiative.

Maximus (2003, cited in (Qarareh, 2016)) claimed that constructivist learning offers learners an excellent opportunity to search about the possible views and solutions for one problem, which contributes to their critical thinking and promotes their thoughts and attitudes. This implies that constructivism encourages teachers to provide students with the best possible learning resources, including the curriculum and pedagogies.

Qarareh (2016) and Dev (2016) claimed that in an ideal situation, constructivism promotes students' critical thinking. Wheatley (1991) stated that constructivist learning presents content in the shape of educational assignments. Thus, it can be concluded that constructivism moves students from the stage of memorisation of facts as passive recipients to another scene, where they are active learners can analyse, explain and predict. In turn, this implies that the constructivist approach moves students from the stage of being knowledge consumers to another level where they become knowledge producers.

2.3.6 Deeper and Surface Learning

In 1972, Craik and Lockhart (1972) suggested the deeper learning terminology. They argued that deeper learning includes higher-level cognitive processing, as opposed to surface learning, where students use lower-level cognitive skills, such as memorisation or rote learning. Beattie et al. (1997) advanced this concept and described both approaches, deeper and surface learning in more detail:

> The deep approach, which implies that a student learns for understanding, is characterised by students who (1) seek to understand the issues and interact critically with the contents of particular teaching materials, (2) relate ideas to previous knowledge and experience and (3) examine the logic of the arguments and relate the evidence presented to the conclusions. The surface approach, which implies that a student learns simply to memorise facts, is characterised by students who (1) try simply to memorise parts of the content of teaching materials and accept the ideas and information given without question, (2) concentrate on memorising facts without distinguishing any underlying principles or patterns and (3) are influenced by assessment requirements. (Beattie, et al., 1997, p. 3)

In 1976, Marton and Saljo originated the concept of deep processing to represent student's engagement with educational tasks, cited in (Laird, et al., 2008). In their view, the deep learning referred to moving beyond the surface understanding of the underlying knowledge. Throughout the 1970s and 1980s, other researchers investigated these terminologies, deeper and surface learning, and suggested strategies and features for each learning approach, see for example Biggs (1979), Entwistle and Ramsden (1982), Marton (1975), Pask and Scott (1972). In line with these researchers, Laird et al. (2008, p. 470) claimed that students who adopt deeper learning approach "read widely, combine a variety of resources, discuss ideas with others, reflect on how individual pieces of information relate to larger constructs or patterns, and apply knowledge in real-world situations".

The scope of this section is to differentiate between these two approaches to learning. An in-depth approach, which is described as meaningful learning, i.e., students are sense makers of what they learn, while the surface approach is represented by the habitual repetition of the content to be learned (Biggs, 1987; Entwistle & Ramsden, 1982; Marton, 1983).

Rosie (2000, p. 45) stated that “deep learning is not a function or attribute of the learner but is a strategy that people can adopt”. The student adopting an in-depth approach to learning concentrates on grasping the taught material, links elements to each other, new concepts to prior knowledge, and concepts to real-life situations. On the other hand, the student who adopts a surface approach favours to memorise discrete experiences and deal with a specific task in isolation from other tasks, concepts and real-life situations (Chin, 1999).

In 2013, deeper learning was adopted by the Hewlett Foundation (2013), who claimed that America’s schools could not prepare students sufficiently to overcome the future's challenges. The Hewlett Foundation addressed six values or capabilities associated with deeper learning:

i. Master the academic content
ii. Think critically and answer complex problems
iii. Consider collaborative learning
iv. Effective communication
v. Know how to learn
vi. Develop academic mindsets

The Hewlett Foundation claimed that these capabilities apply to higher education and online environments, as online learning is becoming more popular.

Conley (2012) described deeper learning as “readiness across multiple dimensions, with an alignment of student skills, interests, aspirations and their post-secondary objectives”. According to Conley (2012), this readiness is outlined in three interrelated categories; *Think*: key related to cognitive strategies that involve problem-solving, research, and interpreting data. *Know*: key related to content knowledge; it includes structuring knowledge in core subjects and the ability to acquire knowledge. *Act*: key related to learning skills and students’ ownership of their learning.

The National Research Council (NRC (2012)) outlines three broad domains of competence. First, the cognitive domain, which involves thinking, reasoning and critical thinking. Second, the intrapersonal domain, which includes self-management, including the ability to regulate behaviour. Third, the interpersonal domain, which represents the ability to express ideas to others, and also interpreting ideas from others. The NRC domains strongly echo the Think, Know, Act competencies that were suggested by David Conley and adds some interpersonal skills as well (VanderArk & Schneider, 2012).

“The cognitive engagement of students with learning material to the extent that they uncover deeper meaning and associations, appraise material critically and generalise their learning from one context to another” (Day, et al., 2010, p. 3). This idea is supported by VanderArk and Schneider (2012), who defined deeper learning as the process through which a student displays what was learned in a specific situation and applies it to new tasks and conditions; in other words, learning for transfer.

The NRC (2012) proposes that pedagogy is a crucial component of deeper learning, i.e., learning for transfer:

> Emerging evidence indicates that cognitive, intrapersonal, and interpersonal competencies can be taught and learned in ways that support transfer. […] Teaching that emphasises […] not only content knowledge, but also how, when, and why to apply this knowledge is essential to transfer. (National Research Council, 2012, pp. 8, 23)

The NRC (2012) advises several policies to expedite deeper learning, such as using various shapes and forms to represent concepts and tasks; foster discussion, questioning and illustration; involve learners in challenging assignments; teach with models, examples and instances; motivate students, as well as the use of formative assessments. Thus, schools are encouraged to re-plan education and develop effective rubrics and assessments that can measure deeper learning skills. For instance, schools need to leverage the use of digital technology in learning, lengthen learning time and develop teachers and students’ technical skills. In turn, this means that the traditional boundaries of learning continue to expand and collapse as mobile technologies shift learning from a place-based to service-based learning. The Alliance for Excellent Education (AEE (2012)) described this as a culture shift from a teacher-centred to student-centred pedagogy.

Previous studies in science education propose that a student’s learning approach impacts the learning outcome. For instance, BouJaoude (1992), Cavallo and Schafer (1994) argued that an in-depth approach to learning is accompanied with a more extensive coherent knowledge, fewer misunderstandings, and interrelated and better understanding of the concepts. In a 2005 study, Smith and her colleagues investigated the association between teaching methods and students' learning outcomes; their findings showed that "a majority of the teachers (64 per cent)… aimed instruction and assignments toward surface learning outcomes" (Smith, et al., 2005, p. 205). Moreover, their findings showed that most of the students (78 per cent) adopted a surface approach to learning. Smith and her colleagues argued that these findings were due to the instruction implemented by the teachers, which appeared in students memorising and recalling fundamental knowledge without perception. These findings support the claim of Hill and Woodland (2002), who suggested that deep learning is not a one-way process, but a two-way dialogue between effective teaching and attentive learning.

To reach a better understanding of the depth of teaching and learning outcomes, Biggs (1979), Biggs and Collins (1982) developed a research-based framework. In this framework, Biggs and Collins represent five levels of complexity of the learning outcomes:

i. The pre-structural level represents unrelated informational factors.
ii. Uni structural level related to students' abilities to create relationships between various fundamental factors without understanding the meaning.
iii. Multi structural level related to students' abilities to create connections among complex factors and information networks, but the meaning of the connections still is missing.
iv. Relational, at this level, students comprehend the relationships between various informational factors.
v. Extended abstract, students move from relational understanding to a higher level of thinking, transferring and generalising.

Biggs and Collins claim that by using their framework, teachers can decide whether learning outcomes and teaching practices foster more in-depth learning approaches.

Rosie (2000) investigated the learning activities of postgraduate students using web-based resources and investigated whether these resources lead to deeper learning. Rosie (2000) adopted a dialectic approach to developing web-based instructional resources. In the dialectic approach, students worked on a task, argument and alternative ideas. Rosie proposed that applying dialectic approach reduces the differences between actual educational outcomes and professional expectations, which fosters deeper learning.

To ensure fostering deeper learning, some researchers recommended the use of more synchronous resources for students. For instance, Offir et al. (2008) claim that synchronous resources support active learning and students' understanding and engagement, which contributes to deeper learning approaches. "When the students are more active in the learning process, the material becomes more relevant and more significant for them, they remember it better, understand it, and as a result, their achievements improve" (Offir, et al., 2008, p. 1181).

Chin (1999, p. 240) suggested five new categories to differentiate between deeper and surface learning; "generative thinking, nature of explanations, questioning, metacognitive activity, and approach to tasks".

Generative Thinking

This category outlines students' capability to create an idea without receiving a ready-made clarification or solution to a specific problem, mainly when the problem is unusual and needs moving beyond recalling fundamental facts.

Nature of Explanations

This category refers to students' ability to produce an explanation to a specific phenomenon or a problem that can link the macro and micro levels. In other words, the ability to explain the effects of non-observable, invisible, entities in a specific phenomenon and create relationships between abstract factors, such as the photon's frequency and electric current in the photoelectric effect.

Questioning

Questions associated with surface learning are concerned with basic knowledge, requiring only a recall of facts. Such questions are often closed questions that have unambiguous answers. They typically are linked to the knowledge contained in the textbook or any simple observation about a phenomenon. On the other hand, questions associated with deep learning reflect students' ability to link several concepts to find the answer to a specific problem. They concentrate on "explanations and causes, predictions, or on resolving discrepancies in knowledge" (Chin, 1999, p. 242). This kind of questions requires higher-order thinking skills as students need to relate the new and existing experience, combine complex and divergent knowledge from various sources, and develop internal relationships between diverse aspects of the latest knowledge in their attempts to understand.

Metacognitive Activity

This category describes students' use of awareness and evaluative approaches that indicate their strategy of thinking. It has been noticed by Chin (1999) that the students, who adopt a deep approach to learning demonstrate higher cognitive self-evaluation and control of their learning, unlike the students who use the surface learning. Moreover, Chin (1999) stated that students with deep learning could evaluate their ideas, detect their mistakes and self-corrected them, consider a range of potential solutions, endeavour to grasp alternative approaches, and acknowledge limitations in their ideas and criticise them.

Approach to Tasks

A student, who adopts a deep approach to learning, shows more persistence in following up a task before moving to another one. In the case of using the surface approach, the student gives up an idea as soon as it did not work. Moreover, when utilising an in-depth approach, the student attempts to create ideas, whereas one applying a surface approach relies on ideas generated by others, such as the teacher or other students.

Table 7 is based on the research conducted by Chin (1999); it shows a summary of the differences between deeper and surface learning.

Deeper learning	**Surface learning**
Students generate their ideas spontaneously	Students repeat the ideas they memorise
Students' responses are more precise	Students' responses are general
Students can describe non-observable entities (microscopic) and cause-effect relationships between microscopic and macroscopic entities.	Students' abilities are limited. They can describe observable entities (macroscopic) roughly.
Students display higher cognitive self-evaluation and control of their learning	Students cannot give accurate cognitive self-evaluation and have poor capability of controlling their learning
Questions associated with a more in-depth approach to learning focus on demonstrations, reasoning, predictions, or concluding discrepancies in knowledge lead to an advancement in conceptual understanding.	Questions associated with the surface approach to learning referred to basic knowledge.

Table 7. Differences between deeper and surface learning

2.3.6.1 Deeper Learning and Instructional Design

> Instructional designers start with the analysis of the learners, then determine learning goals, arrange learning activities and finally develop and implement assessment procedures. All these activities are driven by the learning theories and instructional methods and strategies. (Czerkawski, 2013, p. 10).

McGee and Wickersham (2005, p. 2205) outline the relationship between deeper learning and instructional design by stating that "the deeper learning principles indicate a higher degree of learner control, decision-making, and organisation….. thus, requiring well conceptualised instructional design". This view is backed by Du et al. (2011), who confirmed the significance of instructional design in promoting more in-depth learning.

To design deeper learning environments, instructional designers need to consider the following factors (Offir, et al., 2008; Chapman, et al., 2005; Smith & Colby, 2007; McGee & Wickershame, 2005):

i. Supplying students with authentic learning expertise. Deeper learning "requires that the learning design takes into consideration the learner's context of practice, ways of learning, as well as experience in the world" (McGee & Wickershame, 2005, p. 2206). Therefore, it is essential to link content knowledge with real-life situations.

ii. Challenge students by learning activities that require higher-order cognitive skills, such as problem-solving, creating relationships, evaluation and analysis. Smith and Colby (2007) argue:

> Students, who move beyond surface learning consider any given task as a series of internal rhetorical questions: What do I know about this subject? How does this information relate to what I already know? What is the broader implication or significance of what I've learned? (Smith & Colby, 2007, p. 207).

iii. Developing a meaningful dialogue between students. A dialogue takes place in environments through which members are open to other students' share their point of views, which move students to common ground (Chapman, et al., 2005). Offir et al. (2008) suggest that the dialogues have a positive impact on students' learning as they encourage students to adopt an in-depth approach to learning. This idea was endorsed by Smith and Colby (2007, p. 207) who claimed that "one way to accomplish (deeper learning) is to engage all members of the community in intentional, substantive, and inclusive dialogue about student learning".

iv. Monitoring teaching and learning activities*:* Smith and Colby (2007) noticed in their study that the design of specific materials and tasks can limit students to surface learning. If a learning environment involves tasks that support surface learning, deeper learning consequences cannot be anticipated. Therefore, courses and activities need to be periodically revised to incorporate tasks resulting in more profound learning experiences.

v. Generating periodic feedback using formative assessments: Feedback about student's learning from the teacher or other students is estimated to be one of the most powerful strategies that foster student's accomplishment (Rushton, 2005).

To foster deeper learning, instructional designers need to focus digital educational resources on new forms and methods of education; offer interactive content; consider the concept of differentiation and individualisation; take into account students' cultural experience; provide students with learning activities that guide them to construct their own knowledge and solve real-world problems; promote both types of learning, independent and social learning, including social constructivism (Makarova, 2018).

2.4 DIGITAL TECHNOLOGY, DEEPER LEARNING AND PEDAGOGY

The use of digital technologies in education formulates new challenges to teachers and students. At the same time, it ensures the advancement of the quality of learning, since it becomes feasible to substantially raise the number of resources that can be used for education. Consequentially, the educational space is growing rapidly due to the evolution of the digital environment, such as electronic textbooks, virtual learning platforms, the online courses and distance learning (Makarova, 2018).

Definitions of deeper learning suggest that the shifts in education, including teaching methods (pedagogies), content, digital technology and assessment, is required to facilitate students' engagement with learning, which "stimulate collaboration, communication, investigation and critical thinking" (VanderArk & Schneider, 2012).

According to Dede (2014) and VanderArk and Schneider (2012), it is not possible to foster deeper learning without significant access to essential sources of knowledge supported by digital technology.

Alliance for Excellent Education (2012) defined digital learning as an instructional training that efficiently employs digital technologies to develop a student's learning expertise. Digital learning involves a broad set of tools and manners, including, online assessment; enhancing the quality of educational resources and learning time; online courses; the use of digital technology inside and outside the classroom; adaptive software to be used by students with special needs; virtual learning platforms; and access challenging content and tasks. Hence, students can learn at any convenient time and place, i.e., learning is shifted to be a lifelong activity (Alliance for Excellent Education, 2012).

Digital technology provides teachers and students with new learning environments, which leverage teachers' talent and enable students to reach deeper (VanderArk & Schneider, 2012). Digital learning facilitates new approaches and formats, such as online learning and competency-based learning, which contributes to more in-depth learning by encouraging students to dig deeper, looking for new knowledge. According to Devaux et al. (2017), accommodating every student with the possibilities for more in-depth learning is not possible without the use of digital technology that can maximise learning outcomes and expand student's horizon.

More than 1,000 K-12 teachers and school administrators participated in a questionnaire in the United States. The findings of this questionnaire showed that digital learning fosters deeper learning by offering: personalised learning; the required tools; and extensive access and extended resources (VanderArk & Schneider, 2012). Based on these findings, VanderArk and Schneider (2012) stated that digital technology plays a considerable role in developing students' 21st-century skills. Precisely, skills related to "accountability, collaboration, communication, creativity, critical thinking, ethics, global awareness, innovation, leadership, problem-solving, productivity and self-direction" (VanderArk & Schneider, 2012, p. 11). Bailey et al. (2015) and VanderArk (2014) suggested the relationship between digital technology and deeper learning, as it creates various learning platforms, provides students with customised playlists of learning activities that match their learning level and target their interests. Thus, students are encouraged to improve their performance and reach deeper learning.

The use of digital technologies in learning offers sufficient techniques for propagation and administration of digital knowledge. The growth of essential competencies based on digital literacy shifted the teacher's role from the leading knowledge provider (traditional role) to be a mediator between students and digital technologies. Developing students' critical skills in educational context requires augmenting traditional learning with tools of digital technologies (Akbar, 2016).

Digital pedagogy is the use of electronic equipment, including software and hardware, to enhance teaching and learning and provide flexible opportunities for learning (Dangwal & Srivastava, 2016). The evolution in digital technology offers diverse opportunities for students to learn and encourage teachers to develop their methods of teaching and thus teaching and learning processes have been shifted towards the digitalisation.

The use of digital technology could be most effective when both teacher and digital technology challenge students' understanding and thinking (Dangwal & Srivastava, 2016). The efficiency of digital technology in educational settings is influenced by teachers' knowledge of the taught subject (the content of the curriculum), their experience of using digital technology and their awareness of the ways students prefer to learn (pedagogy) (Ghavifekr & Rosdy, 2015). In line with Ghavifekr and Rosdy (2015), Cuban (2001) and Hooper and Rieber (1995) claimed that teachers' knowledge of digital technology is not a separate mass of expertise from the context of teaching and learning, including pedagogy and the content of the curriculum.

According to Hawkridge (1990) and Levin and Wadmany (2008), the use of digital technology in classrooms can potentially improve students' learning. It changes the traditional role of a teacher in the school; digital technology also encourages interaction and dialogue between students and teachers (Stover & Veres, 2013; Levin & Wadmany, 2008). McLaughlin and Oliver (1999) stated that the pedagogical roles for teachers in a digital technology-supported classroom include setting everyday tasks, exchanging roles, encouraging student self-management, promoting metacognition, adopting various perspectives and scaffolding.

Dangwal and Srivastava (2016) argued that the digital pedagogy emerged from the interaction of technical skills, awareness of pedagogies and the content of the curriculum. The effective application of digital pedagogy promotes learning as it offers flexible learning opportunities for students regardless of their academic level. In turn, this implies that the individual differences are considered in digital pedagogy. It also engages students in a constructive perspective of learning through which students construct their knowledge. Smart classrooms (2008, p. 3) stated, “Digital Pedagogy enhances opportunities for authentic, contextualised assessment that supports learning in a digital context”. Consequentially, the features offered by digital pedagogy ensures a high level of connectivity to global contexts, collaborative environments, flexible delivery of curriculum, develop the assessment techniques and maximises learning outcomes (Smart Classrooms, 2008).

According to Dangwal and Srivastava (2016), digital pedagogy comprises three interrelated areas of knowledge. Firstly, content (C) is the subject matter. Secondly, technology (T), including digital technologies equipment, such as computers, the Internet, tablets, simulations, iBooks and virtual learning platforms. Finally, pedagogy (P) describes the methods of teaching and learning. It also includes knowledge about assessment (Khirwadkar, 2007).

The effective integration of digital technology and education requires the understanding of the relationships between the elements mentioned above. Koehler and Mishra (2005) affirmed:

> good teaching is not simply adding technology to the existing teaching and content domain; rather, the introduction of technology causes the representation of new concepts and requires developing sensitivity to the dynamic, transactional relationship between all three components suggested by the TPCK framework. (Koehler & Mishra, 2005, p. 134)

In terms of understanding the relationships between the elements C, P and T, this study suggested mapping this relationship by three-dimensional model (the **CPT model,** please refer to chapter 5).

Croxall (2013) argued that digital pedagogy helps teachers to understand how their students, the digital generation, prefer to work and learn in a digitalised environment. This argument requires considering different pedagogical dimensions (P), kinds of the content of the curriculum (C) and digital technology tools (T) during teaching and learning, which is the main interest of this thesis. Varying these factors to improve students' attainment is one of the main ideas of the **CPT model** that is presented in this thesis, refer to chapter 5.

2.4.1 Collaborative Learning, Constructivism and Digital Technology

This section outlines the impact of digital technology on both pedagogical dimensions: constructivism and collaborative learning. Migrating both aspects can be viewed in terms of social constructivism that was promoted by Vygotsky and Bruner (Amineh & Asl, 2015). This claim is supported by Eady and Lockyer (2013, p. 84) who claim "collaboration is also deep-rooted in Vygotsky's theory of learning. He believed that there is a natural social nature of learning, and this is reflected in group-based learning".

Digital technologies have a potential impact on constructivism as it facilitates the exploration of new concepts, and keeps students engaged with different learning activities, such as simulations, experimentation and problem solving (Crook, 2001). In turn, this implies that students are encouraged to move towards inquiry-based learning, which was addressed by Bruner as discovery learning. Where students use their own experience and current knowledge to discover new concepts and relationships (Clabaugh, 2010). As such, students can construct knowledge rather than acquiring it through instruction (Lefoe, 1998).

Bruner and Vygotsky suggested the social constructivism perspective. Hence, they moved the emphasis away from the individual towards group-based learning (Jessel, 2013). Mtabi (2012, p. 99) argued that "social constructivists contend that learning occurs through collaboration and interaction amongst learners and their peers as well as their instructors". For instance, the scaffolding process shows how a student benefits from the interaction with other students. Thus, social constructivism explains learning in terms of social, collaborative activities to construct new knowledge. The use of digital technology supports the social dimension in learning, since it facilitates the communication between learners, promotes the collaboration between them and grants them access to a range of knowledge resources (Conole, et al., 2004). In line with Conole et al. (2004), Jessel (2013, p. 22) suggested:

> Asynchronous and synchronous communication can offer the potential for diverse and richer forms of dialogue amongst students, tutors and peers, as well as the access to a range of materials and resources (Conole, et al., 2004). Although verbal text has been the dominant mode through which interactions take place, the speed and power of new technologies can provide a reliable infrastructure that allows a variety of other modalities such as auditory, and visual, including 3D graphics. (Jessel, 2013, p. 22)

Digital technologies have influenced constructivism's approaches by offering intelligent physical and abstract tools that can promote explorative learning environments, such as computer-based simulations within which students can be involved in problem-solving environments as well as learning through activities and experiments (Gilakjani, et al., 2013). "Intelligent Tutoring Systems have also been designed in an attempt to use technology to interact 'intelligently' with the learner in order to promoting explorative learning activity" (Jessel, 2013, p. 19).

According to Isik (2018), the constructivist approach requires teachers to design a learning environment that activates students' prior knowledge, and encourage them to construct new knowledge through the interaction with the created environment. Checking students' prior experience allows the teacher to judge its accuracy. If students do not have previous experience, then the teacher needs to provide additional activities that can form it. During these stages, digital technology contributes to teachers, students and the entire learning process (Siemens, 2005). Kalz (2014) argued that the use of digital technology in educational environments promotes various pedagogical dimensions, such as self, collaborative and constructive learning. Moreover, accessing different resources of knowledge at any convenient time and place provides a foundation for lifelong learning. Students' previous experience and the offered resources allow students to construct new knowledge and modify the old schemes, which forms the philosophy of the constructivist approach (Piaget, 1952; Vygotsky, 1978)

Alexiou and Schipper (2018) claimed that digital technologies consider the individual differences between students as it provides students with various learning environments that are compatible with their readiness. For example, game-based learning allows students to view learning as fun activities rather than strict instructions. Isik (2018) argued that constructivist educational environments are sensitive to individual differences among students. The teacher needs to prepare a range of learning activities that fit with different students' academic level. Being aware that some students learn better through specific pedagogies, repetitions and more practices compared to others. Digital technologies enable students to make as many repetitions and exercises as they need without being embarrassed. Additionally, digital technologies provide students with instant feedback. Hence, they can correct their mistakes. In turn, this helps them to learn and develop their understanding (Radović, et al., 2019).

Amarin and Ghishan (2013) and Gilakjani et al. (2013) claimed that digital technologies enrich constructivist educational environments by providing students with real-world applications, which help students learn through an authentic environment. For example, the use of simulations allows students to form expertise about a specific phenomenon. In turn, it enables them to develop their understanding and construct new knowledge they did not possess previously.

Becker and Ravitz (2001), and Judson (2006) claim that using the constructivist approach supported by digital technology; classes are more attractive, student-centred and more efficient learning is ensured. Allen (2008) stated that the use of digital technologies in the constructivist approach promotes the high-order cognitive skills, which qualifies students to think critically and construct new knowledge. In line with Allen (2008), Isik (2018) suggested that interactive computers developed students' thinking and reasoning skills. These claims are backed by Wang and Reeves (2003, p. 50) who stated that "the interactive multimedia affordances of contemporary networked computers enable us to think of them not only as media for distributing information but also as environments capable of fostering the adaptation of student-centred pedagogy". For more details about collaborative learning and constructivism, please refer to sections 2.3.2 and 2.3.5.

2.5 EDUCATIONAL TECHNOLOGY

Simuforosa (2013) claimed that the use of educational technology could affect the entire process of learning; this effect had been described as positive according to some institutions, including educators and negative for others. Many academic institutions have considered educational technology as one of the main priorities for the plan of education development (Camp & DeBlois, 2007). Higgins et al. (2012, p. 15) stated, “It seems probable that more effective schools and teachers are more likely to use ICT and digital technologies more effectively than other schools”. Researchers, such as Kozloski (2006), Creighton (2003), Owen and Demb (2004) have discussed the connection between digital technology and students’ learning. These researchers agreed on the vital role of digital technology in supporting learning and building new knowledge.

Historically, the use of visual tools for learning was known long before the 20th century since the audio-visual media technology was used to implement education in U.S. museums schools in the early 1900s (Reiser, 1987). This kind of schools used to distribute portable museum exhibits, stereographs, slides, films, charts and other elements that were designed to enhance instruction (Saettler, 1968). References to visual education can be found as early as 1908 when the Keystone View Company’s publication guided teachers’ use of lantern slides and stereographs (Saettler, 1968). In 1910, the first catalogue of instructional films appeared (Reiser, 1987) and, in the same year, the public school system of Rochester adopted films for instructional use. The late 1920s and the 1930s was the period of growth and expansion of visual education, advances in technology as well as radio broadcasting, sound recording and sound motion pictures (Finn, 1972).

2.5.1 Educational Technology Definitions

Educational technology is a broad category that changes as fast as technology is developed. This implies that due to the continuous evolution in the available technological tools (hardware and software); especially the technologies that can be employed to serve learning, it is challenging to agree on one lasting definition for educational technology. Hence, in order to keep the definition up to date, continuous modification is necessary.

> Defining an applied field like Educational Technology is more difficult than defining any of the social science disciplines. The reason is that there is no single knowledge base to ground Educational Technology, as is the case in the social sciences. In an applied field, by its very nature, multiple knowledge bases are employed. The development of new knowledge causes shifts in thinking and introduces change, and in the field of Educational technology, multiple knowledge bases lead to multiplying change. (Luppicini, 2005, p. 105)

Marshall (2002) suggested that educational technology is the broad range of communication tools between educators and learners, transferring knowledge using the related digital technologies that can be used to support learning. It can be seen that this definition focuses on the idea of communication between teachers and students and among students themselves, to exchange knowledge, experience and ideas. In addition to the previous definition, the Association for Educational Communications and Technology (AECT) Definition and Terminology Committee (2004) defined educational technology as the ethical practice of facilitating learning, improving student’s academic performance and innovation, using appropriate technological tools.

Richey (2008) and Aziz (2010) claimed that educational technology is the considered implementation of suitable tools and methods that promote the application of senses, memory and cognition to improve teaching and maximise learning outcomes. In accordance with this definition, educational technology should include the following categories: i) implementation, ii) proper tools and iii) appropriate methods that facilitate learners’ memorisation, constructivism and cognition, as well as improving the teaching skills, practices and sharing knowledge.

Schacter (1999) and Costley (2014) claimed that educational technology has not only become popular and widely used to achieve the learning outcomes and learners’ expectations, but is also recognised by academic institutions as a viable learning alternative to the traditional classroom. Turner (2003) confirmed that using educational technology effectively improves learning since it offers learners advanced skills in computing technology and positive experience of researching. The International Society for Technology in Education (ISTE, 2007) stated clearly that:

> Effective integration of technology is achieved when students are able to select technology tools to help them obtain information in a timely manner, analyse and synthesise the information and present it professionally. The technology should become an integral part of how the classroom functions as accessible as all other classroom tools. (Cited in (Abdullah, 2016, p. 41)

Young (2008) suggested that the term digital technology could include software or hardware tools, such as computers, portable devices and diverse applications (Apps). Young (2008, p. 10) claimed that many schools "use technology to enhance students' learning: tools such as Internet access, digital cameras, email, interactive whiteboards, laptop computers, LCD projectors and course-specific software that support the curriculum".

Kalz (2014) argued that using digital technology could guarantee lifelong learning since digital technology-based learning is not subject to the same limitations as traditional learning is. For instance, communication in traditional learning is limited by classroom space and lesson timing. This echoes Thorpe (2000) who argued that digital technology-based learning could be described as life-long learning as it facilitates the exchange of knowledge and ideas between learners, teachers and curriculum developers regardless of time and place. Baghcheghi et al. (2011) claimed that the lack of collaboration, communication and digital technology tools in the classroom leads to traditional teaching or what can be described as the teacher-centred classroom where a teacher is the main protagonist and students are mere listeners with limited participation in the learning process.

Turner (2003) gives four rationales for schools using educational technology. Firstly, social rationale: since digital technology is an essential part of any society, as long as students are members of society, then students should know how to use digital technology. Secondly, vocational rationale: learning how to use digital technology can improve employment opportunities. Thirdly, pedagogical rationale: digital technology can support pedagogy by developing new methods of teaching, which might improve students' learning. Finally, catalytic rationale: digital technology is a catalyst for students' learning in schools.

In 1997, Tony Blair (the former Prime Minister of the UK, launching the National Grid for Learning) emphasised the importance of digital technology for all people, but particularly in the field of education:

> Technology has revolutionised the way we work and is now set to transform education. Children cannot be effective in tomorrow's world if they are trained in yesterday's skills. Nor should teachers be denied the tools that other professionals take for granted. (Blair, 1997)

As regards education, digital technology has provided a new learning resource for learners, such as audio-visual education (effective watching and listening). It has enhanced the quality of content knowledge and moved it from the theoretical part only to be integrated into three kinds of content: theoretical, practical and interactive content knowledge (Farah, et al., 2016). Furthermore, new technologies offer a connection within the same subject between the theoretical side and the practical side by providing many sorts of innovative services, such as virtual laboratories.

2.5.2 Educational Technology/ Digital Technology Supports Pedagogy

Papert (1996; 1993) argues that the most critical aspect of using educational technology is the belief that digital technology shifts students towards the positive environment of learning by engaging and attracting them and reinforcing the collaboration between them.

Deaney et al. (2003) claimed that the use of digital technology promotes the pedagogical dimensions in general and more specifically, collaborative learning. Digital technology promotes interaction between learners, which leads to a transfer of knowledge and an exchange of experience between the members of the learning process (teachers, learners, curriculum designers and stakeholders).

Juniu (2006) claimed that computer software supports collaborative learning and student-centred learning. Resta and Laferriere (2007), Domalewska (2014) argued that the use of digital technology facilitates communication between learners. In addition to supporting collaborative learning, constructivism, which is the second pedagogical dimension, can also be supported by digital technology as it offers learners the opportunity to access a range of external resources, such as simulations, journals, communication websites and online libraries that can lead learners to build new knowledge (Juniu, 2006). Nanjappa and Grant (2003, p. 39) stated, "a complementary relationship exists between technology and constructivism, the implementation of each one benefiting the other".

Duffy and Cunningham (1996), cited in Nanjappa and Grant (2003), suggested the impact of using educational technology on students' transformation from the stage of memorising knowledge or the passive learning to a new stage, the constructivist context field. In line with Duffy and Cunningham (1996), Hannafin and Land (1997) claimed that the connections between educational technology and student-centred learning could be shown by demonstrating how the integration of digital technology and education improved students' performance, offering them an appropriate environment to promote and support constructive learning (constructivism).

Regarding the third pedagogical dimension, cognitive learning, Noor-Ul-Amin (2013) suggested that educational technology offers students a wide range of resources to investigate concepts and solve problems related to the taught subject. According to Noor-Ul-Amin, digital technology-based cognitive learning is designed to teach learners how to think and process new knowledge. The positive impact of digital technology on the cognitive constructivism aspects was confirmed by Spiro et al. (1992) who claimed that digital technology, including the computers, could offer learners the chance of constructing knowledge as well as promote the cognitive learning in a way that is more flexible and effective than traditional learning.

Jonassen and Reeves considered that:

> Cognitive tools refer to technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem-solving and learning. Written language, mathematical notation, and, most recently, the universal computer are examples of cognitive tools. (Jonassen & Reeves, 1996, p. 693)

Digital technology can offer educators many possibilities for delivering subject's content, which means that knowledge could be introduced to students in a straightforward way, which promotes direct teaching as well (the fourth pedagogical dimension). Nooriafshar (2009) considered that digital technology could sustain and reinforce direct teaching without substituting it or eliminating it, i.e. digital technology has not been used merely to replace the traditional or any other successfully tested and established method. According to Nooriafshar, developing digital technology-based teaching materials means incorporating students' learning preferences, allowing them to build new knowledge based on what they already know and learning by association were always considered priorities.

However, Jessel (2014, p. 915) claimed that "the method of use became important, not just the existence of the technology". This was echoed to some extent by Watson (2001, p. 264) who claimed, "some schools focus on the existence and the appearance of the new technology rather than the useful implementation and the effective use of it", which proves the significance of the method of using digital technology. Even if digital technology is available, it can be misused. For instance, students might use digital technology devices to access inappropriate content during the lesson, such as games or social media sites, which do not always serve or support learning. As such, the impact of digital technology on education will be harmful or at least will not meet the learning expectations. Office for Standards in Education (Ofsted, 2001) stated that the inefficient use of digital technology harms learning or can misdirect learning. However, if digital technology is employed effectively to serve learning, communicate, implement the tasks and evaluate the learning process, then the learning process will be affected positively (FutureofWorking.com, 2015; Costley, 2014).

2.5.3 Difficulties That Might Encounter the use of Educational Technology/ Digital Technology

The development of the learning process includes the development of many components, such as pedagogy, which is used to implement learning and make the content of the curriculum suitable for all students, and technological tools that are used in education to support the pedagogical dimensions.

One of the problems that hinders the integration of digital technology and education can be the teachers' skills and experience in using digital technology and the nature of their past education. Some teachers are trying to teach their students in the same way they were taught. Windschitl (1999) claimed that teachers' history provides them with the teaching style and methodologies that are extracted from their teachers in the past. Therefore, some teachers are becoming no more than identical copies of their teachers who taught them.

Norton et al. (2017) claimed that digital technology has a significant role inside the classroom, but its impact on learning has not reached its potential because not all educators are qualified to deal with it.

Roob (2001) claimed that the effective use of digital technology and pedagogy could lead to a successful learning process, saving time and stimulating the students' interest in learning. Roob's view (2001) suggests that our attitude towards a new approach or technique can be affected by many factors, such as ability, previous experience, morals and thoughts, reinforcement and the degree of support received. These factors affect the attitude toward the use of digital technology. For instance, if a learner receives the necessary support that facilitates the use of digital technology, then a positive attitude will be formed. On the other hand, if this learner does not receive the required support, then a negative attitude will be formed, and this might be a permanent attitude or not easy to change in the future.

Schulze (2014) and Pachler et al. (2010) summarised the difficulties that can face the integration of digital technology and education through several factors. Firstly, the high cost of digital technological tools. Secondly, some of the teachers are not well-trained to use digital technology. Thirdly, the lack of electronic (digital) learning resources and finally, some of the teachers do not believe in the role of digital technology in the learning process.

2.6 THE PORTABLE DEVICES AS TOOLS FOR EDUCATION (MOBILE TECHNOLOGY)

Learners' expectations and requirements rise continuously as an outcome of the rapid evolution in digital technology. Therefore, new technologies, such as mobile devices (laptop, phone, tablet, iPad) are in high demand to meet these expectations (Chee, et al., 2011). Mobile devices are vital elements of educational technology, as these devices facilitate learning for some learners, though not all. These devices can have a positive or negative effect on students' learning since it depends on how it is used or directed by the user (Pachler, et al., 2010; Traxler, 2010; Ling & Donner, 2009).

Howard, et al. (2012), Larkin and Finger (2011), Dunleavy and Heinecke (2007) eSchoolMedia and eSchool News (2006) claimed that using laptops in learning could impact the methods of learning positively. Kim et al. (2016) asserted that using mobile technology devices, learners could save time and efforts, and they became engaged more than before in self-directed learning activities, and encouraged to implement collaborative learning through communicating with other learners. Kearney et al. (2012) suggested three main features that help students to be engaged with their learning in any mobile learning scenarios: authenticity, collaboration and personalisation. According to Kearney et al. (2012), these features can be supported efficiently using portable devices. Many other pieces of research have shown the positive impact of using these devices on learning (Penuel, 2006).

Portable devices offer robust computational functionality and interactivity (Newhouse, 2014). These devices also provide the required software to accommodate learners with special needs (Hasselbring & Williams Glaser, 2000). For example, audio reader applications assist those with visual problems. Therefore, it can be said that the content can be adapted and accustomed to special needs learners using portable devices.

With the aid of mobile devices, lessons are more interactive (Ghavifekr, et al., 2016). Using this kind of tools allows teachers to share the learning recourses with students instantly, so they can store this content, share ideas and thoughts about it and may construct new knowledge. Using interactive devices allows teachers to display the content in different shapes such as theoretical, practical and interactive; in forms of simulations, graphs and videos, so students’ understanding can be improved (Jacob & Issac, 2008; Farah, et al., 2016). Therefore, portable devices support students with unique learning needs to meet their expectations, keeping them up to date and offering various methods of delivery to improve their engagement.

Portable devices can also support assessment practices. Using these devices, teachers could include some media elements, such as movies and photos with the questions to make it more transparent. Moreover, students could do their exams online at any time they prefer during the assigned period determined by the educator (Naismith, et al., 2004):

> Mobile technologies are becoming more embedded, ubiquitous and networked, with enhanced capabilities for rich social interactions, context awareness and internet connectivity. Such technologies can have a great impact on learning. Learning will move more and more

> outside of the classroom and into the learner’s environments, both real and virtual, thus becoming more situated, personal, collaborative and lifelong. (Naismith, et al., 2004, p. 5)

According to West (2013), portable devices can be used as a communication tool to exchange and share knowledge. The flow of documents to and from the portable device is effortless, saving time and securing the documents under a personal account in the cloud. Furthermore, this kind of tools can offer a virtual and effective learning platform, so students can receive the homework online, answer the tasks from any place and then submit it online using an online software tool, such as an email, a learning management system or a dropbox.

The educational activities and assignments that are received using the portable devices can be responded to internally, without any necessary procedure outside the portable device, such as printing the document, scanning it or submitting a hard copy. Furthermore, educators can have continuous access to students’ work, which means it is easier for educators to keep track of students’ progress (Jacob & Issac, 2008).

Vavoula et al. (2007), Ferreira et al. (2015) claimed that portable devices encourage students to be more involved and engaged in their learning, which might participate in shifting students from the passive to active learner status. Vavoula et al. (2007) stated that mobile devices could form steady bridges between technologies, contexts, experiences and learning.

According to Caballe et al. (2010) and Luff and Heath (1998), mobile devices encourage students to move forward in the direction of collaboration. For instance, when students work in groups, they can exchange experience, feedback, answers and knowledge easily, using their mobile technology device. A teacher can send his feedback about students’ coursework using these devices as well.

Note: In this study, laptops and iPads were used as examples of portable devices, please see Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13. These figures show how the teacher and students could deal with the learning management system (LMS) using portable devices, please refer to section 2.7

2.7 LEARNING MANAGEMENT SYSTEM (LMS)

Jamal and Shanaah (2011) define a learning management system (LMS) as a web-based software application platform (a virtual learning platform) that allows teachers and learners to publish their work, exchange their knowledge, submit assignments and track their results. This implies that the LMS facilitates communication between the members of the learning process. Hall (2002) claimed that a learning management system (LMS) offers a comprehensive set of tools for both educators and students to manage the learning process, including assessments, grading, content and resources.

The Learning Management Systems Architecture Laboratory at Carnegie Mellon (2004) stated that the LMS:

> Is a software package used to administer one or more courses to one or more learners. An LMS is typically a web-based system that allows learners to authenticate themselves, register for courses, complete courses and take assessments. (Cited in (Berking & Gallagher, 2013, p. 6)

Abu Shawar (2009, p. 3) defined the LMS as "Internet-based software allowing instructors to manage materials distribution, assignments, communications and other aspects of instructions for their courses”.

The LMS, which was used in this study is called Desire to learn (D2L-LMS), I would define it as a virtual learning platform that can be used by the members of the learning process, such as students, teachers and curriculum developers, as a social publishing platform.

2.7.1 The Significance of Using the Learning Management System (LMS):

Kulshrestha and Kant (2013) described the learning management system LMS as an essential tool to implement learning in any academic institution that relies on digital technology-based learning. This kind of network is easily accessible by all users at any time, which promotes and personalises learning (Edmunds & Hartnett, 2014). In 2009 Rubin et al. claimed that an effective LMS “must support active engagement, meaningful connections between segments of the course, easy communication, and formative feedback on work that is presented in class discussions or through other venues" (cited in (Holmes & Prieto-Rodriguez, 2018, p. 21).

The use of an LMS requires training for teachers so that they can deal with it effectively (Pedro, et al., 2008). This includes the ability to upload the content to the LMS, running the quizzes online, marking and sending the feedback, tracking students' progress and communicating with other students, which can all be done by an LMS (Sharma & Vatta, 2013).

The LMS consists of social media communication facilities so that users can chat with each other, sharing ideas and exchanging experience. The significance of this kind of communication is that it increases learners' engagement and encourages them to be more involved in their learning (Mtebe, 2015).

Sharma and Vatta (2013) claimed that LMS as a publishing platform that saves educators' time and efforts, since the lesson preparation consists of lesson planning, preparing several documents and activities, such as presentations, worksheets, answer keys for the worksheet, assessments, answer keys for the assessments and interactive tools. All of these documents and activities can be prepared ahead of time and stored in the platform itself, which means that these resources and documents are storable, easily accessible and reusable with other classes. Therefore, educators do not have to keep creating the same documents every time they want to teach, but instead, they can add new knowledge to the existed knowledge. This claim is supported by Raiskinmaki (2017, p. 14), who stated that "since material could be found online or saved to computers for further use, the teachers saved the time compared to previous working methods when technology was not so extensively used".

Almrashdeh et al. (2011) claimed that the LMS supports distance learning as it provides learners with many resources that promote the concept of self-learning and constructivism, which helps students to build their knowledge.

> Distance learning uses LMS technology to provide users with different ways of interacting and communicating with each other. Also, distance learning uses LMSs to facilitate user access to learning resources. Furthermore, LMSs give the distance-learning actors a useful and easy way to use the technology's environment to collaborate and direct the learning process. (Almarashdeh, et al., 2013, p. 1472)

The use of LMS reduces paperwork, replacing it with soft copies as teachers upload the subject's content, assignments, assessments and notifications to the LMS. Students download it, work on it, and once the task is completed, students can re-upload it back to the LMS platform, so the teacher can check it (mark it), and send the feedback to students (Uzity, 2018).

LMS can administer assessments (Holmes & Prieto-Rodriguez, 2018). The exam itself will be saved and added to the question bank to be used by other teachers, in case they need a ready source of questions. The LMS can assist in marking some of the questions, which can be marked automatically, such as the multiple choices questions, true/ false, and yes / no questions (Abazi-Bexheti, et al., 2010).

Once the coursework is marked, immediate feedback will be sent to students so that they can track their own progress. Also, school management and parents can monitor the student's progress. In some of the LMSs, automatic reports will be generated and sent to the people who are concerned about student's attainment (Kulshrestha & Kant, 2013).

LMS keeps the data and the content, which is prepared by teachers. Therefore, teacher's work in any semester will be saved and ready to be used in other semesters, which implies that the LMS is saving teachers' time and efforts, by ensuring that they do not have to repeat their work (Raiskinmaki, 2017; Kim, et al., 2016). The following section discusses these claims by offering some evidence from the learning management system, which was used in this study (D2L-LMS).

2.7.2 Description of the Learning Management System used in this Study (D2L-LMS)

The Learning Management System used by the IAT is called Desire to learn, D2L-LMS. The users of D2L-LMS are divided into three categories:

i. The students. They use the D2L-LMS for learning, including receiving documents related to the taught subjects, downloading, uploading, doing online exams and accessing external resources, i.e., D2L-LMS is a virtual platform for different learning resources.

ii. The teachers. They use the D2L-LMS to manage the teaching-learning process, support and assess students.

iii. The administrators, such as the principal, vice-principal and curriculum developer. They keep checking the D2L-LMS to support both teachers and students.

2.7.2.1 *Functions Offered by the D2L- LMS*

D2L- LMS supports content in various formats. For instance, audio, video, and "verbal text" (Jessel, 2013, p. 22). It grants students the possibility to download these files, as shown in Figure 3 and Figure 4

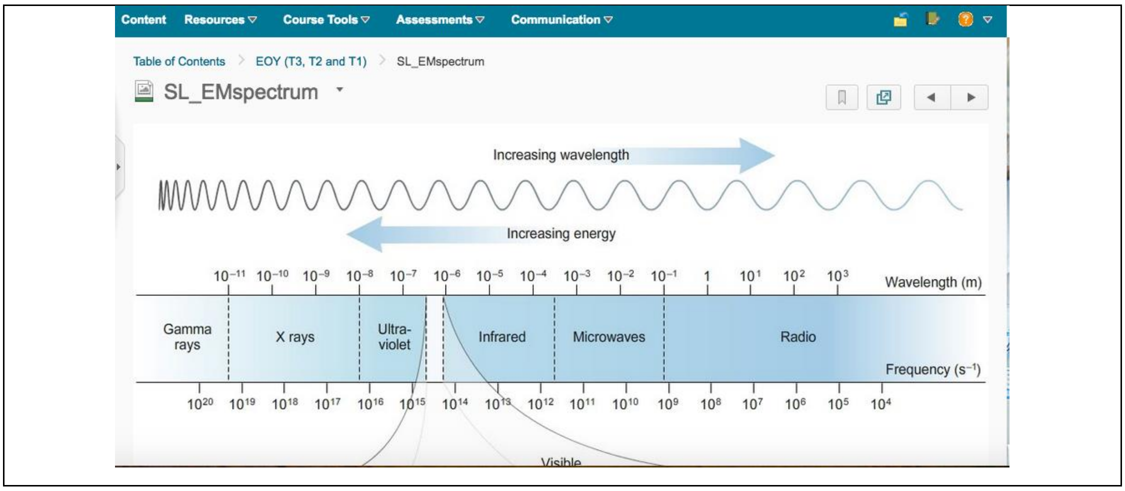


Figure 3. D2L- LMS supports content in jpg image format.

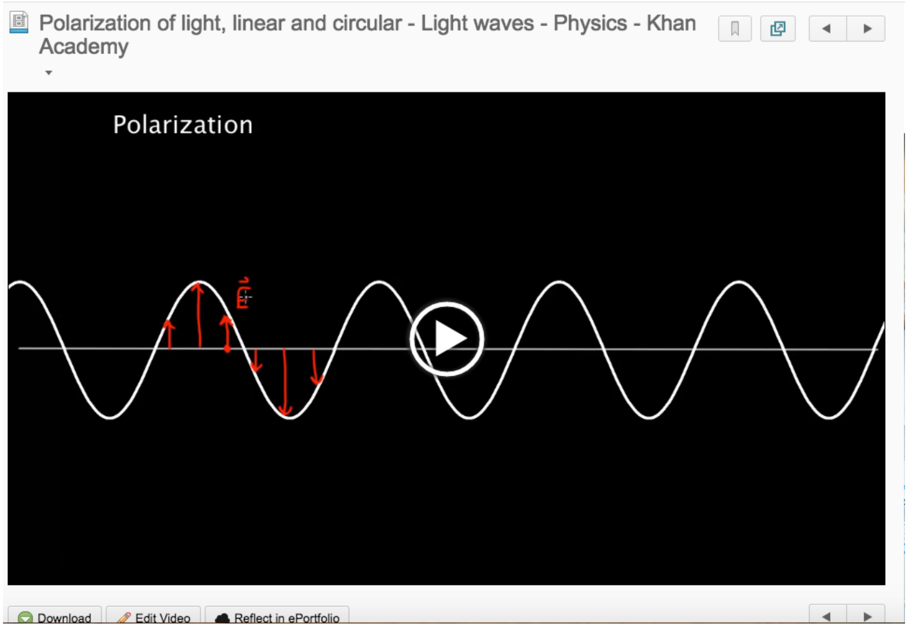


Figure 4. D2L- LMS supports content in video formats.

D2L- LMS allows students to access course content at any convenient time. In turn, this implies that learning is no longer restricted by the classroom. Being aware that D2L- LMS offers each student his/her own account. As such, learning is personalised. See Figure 5.

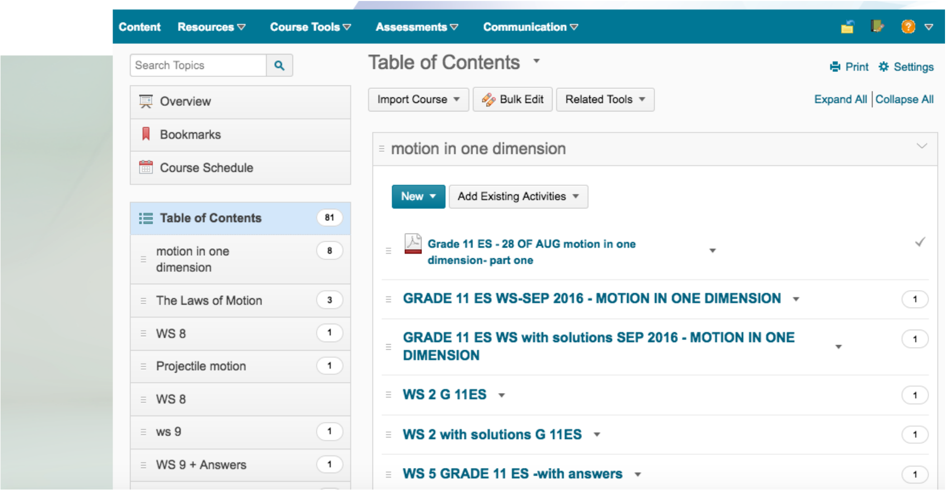


Figure 5. Course content uploaded to D2L- LMS

D2L-LMS supports various activities, such as quizzes, virtual laboratory and assignments' submission. See Figure 6.

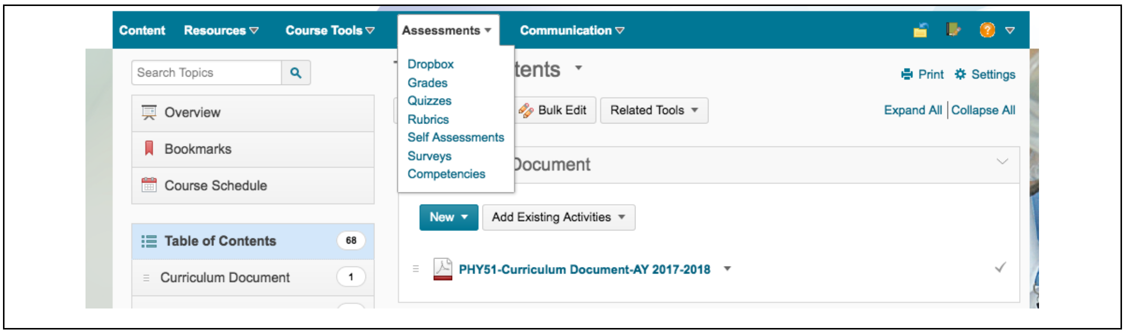
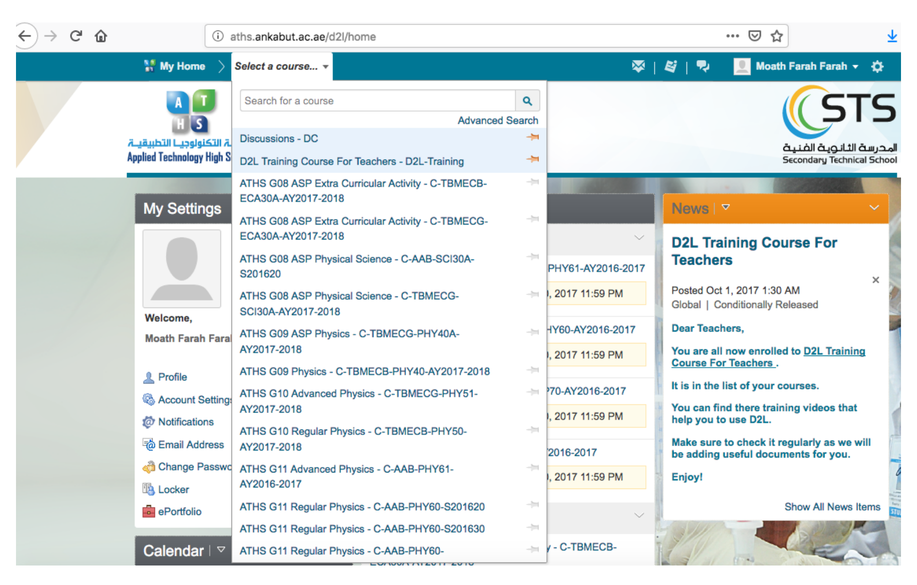


Figure 6. D2L-LMS supports various activities, such as quizzes and group work on different assignments.

D2L-LMS stores the learning resources, including all uploaded documents by teachers and students, for a long time (up to three years). Hence, it saves teachers’ time and efforts, as they can re-use the ready resources with many classes at different times. As shown in the drop-down list, Figure 7, the courses taught in the academic year 2016-2017 are still stored in the D2L-LMS.



Discussions - DC
D2L Training Course For Teachers - D2L-Training
ATHS G08 ASP Extra Curricular Activity - C-TBMECB-ECA30A-AY2017-2018
ATHS G08 ASP Extra Curricular Activity - C-TBMECG-ECA30A-AY2017-2018
ATHS G08 ASP Physical Science - C-AAB-SCI30A-S201620
ATHS G08 ASP Physical Science - C-TBMECG-SCI30A-AY2017-2018
ATHS G09 ASP Physics - C-TBMECG-PHY40A-AY2017-2018
ATHS G09 Physics - C-TBMECB-PHY40-AY2017-2018
ATHS G10 Advanced Physics - C-TBMECG-PHY51-AY2017-2018
ATHS G10 Regular Physics - C-TBMECB-PHY50-AY2017-2018
ATHS G11 Advanced Physics - C-AAB-PHY61-AY2016-2017
ATHS G11 Regular Physics - C-AAB-PHY60-S201620
ATHS G11 Regular Physics - C-AAB-PHY60-S201630
ATHS G11 Regular Physics - C-AAB-PHY60-

D2L Training Course For Teachers

Posted Oct 1, 2017 1:30 AM
Global | Conditionally Released

Dear Teachers,

You are all now enrolled to D2L Training Course For Teachers .

It is in the list of your courses.

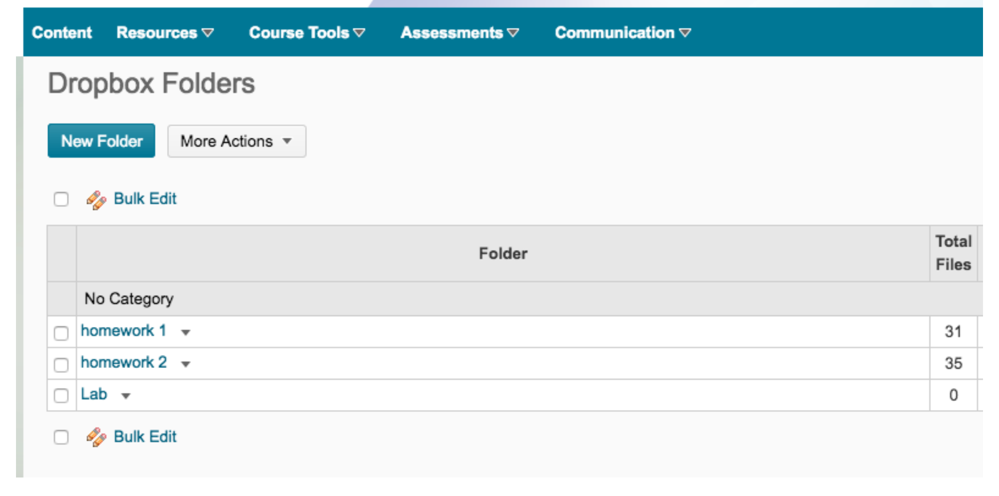
You can find there training videos that help you to use D2L.

Make sure to check it regularly as we will be adding useful documents for you.

Enjoy!

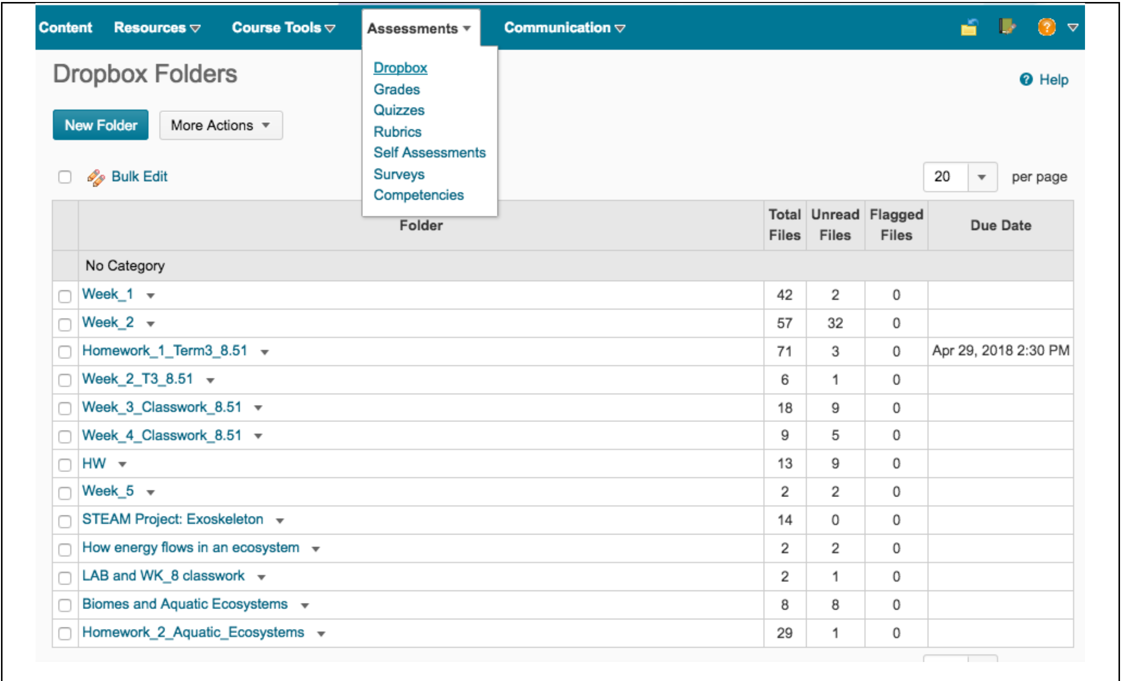
Figure 7. Stored courses in the D2L-LMS

D2L-LMS offers students and teachers huge storage cloud, dropbox, which allows them to submit and store the course work, such as worksheets and homework. See Figure 8 and Figure 9.



	Folder	Total Files
	No Category	
☐	homework 1	31
☐	homework 2	35
☐	Lab	0

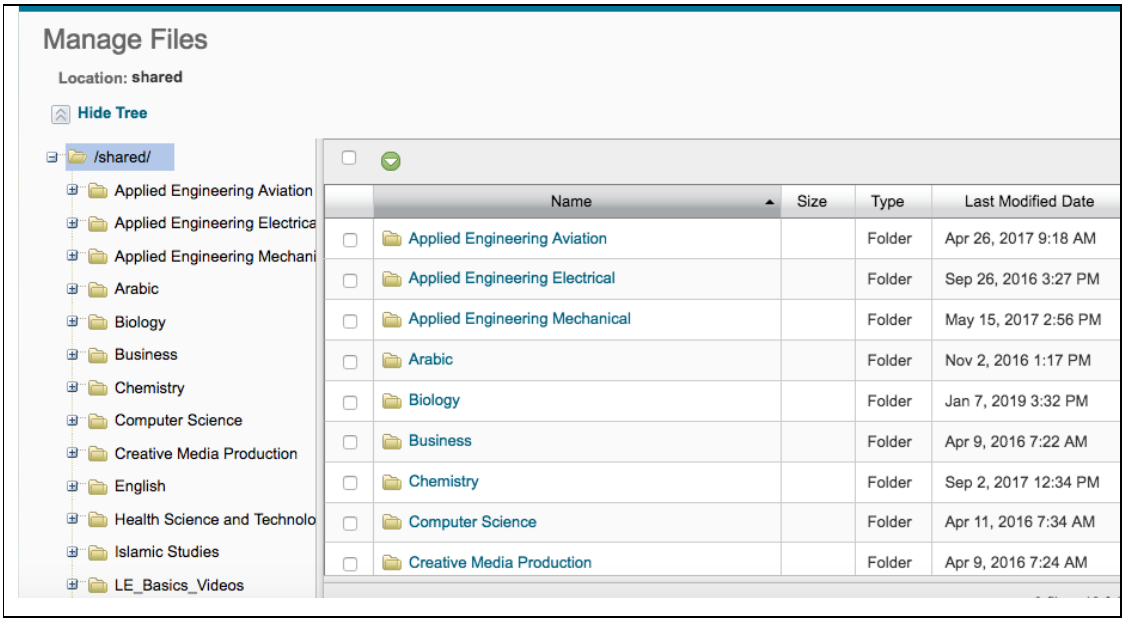
Figure 8. Submitted homeworks to the dropbox in the D2L-LMS.



	Folder	Total Files	Unread Files	Flagged Files	Due Date
	No Category				
☐	Week_1	42	2	0	
☐	Week_2	57	32	0	
☐	Homework_1_Term3_8.51	71	3	0	Apr 29, 2018 2:30 PM
☐	Week_2_T3_8.51	6	1	0	
☐	Week_3_Classwork_8.51	18	9	0	
☐	Week_4_Classwork_8.51	9	5	0	
☐	HW	13	9	0	
☐	Week_5	2	2	0	
☐	STEAM Project: Exoskeleton	14	0	0	
☐	How energy flows in an ecosystem	2	2	0	
☐	LAB and WK_8 classwork	2	1	0	
☐	Biomes and Aquatic Ecosystems	8	8	0	
☐	Homework_2_Aquatic_Ecosystems	29	1	0	

Figure 9. Uploaded materials to the dropbox in the D2L-LMS.

D2L-LMS offers students and teachers various learning resources in different subjects, such as soft copy books, past exams, extra practices with answer keys. Therefore, it encourages students to explore and practice more. These resources are uploaded to the shared folder in the D2L-LMS by the curriculum developers, see Figure 10 and Figure 11.



Manage Files

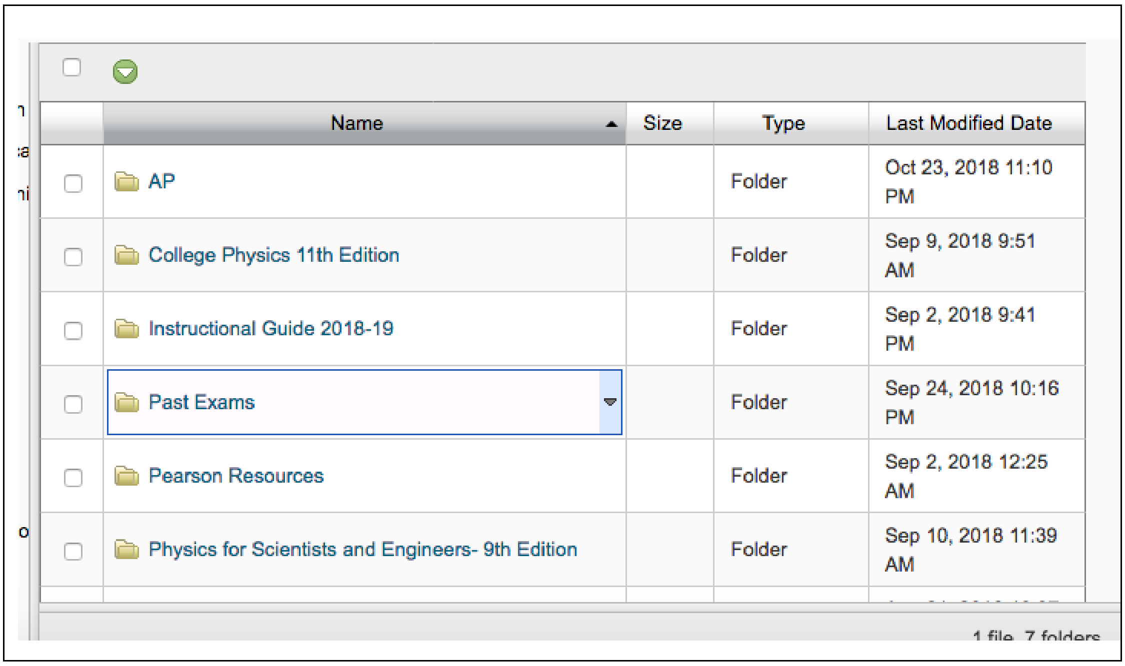
Location: shared

Hide Tree

- /shared/
  - Applied Engineering Aviation
  - Applied Engineering Electrica
  - Applied Engineering Mechani
  - Arabic
  - Biology
  - Business
  - Chemistry
  - Computer Science
  - Creative Media Production
  - English
  - Health Science and Technolo
  - Islamic Studies
  - LE_Basics_Videos

☐	Name	Size	Type	Last Modified Date
☐	Applied Engineering Aviation		Folder	Apr 26, 2017 9:18 AM
☐	Applied Engineering Electrical		Folder	Sep 26, 2016 3:27 PM
☐	Applied Engineering Mechanical		Folder	May 15, 2017 2:56 PM
☐	Arabic		Folder	Nov 2, 2016 1:17 PM
☐	Biology		Folder	Jan 7, 2019 3:32 PM
☐	Business		Folder	Apr 9, 2016 7:22 AM
☐	Chemistry		Folder	Sep 2, 2017 12:34 PM
☐	Computer Science		Folder	Apr 11, 2016 7:34 AM
☐	Creative Media Production		Folder	Apr 9, 2016 7:24 AM

Figure 10. Various learning resources related to different subjects uploaded to the D2L-LMS

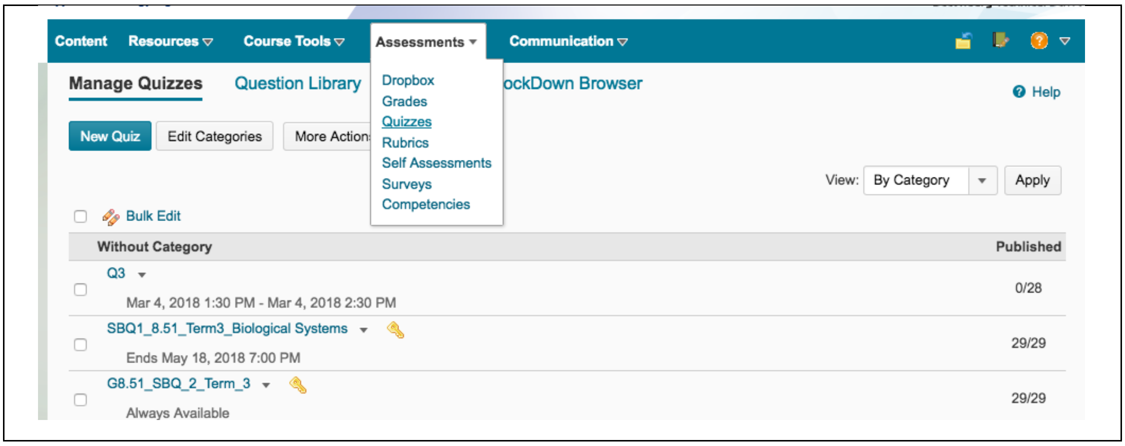


☐	Name	Size	Type	Last Modified Date
☐	AP		Folder	Oct 23, 2018 11:10 PM
☐	College Physics 11th Edition		Folder	Sep 9, 2018 9:51 AM
☐	Instructional Guide 2018-19		Folder	Sep 2, 2018 9:41 PM
☐	Past Exams		Folder	Sep 24, 2018 10:16 PM
☐	Pearson Resources		Folder	Sep 2, 2018 12:25 AM
☐	Physics for Scientists and Engineers- 9th Edition		Folder	Sep 10, 2018 11:39 AM

1 file, 7 folders

Figure 11. Various learning resources uploaded to the D2L-LMS

D2L-LMS allows teachers to examine their students, online assessment. The disadvantage of this function is that the automatic marking system supports only the multiple choices questions, i.e., does not support marking free responses problems, see Figure 12.



Without Category	Published
Q3 Mar 4, 2018 1:30 PM - Mar 4, 2018 2:30 PM	0/28
SBQ1_8.51_Term3_Biological Systems Ends May 18, 2018 7:00 PM	29/29
G8.51_SBQ_2_Term_3 Always Available	29/29

Figure 12. Quizzes conducted using D2L-LMS

D2L-LMS allows teachers and administrators to monitor students' progress, including their attainments and attendance, as shown in Figure 13.

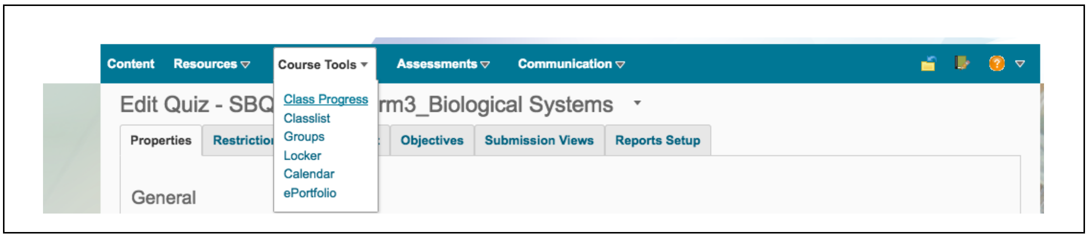


Figure 13. The class progress on the D2L-LMS.

It seems evident that the use of LMS offers a separate learning platform, a virtual platform, for every learner. Each student has their own account and can add their resources and documents, which helps them to be engaged and involved more in their learning.

2.8 TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE (TPACK)

The basic idea of the TPACK framework originated with Shulman in 1986, 1987 (Maor, 2013). Shulman described it as a PCK (Garritz, 2010), which stands for pedagogy and content knowledge. In this approach, Shulman described the teacher's knowledge of pedagogy and the teacher's knowledge about the taught subject (the content knowledge) as two dependent variables that cannot be described solely in isolation (Shulman, 1986). Teachers, according to Shulman, need to use the interaction between pedagogy and content in their teaching to help learners and lead them to a deep understanding of the content they are studying. Hence, teaching can be described as effective teaching. (Koehler, et al., 2014)

After 1987, extensive research was published in this field, which contributed to developing Shulman's idea until it became what nowadays is known as the TPACK model (technology, pedagogy and content knowledge) (Maor, 2013). The TPACK framework, which was suggested, by Mishra and Koehler (2005a; 2006; 2008) described the complex interaction between technology, pedagogy and content knowledge as shown in Figure 14 (Koehler & Mishra, 2009, p. 63).

Mishra and Koehler (2005a) suggested that the technological knowledge domain (TK) should be integrated with content and pedagogical knowledge (PCK) that was proposed by Shulman. They thought that the technology domain had become more significant in peoples' lives than it was in Shulman's time (Archambault & Barnett, 2010). According to Mishra and Koehler (2005a), the core idea of this model is the interaction between technology, pedagogy and content knowledge, which leads to effective teaching and learning (Doering, et al., 2009).

After adding technology to Shulman's model as a third component, the acronym became TPACK. This was introduced by Mishra and Koehler as a conceptual framework to describe what is required to reach the effective learning using technology as it supports pedagogy and content knowledge (Doering, et al., 2009). Rocha et al. (2011, p. 40) stated: "The Technological Pedagogical Content Knowledge, TPACK for short, has revealed itself as the theoretical standard of excellence for effective integration of ICT in the teaching and learning processes". However, Koehler and Mishra (2005a), Voogt et al. (2012) and Graham (2011) stated that implementing successful learning requires a full understanding of the relationship between technology, pedagogy and content knowledge.

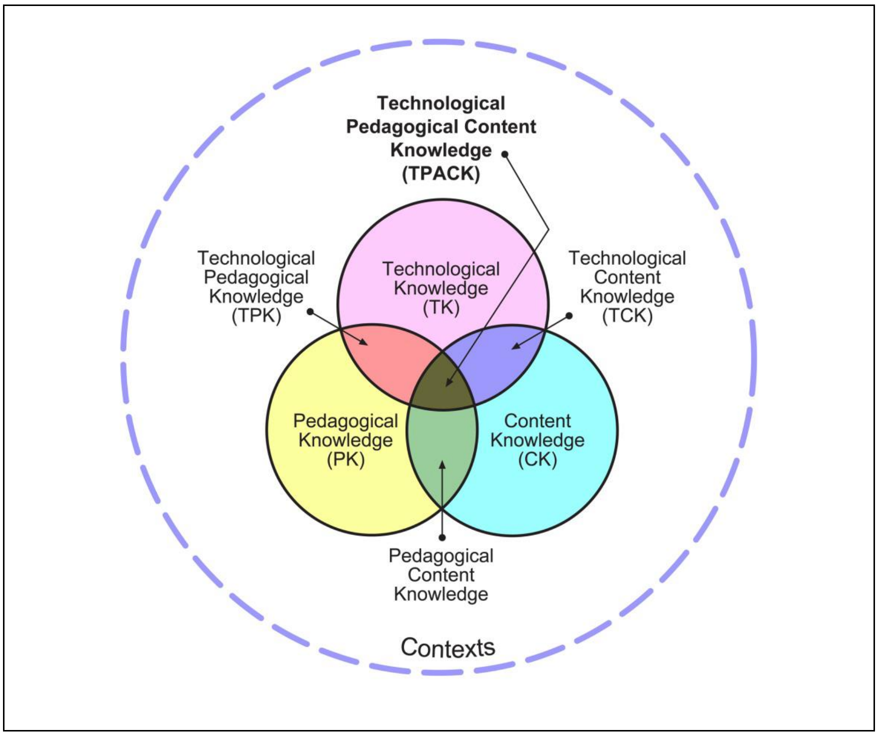


Figure 14. The TPACK framework and its knowledge components (Koehler & Mishra, 2009, p. 63). © 2012 by tpack.org

Mishra and Koehler (2006; 2008) explained that the TPACK framework guides the complex ways in which these domains of knowledge (T, P and CK) interact with one another. However, Graham (2011) claimed that the relationship between T, P and CK is complex and has led to many scholarly debates. Therefore, the TPACK framework faced the same problems that Shulman's PCK framework did, due to the lack of experience in TPACK itself and its components (Archambault & Barnett, 2010). Which agrees with Angeli and Valanides (2009), who claimed that there was a perplexity in addressing the knowledge competencies that form the TPACK domains or what knowledge each domain should consist of, and how the components of TPACK differed or related (e.g. Technological Content Knowledge and Technological Pedagogical Knowledge). These concerns form a challenge for educators who would like to apply TPACK in their teaching.

Another challenge that can face the application of the TPACK model is related to teachers' attitudes towards integrating digital technology with their teaching. Some teachers do not have a positive attitude towards digital technology. This could be due to their inability to cope with new technologies as an outcome of inadequate training and substandard tools (Bingimlas, 2009). In line with Bingimlas, Ghavifekr et al. stated:

> Overall, the key issues and challenges found to be significant in using ICT tools by teachers were: limited accessibility and network connection, limited technical support, lack of effective training, limited time and lack of teachers' competency. (Ghavifekr, et al., 2016, p. 38)

Furthermore, as stated by Windschitl (1999), some teachers had their degrees and finished their courses at a time when educational technology was not popular or accessible, so teachers' experience in the new technologies might not be sufficient to use it effectively. Indeed, there is a relationship between a teacher's knowledge of educational technology and the achieved progress by students. It seems intuitively obvious that "teachers cannot help children learn things they do not understand" (Coe, 2017, p. 17).

2.8.1 The TPACK Domains

The TPACK model consists of three components: content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK). As shown in Figure 14 (Koehler & Mishra, 2009, p. 63), migrating these components or elements will produce common areas where two or more factors interact with each other (Koehler & Mishra, 2008; 2006). Therefore, the TPACK framework has been divided into seven different competencies as follows (Schmidt, et al., 2009):

i. Pedagogical Knowledge (PK).

ii. Content Knowledge (CK).

iii. Technological Knowledge (TK).

iv. Technological Pedagogical Knowledge (TPK is a result of the interaction between technology and pedagogy).

v. Pedagogical Content Knowledge (PCK is a result of the interaction between pedagogy and content knowledge).

vi. Technological Content Knowledge (TCK is a result of the interaction between technology and content knowledge).

vii. Technological Pedagogical and Content Knowledge (TPACK) which is considered as a result of the interaction between the three areas PCK, TCK and TPK.

2.8.1.1 Content Knowledge (CK)

Content knowledge is the knowledge about the taught subject, but not about the ways of teaching it (Chai, et al., 2013). This echoes Koehler and Mishra (2009, p. 63) who stated, "Content knowledge (CK) is teachers' knowledge about the subject matter to be learned or taught".

Content Knowledge is an essential factor for a teacher to implement learning (Guerriero, n.d.). Shulman stated that content knowledge includes the knowledge about the concepts, theories, ideas, structures and frameworks as well as the practices and approaches toward developing knowledge (Koehler, et al., 2013). For instance, if the taught subject is related to art and humanities, then a teacher needs to have a historical background to the topic, a deep understanding of the concepts, an ability to analyse theories and demonstrate a solid knowledge related to their subject.

Koehler, et al. (2013, p. 3) stressed the significance of the content knowledge in learning as they stated: "The cost of not having a comprehensive base of content knowledge can be prohibitive". This implies that if a teacher delivers incorrect knowledge, then students might develop misconceptions about the content area based on the received knowledge (National Research Council, 2000).

2.8.1.2 Pedagogical Knowledge (PK)

Pedagogical knowledge (PK) is the used processes, practices or methods to implement teaching and learning (Srisawasdi, 2012). The significance of the PK component is to find out how students prefer to learn and the best way to implement learning (Farah, et al., 2016). Furthermore, PK assists teachers in managing the class, organise the lesson time and help students to reach a more in-depth understanding

(Mishra & Koehler, 2006).

The Department of Education for the Government of Western Australia (2009) claimed that the successful learning process requires an effective pedagogy to implement learning and deliver the knowledge effectively. An effective pedagogy itself requires skilful teachers, who have a deep understanding of the taught subjects and to know how knowledge should be taught, organised, and linked to other disciplines and real-life practices (Guerriero, n.d.).

"Pedagogy is a highly complex blend of theoretical understanding and practical skill" (Lovat, 2003, p. 11). This implies that teachers need to understand the theoretical background of the term pedagogy in addition to being well developed in the practical side, which is related to delivering the content.

For the purpose of this thesis, I would define the pedagogical knowledge (PK) as the methods used by teachers to implement learning (the methods of teaching and learning). In general, PK requires teachers to have experience in learning theories and styles related to learning and understand how these theories should be applied in the classroom. Moreover, a teacher who has a deep awareness of the PK will be qualified to deal with students in a professional manner and will be able to determine the best method to construct knowledge. For more information about the learning theories (the pedagogical dimensions as addressed in this thesis), please refer to section 2.3.

2.8.1.3 Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge (PCK) was defined for the first time by Shulman in 1986 (Maor, 2013). Shulman (1986, p. 9) described PCK as "the ways of representing and formulating the subject that make it comprehensible to others". Ozden (2008) claimed that PCK is a teacher's knowledge of teaching methods (pedagogical knowledge) and knowledge about the taught subject (the content knowledge). Shulman argued that these two variables could not be described solely in isolation. This idea is echoed by Mishra and Koehler (2006, p. 5) who stated:

> PCK exists at the intersection of content and pedagogy. Thus, it goes beyond a simple consideration of content and pedagogy in isolation from one another. PCK represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organised, adapted, and represented for instruction. (Mishra & Koehler, 2006, p. 5)

Based on Shulman’s view, successful teachers, have to deal with both matters (content and pedagogy) simultaneously by embodying ‘‘the aspects of content most germane to its teachability” (Shulman, 1986, p. 9). In turn, this implies that teachers in this domain combine what will be taught (the content knowledge) and how it will be delivered (the pedagogical knowledge), i.e., how teachers teach and what they teach.

2.8.1.4 Technology Knowledge (TK)

Shulman’s idea of PCK was extended by adding a new component; Technological knowledge (TK), which was described as the inserted tools that are used to implement learning. (Koehler & Mishra, 2008; 2006; 2005a)

As discussed in section 2.2, the problem in defining technology knowledge is that any definition of technology can become out of date in a brief period because of the continuous development in the technology sector. “It is important to note that TK exists in a state of flux, due to the rapid rate of change in technology” (Mishra, et al., 2009, p. 3). Graham (2011) claimed that the perplexity in defining technological knowledge causes a lack of clarity in the TPACK model. However, the term technology knowledge was defined by Mishra and Koehler (2006) as the knowledge of operating systems (Windows, Mac, Linux) and computer hardware as well as the ability to use software tools, such as Microsoft Office (Word, Excel, PowerPoint), Mac applications (pages, keynote, numbers), browsers and e-mail and how to apply them in the case of digital learning.

Technological knowledge in education domain includes not only the ability to deal with the computer software and to some extent the hardware, but also the ability to adapt the new technologies for the benefit of the learning process. This agrees with Graham (2011, p. 11) who stated: “many instructional technologists have very broad conceptions of what technology is and consider technology to be not only physical devices but also processes applied to solving problems”. Graham’s claim agrees with the Committee of Information Technology Literacy of the National Research Council (2000) who argued that the TK or the Fluency of Information Technology should go beyond the basic level of use so that the goals of using technology could be achieved. For more information about the notion of technology, please refer to section 2.2.

2.8.1.5 Technological Content Knowledge (TCK)

Cox (2008) defined technological content knowledge (TCK) as knowledge of appropriate technologies that can be used in a specific discipline and how the application of those technologies influences the content of that discipline. As shown in Figure 14 (Koehler & Mishra, 2009, p. 63), TCK is the common area between technology and content knowledge (Farah, et al., 2016a). This area demonstrates how technology can be employed and integrated with the content of a subject, which improves the learning process Mishra and Koehler (2006). The new technologies have offered learners a new understanding and imagining of the world (Klopfer, et al., 2009). For example, digital simulations might help students to realise and visualise a complex concept in science and mathematics.

During the lesson's delivery process, TCK relies substantially on the teacher, who is the master of these tools and is the one who must match the suitable technology with the content by choosing the best-suited technologies for addressing the content. In other words, it is the teacher who dedicates technology to serve content knowledge. For instance, students can currently study geometric shapes using interactive tools, such as simulations, which enables them to visualise this concept. New technologies simplified complex concepts for students, as well as enabled them to discover and build new knowledge (Humes, 2017; Koehler & Mishra, 2009).

2.8.1.6 Technological Pedagogical Knowledge (TPK)

Technological Pedagogical Knowledge (TPK) is the common area between technological and pedagogical knowledge (Farah, et al., 2016a). TPK area is a combination of how we teach (using which method of teaching) and what we use from the technological tools to implement our teaching (Farah, et al., 2016a). Martin (2015), Koehler et al. (2014), Mishra and Koehler (2006) claimed that learning and teaching would be changed when new technologies are integrated in a specific way to shape education.

> Technological pedagogical knowledge is an understanding of how teaching and learning change when particular technologies are used. This includes knowing the pedagogical affordances and constraints of a range of technological tools and resources as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies. (Harris, et al., 2009, p. 398)

Ghavifekr and Rosdy (2015) stated that TPK makes it easy to realise the role of technology in promoting pedagogical dimensions since technology offers teachers new teaching methods that can improve learning. Portable devices, such as the iPad can be considered a good example of TPK since these devices offer many applications (Apps) to implement learning. These applications support and promote pedagogical dimensions, such as collaborative learning and constructive learning (Valstad & Rydland, 2010), for more information, please refer to section 2.4.1

2.8.1.7 Technology, Pedagogy, and Content Knowledge (TPACK)

Maor (2013) stated that the creation of TPACK extended the goals of learning by adding technology to Shulman’s framework.

The combination of technology, pedagogy and content knowledge have shaped the TPACK model, making it one of the primary models that can be used to implement learning effectively (Koehler & Mishra, 2009; Kushner Benson & Ward, 2013). "An important theoretical framework that has emerged recently to guide research in teachers’ use of ICT is the technological pedagogical content knowledge (TPACK)" (Chai, et al., 2013, p. 31). Schmidt et al. (2009, p. 125) claimed: “TPACK is a useful frame for thinking about what knowledge teachers must have to integrate technology into teaching and how they might develop this knowledge”. Mishra and Koehler (2006) defined TPACK as a framework for effective education relies substantially on using technology effectively to represent the concepts and sufficient experience in the constructive methods of teaching. Thus, learners can develop a new understanding of the world around them.

Voogt et al. (2012) claimed that only a few studies investigated the meaning of TPACK. Thus, there is a need for more studies to strengthen the areas of weakness, fill the gaps in knowledge, explain the relationship between the elements of TPACK, clarify the differences between these elements and to show the significance of each element and its contribution to the framework.

Voogt et al. (2012) recommended three different directions for future studies on the development of the TPACK. Firstly, if TPACK is conceptualised as the knowledge base a teacher requires to teach with technology effectively, then there is a need for a better understanding of what that knowledge base is for particular subject domains.

Secondly, further research should focus on the complex relationship between TPACK domains, which includes teacher knowledge and beliefs. Finally, there is a need for valid and authentic instruments that can assess a teacher's TPACK. This was echoed by Graham (2011), who believed that the TPACK framework has the potential to contribute a strong foundation for educational technology research. However, for that potential to be achieved, researchers must work together to define TPACK domains (components) and find out how these domains are related to each other.

Mishra and Koehler (2006) stated that separating the three elements (content, pedagogy and technology) does not offer an accurate description of the TPACK model since a change in any one of these elements has to be compensated by changes in the other two. Bruce (1997) and Koehler et al. (2013) suggested that treating any of these elements separately can be considered as a real disservice to effective teaching and learning since, content, pedagogy and technology exist in a dynamic transactional and equilibrated relationship.

Mishra and Koehler (2006, p. 1029) suggested that "developing good content requires a thoughtful interweaving of all three key sources of knowledge: technology, pedagogy, and content". This would suggest that the three factors in TPACK (content, pedagogy, and technology) should act as one unit to maintain the state of dynamic equilibrium of learning (Kuhn, 1977). However, Harris et al. (2009) stated that there should be extensive research to demonstrate what teachers need to know about TPACK domains and their interrelationships. The TPACK itself does not illustrate how this can be accomplished.

Based on these perceptions, I would suggest that the TPACK framework depends on both students and teachers. For TPACK to be applied successfully, the educational roles must be distributed to the members of the learning process. Students have to improve their skills in using digital technology as users and knowledge producers rather than receivers only. Hence, social communications and critical thinking aspects could be improved as students will be able to create, share and invent new knowledge. On the other hand, teachers have to develop their skills in digital technology as users, knowledge developers and producers. Teachers must have a deep understanding of the pedagogical dimensions and a substantial background in the taught subject (the content knowledge). Furthermore, the teacher has to create suitable environments (container) where TPACK elements can be placed and combined. Hence, the complex interaction between these elements takes place, which can be regarded as the integration of digital technology and education or educational technology.

2.9 THE ENTRANCE TO TRANOLOGY

This section outlines two types of learning: traditional and digital technology-based learning and their contribution to forming a new academic term called *Tranology* or *Tranology-based learning*. The term Tranology itself is discussed in sections 2.9.3and 8.4.

2.9.1 Traditional Teaching (Nondigital Technology-based Learning)

According to Simpson (2013), the traditional classrooms adopt textbooks (hardcopies), chalkboards, papers and pencils to implement learning. Bracey (1991) and Cuban (1991), cited in (Simpson, 2013), found that traditional teaching methods improved American students' attainment in core subjects and basic skills, such as reading and maths. During the traditional teaching time, which is limited, students would have the chance to ask about the concepts they did not understand (Simpson, 2013). After teaching specific content, a task would be given for students to check their understanding. According to Ipatenco (2010), cited in (Simpson, 2013), students learn effectively when they are supported by the teacher's guidance associated with face to face interaction, hands-on exercises, group work, and various educational resources.

Some teachers adopt traditional teaching techniques because they were taught in this way when they were students (Windschitl, 1999). Therefore, moving towards digital technology-based learning requires a substantial change in teachers' behaviour. This was supported by Pierce and Ball (2009, p. 299), who argued that "it is useful to consider what affects teachers' intention to change from this traditional approach and to use technology in teaching".

Teacher education programs are arranged in colleges and universities to train pre-service teachers to become teachers. Lowery et al. (2012), claimed that if these programs are arranged and instructed through traditional methods, i.e., lectures, drill, practice, direct teaching, chalkboard, then new teachers will follow the same pattern. Therefore, their classrooms are usually teacher-centred, i.e., knowledge and skills are transferred from a teacher to students as the teacher controls the learning process.

According to Ram (2008), traditional teaching is based on face-to-face interaction between teacher and students. For instance, during the traditional lecture technique, the teacher stands before a class to present orally new knowledge and experience (Marmah, 2014). Through this approach, teachers usually spend much time speaking and explaining the content, while students are typically requested to listen to the teacher (Wang, 2007). Students are expected to memorise concepts and a rote glossary of terms from textbooks (Wang, 2007).

Traditional teaching methods are based on three different techniques: lecturing, whole group discussion and drill and practice (Simpson, 2013).

Lecture

The lecture is a traditional teaching technique that is regularly utilised in schools, colleges and universities. Held and McKimm (2009) described the lecture as a method of teaching applied to transfer new knowledge and skills to stimulate further learning.

Ruyle (1995) defines the lecture with simplicity, stating that it is an oral presentation of the content knowledge. Swanson and Torraco (1995) defined the lecture method as a set of teaching techniques that commences with a literal reading of essential paragraphs from the textbook, followed by the teacher’s explanations and interpretations of these paragraphs while students are requested to remain seated, listen and take notes. Vella (1992), cited in (Sullivan & McIntosh, 1996), described the lecture method using a medical perspective, as the prescribed presentation of knowledge performed by the lecturer. Thus, students can recall this knowledge whenever it is needed, for instance, during the examination process.

Machemer and Crawford (2007) argued that the previous studies are mixed regarding the attitudes towards traditional lecture as a method of teaching compared to other methods that challenge students. Machemer and Crawford (2007) and Struyven et al. (2008) found that students value the lecture method as an effective strategy that can improve their performance in the exams. Griffin and Cashin (1989) believe that the one-way design of communication in traditional teaching, where the teacher speaks, and students listen, makes the lecture method an ideal technique to cover the content, and would thus promote factual learning. Goldstein and Benassi (2006) affirmed that traditional lecture leads to a well-managed, structured and organised classroom. Simpson (2013) stated that traditional lectures could be used to deliver critical experience, theories, and concepts to be discussed later in small group environments or during an exercise.

"The lecture method has been criticised for being outdated, being a passive mode of learning which restrict learners to listening and note-taking, and it is a poor way of enhancing the memory of learners" (Mwathwana, et al., 2014, p. 83). In turn, this implies that the lecture technique limits the interaction between the teacher and students and students themselves. This claim is supported by many educators and methodologists, who criticise a lecture as a method of teaching for its regular one-way communication, see for example McIntosh (1996) cited in (Sullivan & McIntosh, 1996) and (Mwathwana, et al., 2014). Munson (1992) cited in (Sullivan & McIntosh, 1996) regarded the lack of communication as one of the significant limitations of the traditional lecture. Moreover, when students have manuscripts of the lecture notes, a considerable portion of students would prefer reading them in isolation from the classroom (Sullivan & McIntosh, 1996).

Traditional lecture as a method of teaching has survived in most of the academic institutions, due to the reasonable cost of transmitting factual knowledge to students (Held & McKimm, 2009). This idea is backed by Marmah (2014), who claimed that:

> …in many developing countries lecturing is the dominant and traditional method of instruction. The reasons for their popularity are not farfetched. Lecture method is quite economical, and it is possible to handle a large number of students at a time and no laboratory, equipment, aids, and materials are required. (Marmah, 2014, p. 603)

Marmah (2014) pointed out several disadvantages of the lecture as a method of teaching, such as the lack of engagement, causing students to become passive learners. Students who are keen on learning techniques other than auditory in a lecture will find it difficult to be engaged by lecture. Consequently, students often find lectures boring and easy to be distracted. Due to the delivery setup, students may not be able to ask questions about the ideas they do not understand. Furthermore, teachers cannot check students' understanding accurately (Marmah, 2014).

Marmah (2014, p. 604) claimed that "this strategy is unhelpful for students who are poor in note-taking skills and disadvantaged students (handicapped students). It is a mistake to assume that all college students are competent note-takers". In turn, this would encourage teachers who adopt the lecture as a method of teaching, to ensure that students are well trained in note-taking skills, assist students in understanding verbal clues and learning methods of organising.

To enhance teaching through lectures and shift student's role from passive to the active learner, Sullivan and McIntosh (1996) suggested some characteristics of the effective lecture, such as careful planning for the lesson, two-way communication between students-teacher and students with each other, shared responsibility between teachers and students to implement learning successfully and to include problem-solving activities within teaching and learning process.

According to Sullivan and McIntosh (1996), the careful planning of a lecture requires a teacher to state the purpose of the lecture clearly; consider the logistics of the lecture; design diverse approaches to implement teaching and learning, such as the use of questioning, small group activities, drill and practice; and finally, prepare in advance the lecture notes.

Whole Group Discussion

Whole group discussion is described as a discussion between the teacher and students, and students to students through an oral exchange of knowledge, with a possibility for students to discuss conceptual problems, think aloud and get prompt responses (Dallimore, et al., 2008). Through this technique, students and the teacher are in charge of exchanging knowledge. The direct interaction between a teacher and students is an advantage of this teaching strategy (Omatseye, 2007). Students remain engaged as they may be asked to participate during the discussion. Hence, teachers can check students' understanding using short questions during the discussion (Kelly, 2012) cited in (Simpson, 2013). A student can also benefit from other students' discussions, questions and the given answers. Eventually, the teacher and students have a shared sense of satisfaction when they construct new knowledge, overcome difficulties, or solve a problem simultaneously (Ram, 2008).

"Students in a discussion class are not passive listeners; neither is the teacher a sole performer. Students are allowed to develop critical thinking ability, learn to evaluate ideas, concepts and principles, procedures and even programmes" (Omatseye, 2007, p. 88). For instance, students involved in a group discussion learn how to defend their viewpoints rationally, argue logically, define concepts and terms clearly, evaluate their answers reasonably, criticise it and acknowledge limitations in their produced work.

Johnson and Johnson (1999)stated that the discussion strategy promotes the collaboration between teacher and students and amongst students. Bennett (1995) and Moradi et al. (2018) claimed that such collaboration enhances students' academic accomplishment, interpersonal relationships and intrapersonal skills. Bender (2003), Davis and Hillman Murrell (1993) and Garside (1996) argue that all students, including high, average and low achievers, benefit from group discussion during the teamwork. Discussions are regarded as an active approach to learning; it promotes critical thinking and higher-order cognitive skills and more in-depth learning (Garside, 1996).

Nicol and Boyle (2003, p. 458) have found that learning through discussion in small groups "lead to improvements in students' conceptual understanding". Likewise, Rabow et al. (1994) claim that if students learn through discussion in small groups, they are expected to be involved more in their learning. In turn, this implies that students will be shifted from the stage of being passive to active learners since discussion groups promote "a high level of analytical thinking" (1994, p. 1), i.e., improves students' critical-thinking skills.

Some researchers claimed that the mere application of discussions strategy does not guarantee the successful implementation of learning. For instance, Laurillard (2002, p. 158) observes that peer discussions do "not necessarily lead them to what they are supposed to know" as some students lack the sufficient knowledge to achieve the expected learning outcomes. Nicol and Boyle (2003, p. 457) explain the challenges teachers encounter when they try to apply "methods centred on dialogue and discussion" as group size increases. Occhipinti (2003) suggested a solution to overcome this limitation, which is to divide students into small groups. Hence, a teamwork environment can be created, i.e., collaborative learning.

The time constraint is another example of the challenges that teachers face when they attempt to apply this technique. According to Ram (2008), time limitations may hinder lengthy discussions on a specific problem. Therefore, the teacher and students may not have a mutual sense of satisfaction. Also, the discussion can go off-topic quickly; hence some students can be distracted. Some students may feel uncomfortable with being placed on the spot during the discussion.

Previous studies suggested procedures to implement the discussions in the classroom effectively. For instance, Simpson (2013) suggested that teachers need to manage the lesson time effectively, facilitate the discussion, and highlight the new topic ahead of time, so that students can prepare the topic in advance. As such, a successful whole-class discussion can be created. Flynn and Klein (2001) stated that students' discussions have been found more productive if students prepared the topic in advance. In line with Flynn and Klein (2001), Dreikurs et al. (1982) suggested the application of a group-oriented pattern, where students' discussions are supported by the teacher's guidance, clear rules and regulations are stated in order to maintain the class focused and oriented towards learning the content at hand.

Drill and Practice

Traditional techniques extend beyond lecture and whole-group discussion. Drill and practice is also a method of traditional teaching. Vazquez-Abad and LaFleur (1990), asserted that repetition, previous instruction, and feedback are essential components of drill and practice approach to learning.

Through repetition process, the acquired knowledge is promoted, students can do repetition on their own as many times as they need (Decoo, 1994). Lewis (2019) asserted that students could solidify newly acquired knowledge when teachers drill through various practice in an effective plan. However, if drill and practice technique is overly used, students may merely start to learn things for the sake of being able to move to the next topic without gaining a full understanding of the taught concepts (Simpson, 2013).

According to Wilson (2004), learning strategy addressed as drill and practice is usually looked at with a negative attitude since they only consider low-level skills. Nevertheless, Salisbury (1990, p. 23) claimed that "recent research on cognitive learning suggests that the role of drill and practice in learning may be more important than has previously been realised".

Since fundamental units of knowledge can be broken down into tinier units, it is the drill and practice strategy that appears to fit well in learning these subunits and assist students mastering subskills and knowledge. This claim is supported by Vazquez-Abad and LaFleur (1990, p. 43), who applied the drill and practice strategy "in which a learning task is broken into subtasks, and then each of these is taken in turn, using feedback to reinforce mastering of each subtask as well as to correct failure to master". Moreover, Vazquez-Abad and LaFleur (1990) recommend some situations where they believe that drill and practice fit best:

> Any time that a job or task calls for 'learnable' subtasks that have to be performed automatically, or when a skill has been targeted for instruction which must be brought in while performing a (more complex) task, we may then be dealing with prime candidates for drill and practice. (Vazquez-Abad & LaFleur, 1990, p. 44)

Lewis (2019) claimed that drill and practice as a method of teaching provide students with mastery of basic knowledge, which is considered, according to Lewis, a prerequisite for acquiring higher-order cognitive skills. Bardenstein (2012) claimed that the disadvantages of drill and practice underlie in the fact that students view it boring activity as they can be distracted easily. Moreover, students may start to rely on just memorising to prepare for the assessment without a deep understanding of the material. Lewis (2019) claimed that just remembering without mastering the delivered knowledge can cause difficulties later when attempting to perform more complex tasks — being aware that memorising is considered as a low order cognitive skill while complex tasks require a higher-order cognitive skill (bloomstaxonomy.org, 2018).

In terms of comparing the impact of drill and practice and the impact of computers on students' learning, Decoo, (1994) claimed that computers are usually misused in education by the users, including students, while drill and practice strategy would seem effectively used. "We may be putting too much of our energy into low-impact CALL (computer-assisted language learning) while neglecting somehow the high-impact drill and practice of CALL" (Decoo, 1994, p. 153).

Based on the discussion of the traditional teaching methods; lecture, whole-group discussion and drill and practice, it can be stated that these methods are applied in the case of digital technology-based learning as well, but the presence of digital technology tools make its presentation different, which plays a considerable role in shaping students' attitudes towards learning. Therefore, this thesis would suggest adopting the term nondigital technology-based learning to express traditional teaching. Furthermore, since there is a possibility for students to be shifted from the stage of being passive to active learners during traditional teaching, this thesis suggests transforming the term traditional teaching to another term, which is traditional-based learning, i.e., moving the process from teaching to learning.

2.9.2 Digital Technology-based Learning

According to Bates (2015), the relationship between technology and education goes back at least 2500 years when verbal communication was the earliest technological tool used for learning. In line with Bates (2015), Salavati (2016) claimed that before the 5th century BC, knowledge transmission was based on recitation, not on writing. Over time, many technologies have been invented to facilitate oral communication. In the 5th century BC, written documents were presented in ancient Greece. In the 12th century, the slate board was used in India. In the 18th century, chalkboards were used in some schools in Western countries. Projectors were used after the 1950s and became generally employed for lecturing until the1990s as other advanced digital technology software, such as PowerPoint and pages were introduced, which initiated the digitalisation era (Salavati, 2016).

The adoption of digital technology has led to essential changes in both structure and functionality of teaching and learning. For instance, digital technologies promote new kinds of learning, such as distance learning. Indeed, the use of digital technologies transforms traditional teaching and supports the adoption of new curricula and pedagogies (Petridou & Spathis, 2001). Bates (2015) claimed that the successful integration of digital technologies and education requires two factors, reorganisation and restructuring. However, these two factors are expensive. Therefore, schools' investment in digital technologies ensures minimum organisational and structural challenges, which may not have a significant impact on learning (Bates, 2015).

Canough (2013) argues that understanding the role of digital technology in the learning process and the ability to use it effectively, is a significant factor to implement learning successfully. Griffin (2003) affirms that the primary motivation to integrate digital technologies and education is to improve students’ learning. Bates (2015) and Griffin (2003) state that it is challenging to address the most effective and appropriate digital technology that can be used to implement a specific task. Mishra and Koehler (2008) suggested that the adoption of specific digital technology is based on the curriculum design, the targeted content knowledge and the teachers' beliefs and values about teaching and learning. For more details, about technology beliefs and attitude in education, see section 3.7.

2.9.2.1 The Impact of Digital Technology on Students' Learning

In an educational context, the rationale for using digital technology is based on the belief that it impacts teaching, learning or both, positively (Newhouse, 2002). Various governments have invested massively in digital technology for their schools (Pilkington, 2008). Several studies have investigated whether this investment has been worth the cost, and suggested that these investments could improve teaching and learning, see for example Kulik (2002) and Harrison et al. (2002).

Quantitative and qualitative researches have been carried out in an attempt to evaluate the impact of digital technology on students' learning (Harrison, et al., 2002; Underwood, et al., 2005; Jenkinson, 2009). On the one hand, quantitative approaches investigated the impact of digital technology through the relationship between the use of digital technology and students' attainment. On the other hand, qualitative approaches have attempted to understand the impact of digital technology on students' learning through observations in classrooms, collecting teachers and students thoughts and attitudes (Newhouse, 2002; Higgins, et al., 2012).

This section outlines the impact of digital technology on students' learning through diverse types of digital technology that have been adopted in this study to investigate the impact of using educational technology (digital) on students' attainment, such as simulations, educational videos, interactive whiteboard and virtual learning platforms, including learning management system (LMS).

The use of simulations in education

In educational settings, a simulation is a software that imitates a complicated real-life situation. Thus, learners are offered the opportunity to develop a new understanding of complex phenomena (Kincaid & Westerlund, 2009). Computer simulation as a teaching tool provides students with practical experience as it offers students the possibilities to examine situations that mirror real-world circumstances or complex schemes. In turn, it enhances a student's engagement and conceptual knowledge (Kirkley & Kirkley, 2005).

Computer simulations are commonly applied in science subjects. Squire (2004) claimed that computer simulations enabled students to understand the complex concepts of physics. In line with Squire (2004), Bell and Smetana (2008) stated that computers could present three-dimensional simulations, which assist teachers in bringing more complex phenomena to life. "Simulations are experiential exercises that transport learners to another world. There they apply their knowledge, skills, and strategies in the execution of their assigned roles. For example, engineers may diagnose the problems in a malfunctioning steam plant" (Gredler, 2004, p. 571).

Kulik (2002), Hennessy et al. (2007) and Taher and Khan (2014) claimed that computer simulations promote inquiry-based learning and higher-order thinking skills. Consequently, it improves students' understanding and accomplishment in subjects related to science, such as physics, biology and chemistry. Akpan (2002) investigated the influence of displaying a computer simulation to introduce a concept, such as three-dimensional simulation of dissection and anatomy. Akpan (2002, p. 13) found that "the flexibility of these kinds of environments makes learning right and wrong answers less important than learning to solve problems and make decisions".

Figure 15 shows an example of an educational simulation of a physics laboratory. The application of this simulation provides students with virtual equipment and materials, such as springs, stopwatch, scales. Using these tools, students run virtual experiments, collect and graph data, and build new knowledge based on the interactive environment. The percentage error in the collected data using such simulation compared to actual experiment using real equipment is negligible as human errors are minimised in the simulations.

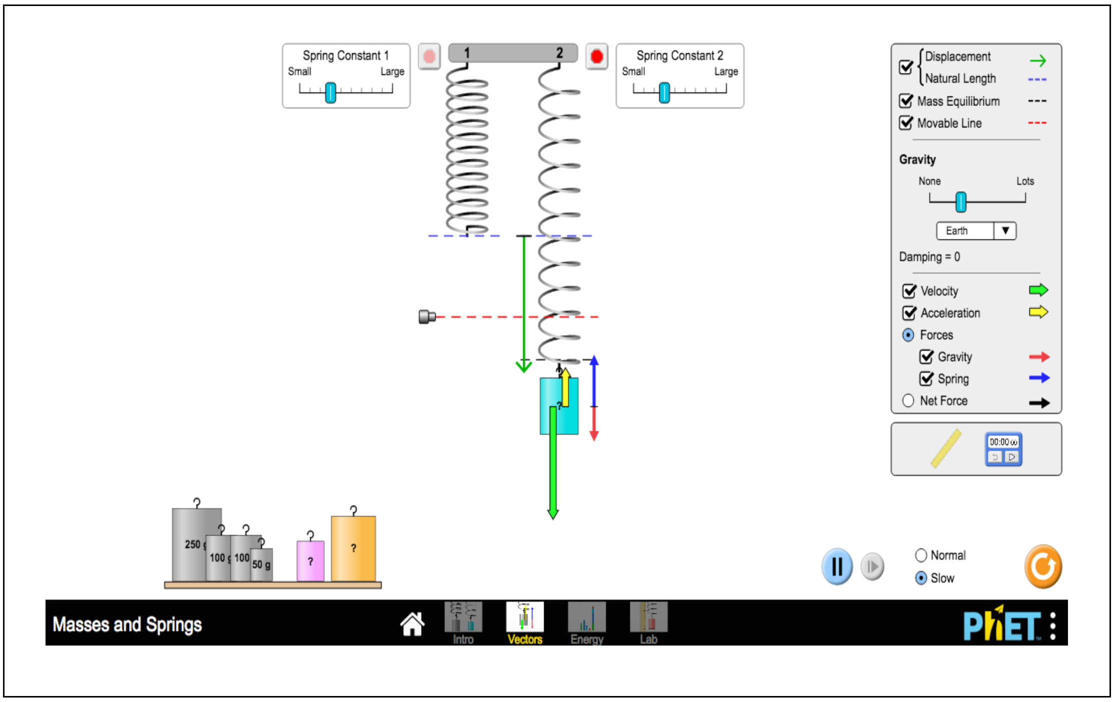


Figure 15. Hooke’s law simulation (spring-mass system). The directions of the velocity, acceleration, gravitational and spring force are shown in the simulation. ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_en.html

Taher and Khan (2014) claimed that simulations are useful tools for learning as students explore new knowledge and develop their conceptual understanding. Simulations typically incorporate rich virtual environments that provide students with the experience of how several conditions interact with each other to produce meaningful data (Madathil, et al., 2017). See Figure 15 as an example.

Simulation systems are capable of mimicking detailed phenomena, such as thermal energy, motion and oscillations. According to Kincaid and Westerlund (2009), simulations are divided into three different categories. Firstly, live simulations where real people utilise real tools, such as surgeons training and aviation exercises. Secondly, virtual simulations, in this type of simulation, learners deal with a simulated environment electronically, such as flight simulators and surgical simulators. Finally, constructive simulations where mock people using simulated tools in a synthetic environment. Kincaid and Westerlund (2009) argued that simulations are used extensively in science, engineering, aviation and many other fields of knowledge. However, to maximise learning outcomes, it is significant to use a suitable category of simulations. In other words, the displayed simulation needs to be planned according to the learning objectives and expected outcomes. Before running a simulation, the teacher needs to prepare students by addressing the required content, concepts and skills that are important for them to know. Hence, students can determine the scope of the simulation.

Simulations offer students the possibility to practice problem-based learning throughout particular tasks that require critical thinking and higher-order cognitive skills (Gredler, 1992). The use of simulations supports the social constructivism aspect of learning as students harvest meaningful knowledge from their interaction with the created environment. The cognitive disagreement between students acts as an incentive for learning. Thus, using simulations, experience evolves within sociocultural negotiation and individual understanding (Kirkley & Kirkley, 2005).

Hertel and Millis (2002) asserted that simulations offer students an authentic experience, and as such, simulations require a student's entire engagement and cooperation. Sequentially, students develop leadership skills and get more experienced at investigation and problem-solving schemes. Brumfield (2005) asserted that the constructivist learning context is created whereby students knit together interdependent factors and knowledge to resolve real-life problems. Hence, simulations support a transfer of knowledge and assist with not only learning inside the classroom but also the application of a specific concept outside, in the real world. Ultimately, it can help students to think critically in a complicated situation (Brumfield, 2005).

Hertel and Millis (2002) suggested that simulations personalise learning as students have the ownership of their roles, the responsibility toward their designated activities. Through a simulation, the teacher performs more as a facilitator and supporter. Simulations capacities grant possibilities for outlining innovative learning environments that facilitate more interactive, relevant, and efficient implementation of the content (Kirkley & Kirkley, 2005). Simulations support a more in-depth exploration of complicated concepts with greater student engagement and entertainment in the learning activity (Adams, et al., 2008).

The use of simulations only cannot guarantee a successful implementation of learning. However, it can offer a well-designed curriculum by making its content more transparent to students (Reid, et al., 2013). In turn, this implies that the simulations cannot replace the teacher or the instructional design.

Teaching science using PhET simulations

The Physics Education Technology (PhET) simulations, developed by the University of Colorado, (Finkelstein, et al., 2005), “are used by millions of teachers and students worldwide” (Price & Perkins, 2016, p. 2). It is used substantially in teaching and learning science, including physics, chemistry and biology (Madathil, et al., 2017). PhET simulations designed the interactive content in the form of virtual laboratories and problem-based learning to be used individually or within small groups. This implies that students can investigate complicated real-world situations using a virtual platform (Adams, et al., 2008). For instance, using PhET simulations, students can construct electric circuits, connect the resistors in series or parallel, check the direction of electrons flow and measure many other factors, such as the electric current, potential difference and equivalent resistance (Wieman, et al., 2010).

Wieman et al. (2010) pointed out five basic strategies required to use PhET simulations effectively. Firstly, stating clearly the learning objectives. Secondly, creating a connection between students’ previous knowledge and the new concepts that are intended to be taught and learned. Thirdly, introducing the real-world problem, which will be investigated by students through the planned simulations. Fourthly, encouraging collaborative and constructive approaches to learning. Finally, encouraging higher-order thinking skills, such as analysis, synthesis and reasoning.

PhET simulations can be employed to introduce new topics (lecture), create the connection between the theoretical and practical content and also as virtual laboratories (Perkins, et al., 2006). For instance, PhET simulations as animated illustrations demonstrate invisible phenomena or particles cannot be visualised by the naked eye, such as photons, electrons and any other subatomic particles. In other words, it makes the invisible visible. Moreover, it can be used to test a concept, such as the conservation of mechanical energy and the relationship between the kinetic and potential energy, see Figure 16.

Students can investigate the concept of mechanical energy using the skater in PhET simulation, as shown in Figure 16. After which, students can write down their notes, construct and share new knowledge and draw their conclusions, which will be discussed with other students in the classroom. As a result of using such simulations, many spontaneous questions from students starting by ‘what if’ emerge. Addressing these questions offer students new knowledge that was not planned by the teacher.

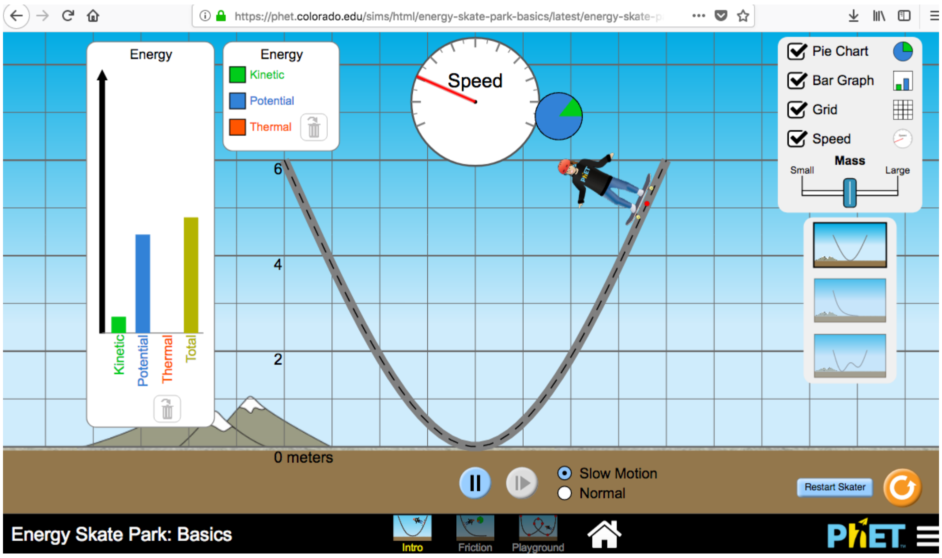


Figure 16. Energy skate park and the conservation of mechanical energy ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/energy-skate-park-basics/latest/energy-skate-park-basics_en.html

According to Perkins et al. (2006) and Wieman et al. (2010), the use of PhET simulations serves learning in many aspects. Firstly, implementing some experiments that cannot be conducted inside the classroom for several reasons, such as the required tools are not available or difficult to set it up in the laboratory. Secondly, it makes the invisible visible. Thirdly, it creates connections with real-world applications. Fourthly, it saves time as the implementation of some experiments, using real equipment, is time-consuming. Fifthly, adjust and control interacted variables cannot be controlled easily in the real-world experiments, such as the amount of light in the photosynthesis and the photon's frequency in the photoelectric effect. Finally, it promotes several pedagogical dimensions, such as self, constructive and collaborative learning.

Comparing with direct teaching, PhET simulations are effective tools that can offer a high degree of interactivity to implement learning allowing students to develop their conceptual understanding of science (Price & Perkins, 2016; Adams, 2010). Adams (2010) claimed that direct instruction could not engage students with their learning; neither activating them to create connections between different concepts and draw conclusions. Finkelstein et al. (2006) claimed that the use of PhET simulations during a lesson leads to create more conceptual questions when compared to direct instruction or a demonstration using real equipment. Finkelstein et al. (2005) stated that several studies compared the effectiveness of PhET simulations to real-world equipment. These studies showed that PhET simulations offer students more in-depth conceptual understanding of physical phenomena.

Mayer (2004), claimed that even if students are supplied by the real equipment, such as batteries, lamps and resistors to construct an electric circuit, without clear instructions, students are quickly distracted, confused, not sure of what they need to do and what they should learn. Finkelstein et al. (2005) in an algebra-based physics course, divided students into two groups. The first group used PhET simulations, and the second group used real equipment, such as resistors, ammeter, bulbs, wires. The final exam about DC (direct current) circuits was conducted six weeks later. The group who used the PhET simulations performed statistically better than the second group who used real equipment. The averages for the two groups were identical on other exams that were not related to DC circuits. Besides, in a practical activity, both groups used real equipment to construct a DC circuit. The students who used the simulations were faster in completing this task, more comfortable and did not need much assistance from the teacher, unlike other students who used the real equipment.

Adams (2010) claimed that when using PhET simulations, minimal guidance from the teacher is required. Consequently, students can be shifted to the stage of being self-guided users. Adams (2010) observed students while investigating a physical phenomenon through PhET simulations. The open conceptual questions encourage them to explore various factors related to the subject. Therefore, the teacher’s supervision can be in the form of conceptual questions related to the investigated concept or physical phenomena. After discussing the conceptual questions, students play the simulation and think out loud, attempting to find answers for the conceptual questions. Adams (2010) found that during this self-guided engaged investigation, students construct their mental framework and fill in the constructed knowledge.

Learning is an active process only when students are sense makers of what they learn (Bransford, et al., 2000). This implies that learning is not mere receiving and memorising but thinking and reasoning. The use of PhET simulations allow students to make sense of the learned knowledge, and thus they can develop new understandings. This provides students with a sense of accomplishment with each success rather than frustration (Malone, 1981; Adams, 2010).

Note: simulations in general and PhET simulations, in particular, were used substantially in this study, as part of the interactive curriculum. For more details, please refer to Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

The use of video in education

Siemens et al. (2015) described the video as a digital content consisting of sound and images that can be stored, shared, and streamed to a range of devices. Siemens et al. (2015, p. 204) claimed that “Educational technology has gone through three distinct generations of development and now a fourth is emerging”. Woolfitt (2015) claimed that the fourth-generation involves the use of video in education. Kaltura in 2015 discussed the use of video in education and stated that:

> Video is permeating our educational institutions, transforming the way we teach, learn, study, communicate, and work. Harnessing the power of video to achieve improved outcomes. For example, a better grade in exams/assignments or more effective knowledge transfer is becoming an essential skill. A key pillar in the drive towards improved digital literacy, video brings considerable benefits to educational institutions: streamlined admissions, increased retention, and improved learning outcomes. (Kaltura, Inc, 2015, p. 1)

Bransford et al. (2000) explored the use of video in education and the significance of interactivity in supporting students’ learning by granting them the opportunities to review the content whenever they need. The findings of their study showed the positive impact of interactive videos on students’ understanding. In line with Bransford et al. (2000), DeBoer (2013) stated:

> The emergence of digital networks, like the internet, disconnected video-watching from a set time because the video can be watched at any time. It has also led to disconnecting the lesson, in some sense, from a set place (i.e. the classroom): the video can be watched on any computer connected to the internet. (DeBoer, 2013, p. 17).

Shifting students to the stage of being disconnected from the lesson inside the classroom, teacher and other students, is a consequence of using digital technologies, such as videos. Siemens et al. (2015, p. 205) described this as “thinning of classroom walls where learners are now able to use a range of technologies and interactions with learners and content from around the world”. In turn, this implies that students have opportunities to exchange knowledge and check different learning resources outside the classroom (Baggaley, 2014; Fox, 2013)

The rapid evolution in digital technology enables students to access videos using several virtual platforms and devices (Bates, 2015; Open Education Special Interest Group, 2014). Greenberg and Zanetis (2012) state:

> Education is undergoing a major shift, as brick-and-mortar classrooms are opening up to rich media content, subject matter experts, and to one another. This shift has been influenced largely by technological and pedagogical trends, greater worldwide access to the Internet, an explosion of mobile phone users, and the appreciation for these technologies by young people, as well as by teachers. Video appears poised to be a major contributor to the shift in the educational landscape, acting as a powerful agent that adds value and enhances the quality of the learning experience. (Greenberg & Zanetis, 2012, p. 4)

Teaching through videos requires a modification of the teaching activities and methods (Guo, et al., 2014). Greenberg and Zanetis (2012) stated that some teachers adopted videos in their teaching as effective learning tools, while other teachers do not have adequate experience to teach effectively through videos. This was echoed by Beaudoin (2014), who found that some teachers do not consider recording lecture's content or inserting videos in their teaching necessary to their jobs.

Using YouTube for Education

YouTube is a well-designed video website that allows users to download, upload and share videos (Duffy, 2008). YouTube was established in 2005 and is a depository for users’ content. Anyone has an internet connection can access the content on YouTube (videos); however, to upload a video, a user needs to create a free of charge account (Burke, et al., 2009). Kim (2012) claimed that YouTube has been shifted from the stage of having mainly users for the generated content, i.e., consumers, to another stage, where users can professionally create content.

Snelson (2011) conducted a review of journal articles related to the use of YouTube. Among 188 peer-reviewed articles, 30 were related to the field of education in diverse areas, such as science and nursing education and higher education. Berk (2009) stated that the use of multimedia videos on YouTube enhances learning in higher education level. Such videos can have a substantial impact on students' learning and encourage them to make sense of the learned topics. According to Berk (2009), using videos in the classroom engage students' effectively, steer their concentration, develop their imagination and improve their attitudes towards learning.

Agazio and Buckley (2009) investigated the use of YouTube throughout various levels of education. They stated that the use of YouTube in both stages; undergraduate and postgraduate, provides flexibility and a more in-depth understanding of the complicated concepts. Tan and Pearce (2011) claimed that YouTube videos could explain critical ideas in a sociology course. The videos were followed by a discussion between the group's members inside the classroom. Tan and Pearce (2011) claimed that the use of YouTube videos was viewed by students and teachers as a useful learning tool. Therefore, Roodt and De Villiers (2011) suggested that the use of YouTube inside the classroom promotes the social constructivism in general and collaborative learning in particular since YouTube's content is a suitable environment for students to interact with, collaborate to reach a common understanding, and build new knowledge through sociocultural context. Additionally, they claimed that the use of YouTube as an innovative educational technology influences students' learning positively.

Game-based learning is another type of digital technology resource that has been employed for teaching and learning complex concepts related to science and humanities (Plass, et al., 2015). Garris et al. (2002) and Squire (2004) claimed that several studies suggested the positive impact of games on students' learning and their cognitive skills. For instance, a study conducted by Squire (2004) to investigate the effect of using game-based learning in teaching and learning physics. Their study showed that computer games could be used to solve scientific problems and improve students' abilities in scientific representations. Shin et al. (2006) investigated the use of handheld gaming in teaching and learning mathematics. The authors found that these games supported students' in general, and low-achievers in particular, in learning mathematics.

Rosas et al. (2003) examined the impact of using educational video games on students' learning and motivation. They used video games to assist students in learning basic mathematics. The authors found that there is a significant difference, in terms of performance, motivation and attainment, between the students who utilised video games and the students who did not. Therefore, they claimed the positive impact of video games on students' learning and motivation.

A study was conducted by Lee et al. (2004), who used *Drill Skill Arena* software game which was designed to assist students in maths problems. They divided the students into two groups. The first group used the software, and the second group used traditional paper worksheets. Lee et al. (2004) found that students who used the game software performed better than the other group. In line with Rosas et al. (2003) and Lee et al. (2004), Squire (2004) claimed that educational games could enhance students' conceptual understanding.

Note: videos in general and YouTube, in particular, were used substantially in this study, as part of the interactive curriculum. For more details, please refer to Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

Another evidence about the impact of digital technology on teaching and learning is related to the use of **an interactive whiteboard** in the classroom. According to Fletcher (1990) and Harrison et al. (2002), the smart whiteboards influenced students' learning positively as it enables teachers to display knowledge through an incorporated text, images and audio. Nugent (1982) found that students' attainments were improved significantly when the knowledge was introduced to them through text, audio and figures. A study conducted by researchers at the University of Newcastle examined the effect of the interactive boards on students' performance in some selected schools. Their study showed that using the interactive whiteboard in the classroom enhanced students' performance in different areas, such as literacy and mathematics (Higgins, et al., 2005). Miller and Glover (2006) claimed that the use of interactive whiteboards for mathematics lessons could promote mathematics teaching and enhance students' engagement with their learning.

Learning management system (LMS) is another example of the digital technology-based learning. The LMS which was used in this study is the Desire to Learn (D2L) or (D2L-LMS), please refer to section 2.7.

Computer-supported collaborative learning (CSCL)

The use of digital technologies facilitates communication between students. For example, the internet allows students throughout the world to communicate and exchange their knowledge. Gilakjani et al. (2013, p. 51) stated: “another positive and desirable effect of bringing technology into the classroom is the increase in collaboration among teachers and students”. Marshall, 1995, defined collaboration as "a principle-based process of working together that produces trust, integrity and break-through results by building true consensus, ownership and alignment", cited in (Lehtinen, et al., 1999, p. 6). In turn, this implies that the collaboration process is based on the interaction between learners with complementary skills for developing a shared understanding.

The mere application of collaborative learning does not guarantee to promote higher-order cognitive skills and understanding the complex concepts. However, for effective implementation of the collaboration between students, interactive tools that belong to digital technologies are required (OECD, 2016). These tools offer students the flexibility to explore external resources and make their ideas and constructed understandings more transparent to others (OECD, 2016).

Many researchers suggested that the computer as an example of digital technology supports communication between learners. For example, Ghavifekr and Rosdy (2015, p. 175) claimed that the “Integration of Information, Communication, and Technology (ICT) in education refers to the use of computer-based communication that incorporates into daily classroom instructional process”. In line with Ghavifekr and Rosdy (2015), Lehtinen et al. (1999, p. 38) stated: "it is obvious that introducing a computer environment can improve the amount and quality of social interaction among students and between teachers and students".

The term ‘computer-supported collaborative learning’ (CSCL) focuses on how learning takes place among people with the help of computers (Stahl, et al., 2006) cited in (Jessel, 2013). Hence, a learner is no longer isolated from others as computers bring them together through “creative activities involving intellectual exploration and social interaction” (Jessel, 2013, p. 33).

Using CSCL, there is a possibility for learning to be socially constructed through knowledge-building communities (Scardamalia & Bereiter, 1994). Learners interact with each other and share different resources. Computers allow students to move through different virtual learning platforms. For instance, many academic institutions adopted digital networks (virtual learning platforms), including the learning management systems (LMSs) to organise learning. Hence, learners, using computers, can interact with each other, share their experience and look for new knowledge. Using these platforms, learners collaborate with internal communities, from the same institution, or external communities, learners from other institutions.

CSCL support various explorative learning activities, such as simulations, educational videos, virtual laboratories and game-based learning. Through these activities, students collaborate; participate as active members, exchange their experiences and develop their understandings. This idea is supported by Lehtinen et al. (1999, p. 17) who stated that "many different program types like databases, spreadsheets, maths programs, programming languages, simulations, multimedia authoring tools, etc. have been successfully used as tools to promote collaborative and cooperative learning".

Crook (1994) investigated the way computers can enhance collaborative learning. Crook distinguished between the interaction around and through computers. The first aspect concerned with using computers to promote face to face collaboration between students seated in pairs or small groups. Regarding the second aspect, which is the interaction through computers, it refers to the use of networks (the Internet) to provide education with various mediating tools for collaboration, such as e-mail, blogs, social media web sites.

Crook (1994) claimed that computers support collaboration between students by providing them with shared sources of knowledge. Thus, students' action and attention are focused. Crook argued that a traditional classroom lacks the required resources for supporting successful collaboration.

Note: in this study, the computers, MacBook Pro laptops and iPads were used to implement learning, including collaborative learning. Students used their virtual platforms, including LMS, emails and Airdrop to exchange some online links, documents, thoughts and ideas. For more details about collaborative learning, please refer to section 2.3.2.

2.9.2.2 *The Impact of Digital Technology on Teaching*

Having viewed studies related to the impact of digital technology on learning, it is now essential to review research on how digital technology impacts teaching. The potential impact of digital technology can be reached when teachers alter their teaching approaches. This claim is supported by Viadero (1997), who stated:

> "Placing computers and software in the classroom is not enough. Discovering whether technology 'works' is not the point. The real issue is when and under what circumstance. Like any other tool, teachers have to come up with a strategy or pedagogy to make it work." (Viadero, 1997, p. 16)

Adopting digital technology could assist teachers in planning and preparing their teaching more efficiently by enabling collaboration among them (Higgins, et al., 2005). Some teachers believe that there is no sufficient time to plan their lessons using digital technology (Underwood, et al., 2005). Some investigations, see, for example, the ICT Test Bed project, propose the contrary: digital technology can save teachers' time and efforts through creating and sharing (Somekh, et al., 2007). In turn, this would suggest that there is a need to show teachers how to integrate digital technology and education effectively, as they might not be doing it properly, so they consider it time-consuming. In terms of confirming the need for training teachers on using digital technology, Somekh et al. (2007) claimed that several studies investigated the impact of digital technology on teaching, implied that the infrastructure is available, especially in developed countries, but more enhanced training is required for teachers to promote innovative pedagogy.

International Telecommunication Union (ITU, 2003) claimed that digital technology provides students with significant learning opportunities and also it promotes self and constructive learning and thus, students can work independently. Consequently, teachers have sufficient time to plan lessons that fit the needs of other students, such as the low achiever students (ITU, 2003). Higgins et al. (2005) and Harrison, et al. (2002) claimed that the use of digital technology influences the collaboration between teachers, as they share different resources related to curricula, which reduces the preparation time for the lessons, sustains their teaching and ultimately improves students' learning. For more details about the impact of digital technology on teaching methods, please refer to sections 2.4 and 2.5.2

The studies mentioned above showed that there are various reasons for using digital technology in learning and teaching, such as improving students' understanding, motivating students to learn, promoting higher-order thinking skills and saving teachers' time and efforts. Overall, based on these experimental studies, it seems evident that digital technology has a positive impact on teaching and learning.

2.9.3 Tranology

This study introduces the term *Tranology* to refer to a combination of two main kinds of learning: traditional and technology-based learning. The new term Tranology or Tranology-based learning suggests that digital technology-based learning has to be used as a supplement to traditional learning, not as a replacement. Hence, these two components complement each other. In other words, traditional-based learning, represented by textbooks, papers (notebooks) and pens to be integrated with digital technology-based learning, represented by computers, smart devices and diverse applications (Apps).

Like any other learning approach, successful implementation of Tranology-based learning requires students to be active in both components; traditional and digital technology-based learning, as well as it requires effective integration of digital technology and education.

In this kind of learning (Tranology), students use both traditional and digital technological tools. Teacher's role is to monitor students' progress, give guidance and distribute tasks. This thesis suggests two stages underlie the application of Tranology. At the first stage, students will be activated through traditional teaching methods, such as lecture, group discussion and drill and practice, students need to participate in these methods effectively. Exposing students to traditional teaching techniques allow them to gain new units of knowledge. At the second stage, students need to expand the gained units of knowledge using digital technology, which leads to broadband their horizons and develop their critical thinking skills.

For instance, when students study a complex concept in the physics subject using traditional-based learning, i.e., nondigital technology-based learning. Students, as active learners, can master the gained knowledge theoretically. In other words, they can give definitions for the terms; to some extent, they can describe some real-life applications related to it; solve mathematical problems related to the concept.

Even though students are active learners during the traditional teaching methods, still there are covered areas that need more specialised sources of knowledge, such as recently published research, virtual laboratories and computer simulations (digital interactivity), to uncover it, i.e., bring a complex concept to life. Hence, students can create links between macroscopic and microscopic entities, explain the cause-effect relationships and describe accurately real-life applications related to the concept. For instance, digital technology allows students to visualise and investigate complex concepts, such as the dual nature of the electron, photoelectric effect and the uncertainty principle.

Passing through these stages, students' critical thinking skills can be developed. Hence, new knowledge, related to the concepts investigated, emerges. The combination of both learning systems to form Tranology-based learning can improve students' conceptual understanding and assist them in constructing new knowledge by accessing a range of knowledge resources. In turn, this implies that using *Tranology;* students can reach deeper learning. This claim would suggest that Tranology can be viewed as the road map, which assists students in moving from the surface to deeper learning. For more details about the surface and deeper learning, please refer to section 2.3.6. Further information about Tranology is given in section 8.4.

2.10 SUMMARY OF THE LITERATURE REVIEW

The literature review has substantially influenced this study since it has addressed and discussed the main areas investigated in this study. Therefore, I would claim that this chapter has provided a comprehensive view of these areas.

In this chapter, I discussed the term learning as a general term and its definition according to the literature reviews. The notion of technology and the concepts of digitalisation sections are added to discuss the terms technology, digital technology, and educational technology. Three different perspectives of learning, associationist, cognitive and situative, are described and added to this thesis. Thus, the relationship between the definition of learning offered by this thesis and these learning perspectives could be presented. This was followed by the learning theories (the pedagogical dimensions) that can be used in the classroom to implement learning, such as i) self-learning, ii) collaborative learning, iii) competitive learning, iv) behaviourism and direct teaching, v) cognitive constructivism learning, which has been discussed from three different perspectives: Jean Piaget, Vygotsky and Bruner. Moreover, I investigated the deeper and surface learning and explored the differences between them.

In this chapter, I explored the term Educational technology, including the historical background of ICT implementation and its implications. Followed by educational technology definitions and the relationship between digital technology and the pedagogical dimensions, such as i) social-collaborative learning, ii) constructive learning, iii) cognitive learning and iv) direct teaching. I presented a description of the learning management systems and portable devices as tools for education. The TPACK model as a mean for effective teaching and learning was discussed as well.

I explored the concepts of Traditional Teaching (Nondigital technology-based learning) and Digital technology-based learning and linked them to Tranology. Moreover, I investigated the use of Simulations, video, Game-based learning, Computer-supported collaborative learning (CSCL) and the learning management system (LMS) used in this study.

The literature review chapter participated in forming a better awareness of some essential research areas, such as learning theories (the pedagogical dimensions), the content knowledge and digital technology. Therefore, I would claim that this part of the study played a considerable role in the study approaches, highlighting the main areas in this research and identifying the knowledge gaps to be filled later using a specific framework and methodologies, which will be discussed more in detail in the next chapter. Moreover, this chapter fostered the research approaches as it participated in highlighting the theoretical framework of this study, see Figure 17 in the next chapter, where the focus is on the research methodologies and framework.

CHAPTER THREE –

Methodology

3 METHODOLOGY

INTRODUCTION

This chapter describes the steps of the conducted research, the paradigm in which it is located and the development process.

The first part of this chapter discusses the theoretical framework of the study. In this section, I outline the main areas of the conducted research, followed by a research paradigm and the study approach. The research paradigm is defined as an attempt to understand the surrounding as it is, based on the individuals' experiences, such as interviewing or observation (Kaplan & Maxwell, 1994). I included an overview of the United Arab Emirates (UAE), and the educational system of the UAE, as well as an overview of the Institute of Applied Technology (IAT) and the Applied Technology High Schools (ATHS). Moreover, I discussed the application of educational technology in terms of students' ethnicity and socioeconomic status (SES) in the Institute of Applied Technology through the lens of social constructivism. Teachers' pedagogical beliefs and digital technology-based learning are discussed as well.

The second part of this chapter describes the two main phases of the study. Firstly, the methodology of initial investigation (the pilot study), which was focused on teachers, so as to investigate their thoughts and ideas towards using educational technology. Secondly, the methodology of the main study (the in-depth investigation) represented by stages two and three, which investigated the impact of using educational technology on students' attainment.

The methods and instruments that were used to collect the data and a description of the samples recruited for this research are described as well.

Finally, I describe the statistical functions that were used to check the reliability and validity of the findings. The rationale for selecting the samples have been discussed in this chapter as well. The chapter concludes by considering the reliability and validity of the collected data and the ethical issues related to this research.

3.1 MAPPING QUALITATIVE RESEARCH

Researchers have long been investigating educational technology in general and the relationship between the content of the curriculum, pedagogy and digital technology, in particular. The focus of educational research conducted by researchers, such as Mishra and Koehler (2006), Voogt et al. (2012) examine how findings from such studies can be applied in the learning process to achieve the best learning outcomes.

According to Biesta and Burbules (2003), educational research could gain its value by contributing to the development of the learning process and allowing teachers to deal with daily problems while implementing learning more intelligently. However, educational research cannot be considered as scientific research that are related to natural science, which can be replicated wherever it is conducted as long as it is done under identical circumstances, such as the general laws and equations that underpin natural science research. In contrast, educational research cannot be replicated to give the same results everywhere; therefore, it cannot be described as laws and its findings cannot be generalised to other populations.

Niaz (2007) claims that most of the qualitative research is not based on sufficiently representative samples, which implies that the findings of qualitative research cannot be generalised to external populations. In other words, there is no guarantee that the findings of specific qualitative research will be applicable to other samples and different circumstances, such as participants, time and place. According to Niaz (2007), even Piaget's work was not based on representative samples, so one might ask how it is that Piaget's findings in constructivism were generalised and approved by the educational research community.

Nevertheless, the findings of qualitative research cannot be generalised to external populations; it can give the researchers a deep understanding of specific phenomena that are not based on a clear plan and structure. Bryman (2012) states that the findings of qualitative studies do not provide results that can be generalised, but it offers a rich understanding of the investigated aspects. Polit and Beck endorsed this idea by stating that:

> The goal of most qualitative studies is not to generalise but rather to provide a rich, contextualised understanding of some aspects of human experience through the intensive study of particular cases. (Polit & Beck, 2010, p. 1)

Biesta (2003) claims that in scientific research, theory comes before practice, so that findings can be generalised, unlike educational research, which starts with practice to be able to develop a theory. Furthermore, educational researchers should have understandings of the underpinning circumstances of their research setting, such as philosophies, theories, ethical issues and policies – so that their work can be contextualised (Crotty, 2003).

According to Biesta and Burbules (2003), the credibility of research related to education and social sciences can be determined by four different factors:

i) The epistemology, which describes how we get the knowledge, for instance, using interpretive methods.
ii) The ontology, which is a belief about reality (single or many realities or truths).
iii) The methodology, which describes instruments used in the study and mechanisms for collecting data.
iv) The sociological and political dimensions.

3.2 THEORETICAL FRAMEWORK

In this research, the pilot study and the literature reviews have played a considerable role in designing the theoretical framework of this study, pointing out the main areas in this research and identifying the knowledge gaps to be filled using a specific framework and methodologies. During the initial period of this study, I conducted some informal interviews with teachers to discuss different topics related to the field of learning and digital technology (refer to section 3.12.1). As an outcome of these meetings, I formed an initial understanding of these teachers' thoughts and ideas about the use of digital technology in learning; the teachers' ideas and concerns were shaped to some degree, by the questions in a questionnaire (refer to section 3.12.2).

Informal meetings with teachers, the questionnaire and the literature review, these three factors have helped in developing the research approaches. That were focused at the beginning onto the impact of digital technology on learning and was promoted to be focused onto the impact of different factors, such as pedagogy, the content of the curriculum in addition to digital technology on students' attainment.

Based on the analysis of the pilot study data, I began to decide on the crucial aspects that would form the theoretical framework of this research, which is concentrated on the interaction between three key factors: the content of the curriculum, which might take three shapes: theoretical, practical and interactive (Farah, et al., 2016), pedagogical dimensions and digital technology.

Based on the findings of the pilot study, I designed and created the theoretical framework of this research, which is shown in Figure 17. The theoretical framework comprises students and teachers who can be considered as the primary members in the process of learning. These members are involved in using digital technology, pedagogy and content knowledge. This framework was investigated within two phases: the pilot study and the main study. The pilot study in this research investigated teachers' thoughts and ideas towards the content of the curriculum, pedagogy and the use of digital technology in learning (qualitatively). The main study (in-depth investigation) required both teachers and students to investigate the impact of using digital technology on students' attainment, which was achieved by mapping the relationship between the content of the curriculum, pedagogy, digital technology and their impact on students' learning (quantitatively).

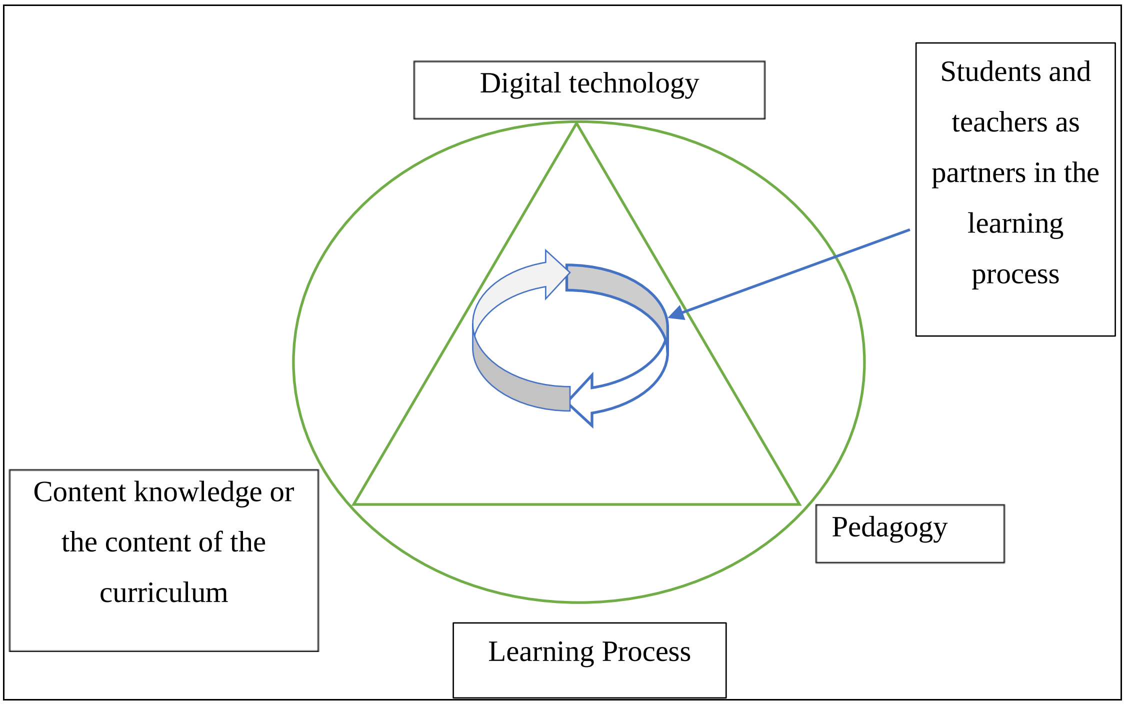


Figure 17. The theoretical framework of this study, which shows the main areas that are included in this research.

3.3 RESEARCH PARADIGM AND THE STUDY APPROACHES

At the beginning of this research (during the pilot study stage), a questionnaire for teachers was used to investigate their educational and technological level and their thoughts regarding the integration of education and digital technology (refer to sections 3.12.2, 3.12.3 and 3.13 in this chapter for more details about the questionnaire, the procedures that were considered, participants and the recruited samples in this study). After collecting the completed questionnaire from teachers, analysing the collected data as an interpretive paradigm. I could claim the positive impact of educational technology on students' learning. This claim agrees with many other researchers. For instance, Deaney et al. stated in their study:

> Many claims have been made about ICT potential contribution to pupils' learning, as it provides relatively immediate tools for teachers and students, and its use as calling primarily for the development of technical skills. (Deaney, et al., 2003, p. 1)

Tutty and White (2006) also claimed that digital technology devices could create a more effective classroom environment than the traditional tools, such as chalk and board or even the lecture notes could. The significance of educational technology was explained by Shelly et al. (2012), who considered digital technology as a vital factor in the 21st-century skills for learning, as it offers teachers and students a suitable environment to motivate their critical thinking. In addition to that, mobile technology devices offer learners access to additional sources of knowledge and social interaction through virtual learning platforms, such as a learning management system and the social media websites (Pachler, et al., 2011).

Even though many researchers investigated the relationship between content knowledge, pedagogy and technology, none of them dealt with this relationship using a mathematical model for predicting the impact of digital technology upon attainment. Therefore, I developed a mixed-method approach for collecting data such as teachers' thoughts and point of views (qualitative), and students' scores or the improvement in students' attainment as an outcome of using educational technology (quantitative).

This research explores the impact of using educational technology on students' attainment by mapping the relationship between three elements: digital technology, pedagogy, the content of the curriculum, and their impact on students' learning. To achieve this goal, this research investigated the following areas that are related to teachers and students:

i) Teachers' thoughts and beliefs towards the integration of education and digital technology.
ii) The relationship between three critical factors in the learning process: digital technology, pedagogy and content knowledge.
iii) Students' attainment with regard to the nondigital technology-based learning in different subjects that belong to humanities and science.
iv) Students' attainment with regard to digital technology-based learning in the subjects that were tested in the previous point.
v) The collected data (students' attainment with regard to nondigital and digital technology-based learning) were compared statistically to verify the impact of using digital technology on students' attainment.

Note: This thesis considers the terms educational technology and digital technology to express the new technologies that were used to implement the teaching and learning during the study, such as laptops, iPads, Internet, software programs, simulations, digital videos, smart boards, projectors, and the learning management system. In some places in this thesis, the terms digital technology and educational technology might be used interchangeably. However, I confirm that what is meant by the use of any of these terms is the new technologies, i.e., digital technologies.

3.4 OVERVIEW OF THE UNITED ARAB EMIRATES

The United Arab Emirates (UAE) is a federation of seven Emirates: Abu Dhabi, Dubai, Sharjah, Ras al-Khaimah, Umm al- Quwain, Ajman and Fujairah (Al Jafari, 2012). The UAE is located in south-west Asia, at the eastern part of the Arabian Peninsula, bordered by the waters of the Arabian Gulf and the Gulf of Oman. The UAE is bordered on the southwest by the kingdom of Saudi Arabia, and to the southeast by Oman (National Media Council, 2017), as shown in Figure 18. The country has an area of 83,600 square kilometres, which is equivalent to approximately 30,000 square miles (Al Jafari, 2012) of which “ 87 per cent is accounted for by the Emirate of Abu Dhabi” (National Media Council, 2017, p. 6). The UAE, like the rest of the countries in the Arabic Gulf, has a desert climate, hot and humid in the summer and mild winter (Bradshaw, et al., 2004).

Figure 18. The United Arab Emirates and adjacent countries map (https://www.google.com/maps/@25.1336892,52.6550654,6z)

Regarding the political system of the UAE, "The Sheikh Zayed bin Sultan Al Nahyan became ruler of the Emirate of Abu Dhabi on August 6, 1966" (National Media Council, 2017, p. 8). Sheikh Zayed launched an extensive set of initiatives and plans to advance the emirate. The plans of development were not limited to Abu Dhabi only, but also it covered all of the emirates as Sheikh Zayed bin Sultan endeavoured to establish the federation (Statistics Centre, 2015). Sheikh Zayed stated, “The Union is the path to power, pride, strength and mutual welfare. Separation only causes weakness, and weak states do not have a place in today’s world…” (National Media Council, 2017, p. 8)

The federation was established in 1971, the population of all seven united emirates was 180,000, with significant differences in terms of area, oil reserves, levels of development and inhabitants (National Media Council, 2017). Following significant efforts by the late Sheikh Zayed, "the rulers agreed at a meeting on July 1971 to unite, with a Federal Supreme Council being formed that would hold supreme authority in the new country. Comprised of Their Highnesses, the Rulers, the Federal Supreme Council elected Sheikh Zayed to be the first President, for a renewable term of five years, while Sheikh Rashid was elected as Vice President" (National Media Council, 2017, p. 8).

In terms of economic status, The UAE is ranked as the world's seventh-largest proved oil reserves, around 97.8 billion barrels, which makes it one of the wealthiest countries in the world. 96% of the proved oil reserves are located in the Emirate of Abu Dhabi, with 4% of total proved reserves are spread within the Emirate of Dubai, Ajman, Fujairah, Ras Al-Khaimah, Sharjah, and Umm Al-Quwain (Energy Information Administration, 2017). Nevertheless, since the establishment of the UAE, Abu Dhabi is making significant annual contributions to the federal budget (Al Jafari, 2012).

UAE society has witnessed significant developments in both infrastructure and services, as an outcome of distinguished economic growth, which can be seen clearly in Figure 19. This growth influenced the education sector substantially (government.ae, 2019). According to statistics conducted by the government of the UAE, in 1975, the percentage of adult literacy was 54 per cent amongst male and 31 per cent amongst female. Nowadays, the literacy percentages for both genders are almost 95 per cent (uae-embassy.org, 2019).

Figure 19. Dubai city in 1990 and 2015, cited in (Kamal, 2018), the author of the photo © 2017 Miroslav Petrasko

In terms of education, at the beginning of the federation (1971), there were very few Emirati teachers (Gardner, 2010). The vast majority of the teaching staff were mostly drawn from adjacent Arab countries (Findlow, 2001). In 1994, 26% of the teachers in the UAE schools were local, which is a 500% jump from the numbers in 1984 (Stateuniversity.com, 2010). In 2009, the Ministry of Education declared that Emiratis male teachers in the government schools made up 11 per cent of the male teacher population, and 71% of the female teacher population were Emiratis female (Ridge, 2010). According to Abdulla (2007), Emirati females are willing to become teachers; he connected this willingness with the UAE cultural beliefs, thoughts and habits. The fact that the gender-segregated strategy is applied in the UAE public schools makes the teaching job for females culturally accepted and desired. According to the UAE culture, single-gender classes are arranged in all schools within the UAE (Gaad, *et al.* 2006).

The education policy in the UAE is influenced by several factors, such as “the Islamic religion, Constitution, heritage and history, economic, social and political status, the status of education, UAE relationships and future aspirations and challenges” (Al Jafari, 2012, p. 12). Education is one of the UAE’s highest priorities. As President His Highness Sheikh Zayed Bin Sultan Al Nahyan, the founder of the UAE, noted, “The greatest use that can be made of wealth is to invest it in creating generations of educated and trained people” (uae-embassy.org, 2019).

The UAE’s education system includes many forms, such as technical, vocational, religious and general. Most children commence school at the opening of the academic school year in which they will turn six years old and remains in schools for 12 years (Bradshaw, et al., 2004). Within this period, students pass through three interrelated stages: primary level, which starts at the age of 6 years until the age of 11 years old, preparatory level, from 12 to14 years old, and the last stage; secondary level from 15-18 years old (internations.org, 2019).

The UAE's education system is relatively new. In 1952, a few public schools were opened. In the 1960s and 1970s, the school building program expanded. Thus, there was an expansion in the education sector in the UAE. In 2006-2007, around 650,000 students were registered at 1,256 public (government) and private schools (uae-embassy.org, 2009). In the 2013-2014 academic year, the number of students increased to 910,000 students were enrolled at 1,174 public and private schools (uae-embassy.org, 2019). “The UAE's education sector is one of the fastest-growing in the region. There are about 1.03 million students enrolled in both public and private schools as of the academic year 2016-17” (government.ae, 2019a). As estimated, “the total number of students in schools and universities in the UAE is projected to grow by 4.1 per cent annually until 2020”. (government.ae, 2019a)

Table 8 shows the growth in the number of schools, students and the teaching staff between the academic years 1971-1972 and 2019-2020. The table shows that the number of schools has been increased during this period by 17 times, and the number of students increased by approximately 33 times, the same goes on for the teaching staff as teachers’ number increased by around 45 times (Al Jafari, 2012; MOE.gov, 2019).

	1971-1972	2018-2019
Number of schools	74	1219
Number of students	32862	1081020
Number of teaching staff	1585	70000

Table 8. The number of schools, teachers, and students between 1971 and 2019 in the UAE. (Al Jafari, 2012; MOE.gov, 2019)

UAE President His Highness Sheikh Khalifa Bin Zayed Al Nahyan established the Abu Dhabi Education Council (ADEC) in 2005 to advance the education system throughout the UAE, including the public and private schools (Warner & Burton, 2017). ADEC plays a considerable role, modernising facilities, diminishing bureaucracy, developing curricula integrated with digital technology (Ridge, et al., 2017).

Education reforms in the UAE are focused on careful preparation for students, higher standards and professionalism. Moreover, replacing rote instruction with interactive methods of learning. The English language is being used to teach subjects that belong to both clusters, science and humanities (Ridge, et al., 2017). The Abu Dhabi Education Council (ADEC), the Dubai Education Council (DEC) and the UAE Ministry of Education (MOE) are in charge of education reforms while conserving the local traditions, beliefs and the cultural identity of the UAE (The Cultural Division of the Embassy of the United Arab Emirates, 2019). ADEC, DEC and the MOE aim to meet international standards by “focusing on international accreditation and comprehensive quality assurance programs” (uae-embassy.org, 2019).

The Ministry of education of the UAE has spent more than four decades, since the founding of the Federation, to improve students’ learning through developing teachers’ skills and knowledge, and equipping the schools with the required tools to support both, teachers and students (MOE.gov, 2019a). The Ministry of Education promotes and observes the reform actions, including inspections of each school in the UAE, assessing the system, which comprises students, stakeholders, teachers, schools, administrators, rules and regulations of the Ministry itself and arranging continuous professional development workshops for teachers and administrators.

The ministry of education vision, mission, values and strategic objectives:

Vision (MOE, 2017)

Innovative education for knowledge, pioneering, and global society

Mission (MOE, 2017)

Develop an innovative Education System for knowledge and global competitive society, that includes all age groups to meet future labour market demand, by ensuring quality of the ministry of education outputs, and provision of best services for internal and external customers

Values (MOE, 2016)

1. Citizenship and Responsibility: Enhance national citizenship and social responsibility.
2. The Principles and Values of Islam: Ensure human values in discussion, tolerance, moderation, peace and volunteering.
3. Commitment and Transparency: Commit to professional and transparent performance.
4. Equality and Justice: Commit to community partnership and accountability in the education process.
5. Participation and Accountability: Ensure equal educational opportunities for all.

6. Science, Technology and Innovation: Encourage a society that is driven by science, technology and innovation.

Ministry of Education Strategic Objectives (MOE, 2016)

1. Ensure inclusive quality education, including pre-school education.
2. Achieve excellent leadership and educational efficiency.
3. Ensure quality, efficiency and good governance of educational and institutional performance, including the delivery of teaching.
4. Ensure safe, conducive and challenging learning environments.
5. Attract and prepare students to enrol in higher education internally and externally, in light of labour market needs.
6. Strengthen the capacity for scientific research and innovation in accordance with the quality, efficiency and transparency standards.
7. Provision of quality, efficient and transparent administrative services, in accordance with the quality, efficiency and transparency standards.
8. Establish a culture of innovation in an institutional working environment.

Based on the stated vision, mission, values and strategic objectives of the ministry of education, the UAE's government announced the UAE Vision 2021, which states:

> Education is a fundamental element for the development of a nation and the best investment in its youth. For that reason, the UAE Vision 2021 National Agenda emphasises the development of a first-rate education system, which will require a complete transformation of the current education system and teaching methods. The National Agenda aims for all schools, universities and students to be equipped with smart systems and devices as a basis for all teaching methods, projects and research. There will also be significant investments to promote and reinforce enrollment in preschools as this plays an important role in shaping children's personalities and their future. Furthermore, the National Agenda has set as a target that the UAE students rank among the best in the world in reading, Mathematics and Science exams, and to have a strong knowledge of the Arabic language. Moreover, the Agenda aims to elevate the rate of graduation from secondary schools to international standards and for all schools to have exceptional leadership and internationally accredited teaching staff. (UAE Vision 2021, 2018)

Regarding the higher education, a broad range of universities from both sectors, public and private, is available all over the Emirates. Some of the world's reputable universities have opened their branches in the UAE, such as the Sorbonne, New York University and Johns Hopkins' Bloomberg School of Public Health (uae-embassy.org, 2019a). The Emirati students (UAE citizens) can enrol in the government universities free of charge (Ridge, et al., 2017). According to statistics conducted by the UAE government 95 per cent of the female students and 80 per cent of the males, who attended the secondary school, grades 11 and 12, apply and enrol at the higher education institutions after finishing grade 12 successfully (emiratisation.org, 2012).

3.5 OVERVIEW OF THE INSTITUTE OF APPLIED TECHNOLOGY (IAT) AND THE APPLIED TECHNOLOGY HIGH SCHOOL (ATHS)

All stages of this research were conducted in two schools (boys' school and girls' school) that belong to the *Institute of Applied Technology* (IAT). This institution has fourteen schools that are distributed in the United Arab Emirates. The rationale for choosing this sample is explained in a separate section in this chapter (refer to section 3.9.1.1):

> The Institute of Applied Technology (IAT) was founded in 2005 through the Royal Decree of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the UAE, Ruler of Abu Dhabi Emirate. IAT provides educational programs within Engineering, Information Technology and Health Sciences to meet the industrial and research development needs of the country. IAT manages both secondary and post-secondary education systems. The Applied Technology High Schools (ATHS) represent IAT's secondary level of education, while the Fatima College of Health Sciences and the Abu Dhabi Polytechnic deliver its post-secondary programs. With branches located throughout Abu Dhabi, Al Ain, the Western Region (Al Baynounah), Dubai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah and Fujairah, the Applied Technology High Schools serve both male and female students. Branches of Fatima College of Health Sciences are located in Abu Dhabi, Al Ain, Ajman. Abu Dhabi Polytechnic is located in Abu Dhabi and Al Ain. (IAT, 2018a, p. 5).

The vision and mission of The IAT (IAT, 2019)

Vision

Create a world-class Career Technical Education (CTE) system that will produce the scientists, engineers and technicians needed for the UAE to build a knowledge-based economy.

Mission

The ATHS system contributes to the development of the UAE by:

i. Providing distinctive secondary school programs that integrate career and technical education with a rigorous academic core
ii. Providing post-secondary CTE programs to meet the industrial needs and requirements of the nation
iii. Maintaining externally benchmarked standards for all programs offered
iv. Fostering close and cooperative relationships with the community, industry and government to ensure that ATHS is responsive to national needs and expectations
v. Organising public and industry continuing education programs in line with the needs of all stakeholders.

The Institute of Applied Technology (IAT) was established in the year 2005 to provide the UAE with a developed generation of technicians, engineers and scientists (IAT, 2019). The IAT created blended curricula connecting the theoretical and practical aspects of knowledge (Bajracharya, 2014).

The Applied Technology High Schools' programs are designed to create competent students, improve their talents through vocational education and various specialised programs supported by digital technology, such as laptops, iPads, iBooks numerous virtual learning platforms.

This study took place in the Applied Technology High Schools (ATHS). These schools represent the secondary level of education at the Institute of Applied Technology (IAT). To support Emirati students in being the "scientists, engineers and technologists needed to meet the knowledge-based economy of the UAE" (IAT, 2019), ATHS has provided them with a reliable, high standard curriculum, particularly in the science subjects and mathematics.

In 2018, the IAT adopted a plan that incorporates several subjects and disciplines; Science, Technology, Reading, Engineering, Arts and Mathematics. This plan was given the acronym STREAM (IAT, 2019). This approach to learning is designed to challenge students' intellectually and motivate them to think critically, investigate, analyse and look for knowledge. The implementation of STREAM projects requires students to work together, collaborative learning, and to construct new knowledge. In turn, this implies that the social constructivism dimension will be promoted.

Another initiative that was launched is the Student Academic Mentoring (SAM) program, which is one of the activities that are applied in the ATHS. It contributes significantly to the development of students' personality and social skills, motivating them to participate in voluntary activities that are of benefit to the community. *"The real wealth is the hard sincere work which is beneficial for the humans and society",* Sheikh Zayed Bin Sultan (edarabia.com).

The ATHS become a magnificent edifice that has an excellent reputation in the UAE society (IAT, 2019a). Nowadays, the IAT in general and the ATHS in particular, compete with many educational institutes that "have long been shaping the minds and disciplining the souls. For us, this is just the beginning of a long path in the technical and vocational field, which we are planning to continue to see our dear students achieving prominence in the highest positions of scientific achievement and in the world, proving the true wealth of the UAE" (IAT, 2019a).

3.6 EDUCATIONAL TECHNOLOGY AND STUDENTS' ETHNICITY AND SOCIOECONOMIC STATUS (SES) IN THE INSTITUTE OF APPLIED TECHNOLOGY (IAT)

At the beginning of this section, which is related to students' ethnicity, socioeconomic status (SES) and educational technology, it is essential to confirm that all students who participated in this study (pilot study and in-depth investigation) are citizens of the UAE, which implies that all of them have the same ethnicity. Being aware that the IAT policy states that the applicant (student) must be a UAE national. Mistry and Sood (2013, p. 44) described such population as a “mono-cultural/mono-ethnic” population.

Students’ socioeconomic status (SES) did not affect the study since every student throughout their studies in the IAT receives the same scholarship amount from the government of the UAE. Moreover, the tools used in this study, such as laptops, iPads and virtual learning platforms, including the learning management system, emails and iBooks are offered free of charge by the IAT to all students (the IAT grants its students these tools the moment they join the school). Furthermore, I do confirm that there were no students with special educational needs within the samples included in this study.

Note: As long as the population I investigated is mono-cultural/mono-ethnic/mono SES (students’ ethnicity and socioeconomic status are not digital dividing factors in this study). I decided to discuss these factors using the perspectives of other researchers.

The ethnicity of a student has been recognised as a digital dividing factor (Attewell, 2001; Hesseldahl, 2008). A study conducted by Ritzhaupt et al. (2013) showed a digital divide between white and non-white students on all measures of technology literacy. The results of their research showed that white students are performing significantly better on digital technology-related tasks. In line with Ritzhaupt et al. (2013), Junco et al. (2010) stated that white and Asian students are more likely to use computers and the Internet than their counterparts, partially because of the excessive resources available to these students at school and home, and partially because of cultural and societal influences that motivate them to use digital technology and restrain other students from diverse ethnicities.

According to Heemskerk et al. (2005, p. 8), students from “ethnic minority groups less often have access to computers at home”, “which results in a different user experience that may have implications for technology skills” (Junco, et al., 2010, p. 620). Therefore, Heemskerk et al. (2005) suggested offering students educational tasks at various levels of difficulty to minimise the impact of the differences in computer skills and knowledge, and to allow students to construct the knowledge socially. Hence, scaffolding aspect takes place (social constructivism dimension) (Chisholm, 1995; Maurer & Davidson, 1999).

Henderson (1996, p. 95) argues that there is a need for an interactive multimedia model that incorporates students from minority ethnic groups. Such model integrates "academic, mainstream, and minority cultures, it acknowledges that ethnic/racial minorities have little choice but to become bicultural if they are to succeed academically". Henderson claimed that students appreciate this integration since the incorporation of their culture, including “current-traditional” pedagogies into the learning materials, can motivate them to start mastering academic genres and valuing other approaches to learning (Henderson, 1996, p. 95).

Adler (1999), McLoughlin (1999), Gillani (2000), cited in (Heemskerk, et al., 2005), claimed that some researchers focus on the sorts of learning activities that require social interaction. However, in terms of ethnicity and social background, such interaction and communication with others can be problematic for some students. For instance, having a different view from, and arguing with others, particularly adults, is not a normal part of the culture of some ethnic groups. Students' cultural background impacts their perceptions and interpretation of the learning environment (denBrok, et al., 2003; Nguyen, 2008). The different perceptions that students with different cultural backgrounds have, may lead to conflicts between students due to a lack of understanding of each other’s cultures (Tielman, et al., 2012). However, I do confirm that in this study, all students are from the same ethnical background. Hence the communication difficulties due to misinterpreting different cultures are less likely to arise.

Baker and Clark (2010), Coelho (1994) stated that in a multicultural classroom, language difficulties limit the effectiveness of the interaction in a working group and influence interpersonal skills. Therefore, Mistry and Sood (2016) have discussed the significance of globalisation in primary education and stated that primary schools need to embed globalisation in their curricula to satisfy the needs of pupils with English as an Additional Language (EAL). According to Bakhtiari (2011, p. 95) globalisation "may refer to the transfer, adaptation, and development of values, knowledge, technology, and behavioural norms across countries and societies in different parts of the world". Ritzer suggests that globalisation is "the worldwide diffusion of practices, expansion of relations across continents, organisation of social life on a global scale, and the growth of a shared global consciousness" (2004: 160) cited in (Mistry & Sood, 2016, p. 30). These definitions suggest that there is a need to generate a global culture in educational contexts through teaching and learning (Mistry & Sood, 2016). However, apart from language proficiency, students in a multicultural classroom bring with them various ways of

> Reasoning, rules governing conversation, parameters for effective leadership styles, emphasis on conformity, or concern for social relationships among group members. These differences influence group characteristics such as cohesiveness, decision quality and group member satisfaction. (Baker & Clark, 2010) cited in (Tielman, et al., 2012, p. 105)

Another critical issue that needs to be considered when applying educational technology among "multi-cultural/multi-ethnic" (Mistry & Sood, 2013, p. 43) students, is the Socio-Economic Status (SES) of students. Several studies have been conducted to investigate the relationship between the SES of students and their skills in using digital technology. For instance, based on data extracted from the Program for International Student Assessment (PISA) in the year 2006, Zhong (2011, p. 736) stated: "at the individual level, self-reported digital skill is affected by home ICT access, adolescents' SES, gender, and their history of using ICTs". Attewell (2001), Hesseldahl (2008) found that low-SES families have less access to digital technology, such as computers and the internet, at their homes. In line with Attewell (2001) and Hesseldahl (2008), Ritzhaupt et al. (2013, p. 301) stated that "children of lower-SES families are less likely to be proficient users of ICT".

Hargittai (2008) claimed that even though some students have their own computers, some students do not. Therefore, if they wish to use computers, then they need to use them at the campus labs, which may have some implications on their technology skills. In other words, students' experience of using computers will be influenced (Hargittai, 2008). These claims are supported by a study conducted by Ritzhaupt et al. (2013), who stated:

> a digital divide between low and high SES, white and non-white … poor and minority families in the United States are less likely to have access to a computer and broadband Internet connection at home and less likely to have the necessary skills and knowledge to meaningfully use these resources. (Ritzhaupt, et al., 2013, p. 291)

Hohlfeld et al. (2008) reviewed the kinds of software used by teachers and students in high- and low-SES schools. The findings of their research showed significant differences between high and low SES schools at every level in terms of accessing and using software by students and teachers, as well as the level of digital technology support. Moreover, Hohlfeld et al. (2008) found that students in high-SES schools could access more productive software installed on the machines. In terms of usage, they found that students' usage in low-SES schools is limited by drill-and-practice software, while students in high-SES schools are using different sorts of productive software to implement learning, such as simulations and virtual learning platforms.

However, as highlighted at the beginning of this section, students' socioeconomic status (SES) did not affect the findings of this study. Three reasons can be considered to support this claim. Firstly, every student in the IAT receives the same scholarship amount (monthly salary) from the government of the UAE. Secondly, the IAT offers the digital technology tools used in this study free of charge to all students. Finally, the UAE is ranked as one of the wealthiest countries in the world, which is reflected positively on the economic status of the Emirati citizens.

3.6.1 Social Constructivism in Multicultural Education

Tielman et al. (2012) considered a classroom to be multicultural if it comprises at least five individuals from a minority group. In other words, "those individuals who were born in a country different from the country of residence or whose parents are from other countries" (2012, p. 105) or at least two different cultural groups. Several researchers have affirmed the significance of considering students' ethnicity in a multicultural classroom. For instance, Sleeter (1993) describes teachers who ignore students' ethnicity by the ones who have colour blindness. In line with Sleeter (1993), Gay (2000) and Moon et al. (2009) stated that ignoring the reality of different cultural background groups in the classroom impacts students' learning negatively. These claims are endorsed by a study conducted by Mistry and Sood (2013, p. 43) who stated that "every child is a unique child, children learn to be independent through positive relationships, children learn and develop in enabling environments, and the understanding that children learn in different ways and at different rates".

According to Jones and Brader-Araje (2002), constructivism is defined as an approach to learning where students are actively involved in constructing new knowledge from their experiences. Constructivism is divided into two different perspectives: cognitive constructivism and social constructivism. Jean Piaget suggested the cognitive approach, explains learning as an individual process. This approach was criticised since it ignores the social and cultural factors that impact students' learning (Braungart, et al., 2011). Lev Vygotsky suggested the social constructivism approach (Vianna & Stetsenko, 2006). Social constructivism moved the emphasises of learning from individual to social context (Jessel, 2013).

Multicultural education is defined as a sort of "education and instruction designed for the cultures of several different races in an educational system", i.e., to include various cultural background into instructional materials (Wilson, 1997). According to Wilson (1997), this method of teaching and learning brings positive racial characteristics to the classroom's atmospheres, and also it brings inclusivity in the curricula. Incorporating different cultural backgrounds, histories, and viewpoints into a classroom grants students better connections with the topic being taught (Banks, 2016).

For successful implementation of social constructivism in multicultural education, some conditions are required, including reforming schools, classrooms, curricula. This idea was suggested by Banks (2016), who stated that:

> there is a general agreement among most scholars and researchers in multicultural education that, for it to be implemented successfully, institutional changes must be made, including changes in the curriculum; the teaching materials; teaching and learning styles (Lee, 2007), the attitudes, perceptions, and behaviours of teachers and administrators; and the goals, norms, and culture of the school. (Banks, 2016, p. 4)

According to Banks (2016), social constructivism and multicultural education involve five categories. First, content integration indicates the extent to which teachers bring standards and content from diverse cultures to demonstrate key concepts and theories in their subject domain or discipline. Second, the knowledge construction process is related to the extent to which teachers assist students in understanding, examining, and learning how the inherent cultural perspectives impact how knowledge is constructed within it. Third, an equity pedagogy exists when teachers adjust their teaching and apply various teaching methods that are compatible with diverse cultural background and ethnic groups. Fourth, prejudice reduction, this dimension is related to teachers' efforts in modifying students' racial attitudes towards diverse cultures through teaching methods and materials. Finally, an empowering school culture and social structure, this dimension is related to empowering students from different racial, ethnic, and cultural backgrounds through activating different areas, such as "sports participation, disproportionality in achievement, and the interaction of the staff and the students across ethnic and racial lines are among the components of the school culture" (Banks, 2016, p. 5).

Social constructivism and multicultural education can be combined to improve students' learning. A study conducted by Rodriguez and Berryman (2002), they combined multicultural education and social constructivism in the teaching and learning process. Their research showed that using this approach to learning enhanced students' understanding of the topic and also it improves their attitudes towards the subject. Au (1998, p. 297) suggested that the implementation of a framework that combines both social constructivism and multicultural education "offers implications for reshaping schooling in ways that may correct the gap between the literacy achievement of students of diverse backgrounds and that of mainstream students."

According to Marri (2005; 2008), the framework for classroom-based multicultural democratic education and social constructivism incorporates three elements. Critical pedagogy, the building of community, and thorough disciplinary content.

Critical Pedagogy

Ball (2000) and Parker (2001) stated that critical pedagogy encourages students to work together in problem-solving activities. Students are allowed to pick the problem they think it worths solving.

The application of critical pedagogy passes through three stages; critical thinking in the classroom, individual social action, and finally through group social action (Marri, 2008).

At the first stage, teachers motivate students to practice within the classroom. Teachers may employ inquiry-based learning or investigations in order to foster students' critical thinking. Such activities promote the democratic values between students. At the second stage, students are also motivated to practice, but with a larger domain, such as the school itself (Ball, 2000). "Students may, for example, work to have the school send newsletters and flyers in multiple languages to help parents/guardians who may not understand English" (Marri, 2005, p. 397). The third stage focuses not only at an individual level but also at the level of potential for group agency (Ball, 2000). For instance, to encourage students to work with others, such as teachers, students, and parents, to address a community problem (Marri, 2005).

Building of Community

In terms of group work, Coelho (1998) claimed that students with similar backgrounds and interests tend to work together in the same group. To overcome this problem, Allport (1954) suggested creating groups formed of students from different cultural background, hence the different cultural groups in the classroom will be equalised. A teacher has a considerable role in the classroom in motivating students from different cultural background to collaborate and assist each other to build new knowledge through the lens of social constructivism (Keppler, et al., 2016). For instance, sharing common learning goals contributes positively to the group's interaction, motivates the group to develop a sense of identity and reduces the stereotypical visions about other group members (Tielman, et al., 2012).

Building a community in a multicultural classroom requires the teacher to create an environment of mutual respect between students to help them develop positive relationships, resolve disputes, and promote social problem-solving skills (Marri, 2005). As such, the teacher promotes the social interaction between students as they are motivated to communicate with each other regardless of their cultural background, including the racial, ethnic and culture. Hence, the teacher can build collaborative groups that enable students from diverse ethnicity "to be seen as individuals, instead of representatives of a specific grouping" (Marri, 2005, p. 398).

Thorough Disciplinary Content

The principle of thorough disciplinary content comprises two interrelated elements. First, teaching mainstream academic knowledge, behaviours, and values.

“Most of the knowledge that constitutes the established canon in the nation’s schools, colleges, and universities is mainstream academic knowledge” (Banks, 1995, p. 393). The second element is the transformative academic knowledge, which consists of the concepts and paradigms that challenge the mainstream academic knowledge (Banks, 1995).

Teachers need to supply students with content that demonstrates more than the traditional viewpoint and challenges the postulate that traditional interpretations are “universalistic and unrelated to human interests” (Collins, 1990, cited in (Marri, 2005, p. 398). Transformative academic knowledge represents the content that investigates and criticises the conventional beliefs admitted by the dominant group. In other words, students are presented to various perspectives and cases on a given subject matter (based on race/ethnicity, class, and gender) and included stories from diverse groups to present more comprehensive content.

3.6.2 Multicultural Education and Teaching Implications Through the Lens of Social Constructivism

Multicultural education requires modifications in the entire school environment in order to generate equal educational opportunities for all students (Banks, 2016). In line with Banks (2016), Mistry and Sood (2015) claim that school practitioners and leaders need to consider the equity and justice dimensions when debating the perceptions of diversity. As such, students with different cultural background avoid being labelled or treated as having special needs and disabilities. Mistry and Sood (2015, p. 44) described the term equity as **“**Making sure that all children have the same opportunity to access all learning experiences”. According to Mistry and Sood (2015)**,** the equity approaches in the Early Years could be developed by checking the discrepancies between the school community and the broader world and explore how every student can have the basic rights.

According to Banks (1993), through the lens of social constructivism, five types of knowledge should be taught in a multicultural curriculum: First, personal/cultural knowledge, which is represented by the concepts, information, and interpretations that students obtain from their personal experiences and cultural background. Second, widespread knowledge, which includes the facts, concepts, explanations, and interpretations that are standardised within the culture. Third, mainstream academic knowledge: the concepts, paradigms, theories, and explanations that create knowledge in history and the behavioural and the social sciences. Fourth, transformative academic knowledge: the facts, theories, paradigms, themes, and interpretations that challenge mainstream academic knowledge and substantially review established canons, standards, ideas, information, and research methods. Finally, school knowledge: the facts, theories, generalisations, and explanations that are included in textbooks, teacher's guides, and lectures by teachers.

The five types of knowledge outlined above have significant implications for teaching a multicultural curriculum. In multicultural education, students need to be given chances to investigate and "determine how cultural assumptions, frames of references, perspectives, and the biases within a discipline influence the ways the knowledge is constructed" (Banks, 1993, p. 11). As such, students can build their knowledge through social context.

In line with Banks (1993), McKenzie and Van Winkeelen (2004, cited in (Moloi, et al., 2009) propose a six-point framework of competence for promoting school practice for globalised curricula or as described by Mistry and Sood (2016), the globalised curriculum competencies. First, competing, the drive towards improvements in performance, teachers need to use the lens of globalisation aspect to shape their curriculum and teaching and learning strategies. Second, deciding, "knowledge underpins effective decision-making" (Mistry & Sood, 2016, p. 31) in that we need to know both what to do and how to do it. Third, learning, enabling individuals and social groups to learn more efficiently and effectively. Fourth, connecting, active connections allow knowledge flows in both directions; internal and external, i.e., knowledge exchange. Fifth, relating, designing and working in many different forms of knowledge-sharing relationships, while maintaining a coherent organisational identity. Finally, monitoring, managing intellectual capital and communicating its current and potential value by measuring and assessing the return on knowledge investments.

McKenzie and Van Winkeelen (2004, cited in (Moloi, et al., 2009) framework considers learning through the lens of social constructivism. This can be seen clearly in the third, fourth and fifth elements, which promote effective learning and the construction of knowledge through a social context. Moreover, the first and third elements underpin the content of the curriculum through the lens of multicultural education, i.e., the use of the globalisation aspect to shape their curriculum. Those competencies (six-point framework of competence) affirm the significance of specific terms related to social contexts, such as knowledge flows, social groups, communication, active connections, knowledge-sharing relationships and communication, digital technology can play a considerable role in mediating these terms. Thus, based on this argument, I would claim that the content knowledge, pedagogy and digital technology were implied though not plainly expressed in McKenzie and Van Winkeelen framework.

Cummins, 1986, cited in (Au, 1998), suggested a theoretical framework for empowering students of diverse cultural backgrounds. The suggested framework is compatible with the social constructivist aspect as it confirms the significance of creating the connection between the school's events and the situation of the society, including the associations between schooled knowledge and individual's culture and experience. The empowerment is a fundamental idea to Cummins’ framework. Au (1998, p. 304) claimed that empowered students "are confident in their own cultural identity, as well as knowledgeable of school structures and interactional patterns, and so can participate successfully in school learning activities".

In terms of power, Cummins (1994) differentiated between coercive and collaborative relationships. Coercive relationships lower the status of students with different cultural backgrounds on the "assumption that there is a fixed amount of power so that the sharing of power with other groups will necessarily decrease the status of the dominant group" (Au, 1998, p. 304). In collaborative relationships a group cannot be above others, and "power is not fixed in quantity" (Au, 1998, p. 305), as it is generated during the interactions between groups and individuals. The constitution of the zone of proximal development (ZPD) in particular, and social constructivism in general, depends on these interactions.

The kind of power relationships, whether coercive or collaborative, shapes the interactions between teachers and students in schools. Cummins (1986) cited in (Au, 1998) claimed that these interactions are mediated by the role definitions that teachers assume. Three social contexts influence these roles. First, power relationships between groups within society. Second, relationships among schools and diverse groups. Finally, the interactions between teachers and students inside the classroom.

Cummins argued that the academic achievement of students of diverse cultural backgrounds depends on the patterns of interaction in the school. Cummins claimed that empowering these students, require teachers to redefine their role in four fundamental elements. The first element is related to incorporating the language and culture of students of diverse background. The second element focuses on the school's program and to what extent these programs aim to integrate these students and consider the term diversity. The third element is related to pedagogy that motivates students of diverse cultural backgrounds to use language to build their knowledge. The fourth element is concerned with assessments, which shows to which extent teachers tend to label or disable students of different cultural backgrounds (Au, 1998).

Through these elements, Cummins presents a comprehensive framework to empower students of diverse cultural backgrounds. However, Au (1998) criticised this framework for being centred more on the roles of teachers than on other issues of power related to the society that restrain teachers and students. Moreover, Cummins' framework does not focus on the material circumstances with which teachers and students must contest.

However, as mentioned at the beginning of this section, all students who participated in this study (pilot study and in-depth investigation) are citizens of the UAE, i.e., all of them have the same ethnicity, the IAT policy states that the applicant (student) must be a UAE national.

3.7 TEACHERS' PEDAGOGICAL BELIEFS AND DIGITAL TECHNOLOGY-BASED LEARNING

This section outlines a few relevant studies discussing teachers' pedagogical beliefs and its implications on the use of digital technologies in their everyday instruction practice.

Richardson (2003) explained the term beliefs as subconscious understandings, assumptions, or statements felt to be accurate; whereas, knowledge, according to

Calderhead (1996), is interpreted as true statements and accurate perceptions. According to Pajares (1992), personal beliefs work as own guidance that allows people to understand the world and deal with their environment. In terms of education, pedagogical beliefs pertain mainly to perceptions, assumptions, or schemes concerning teaching and learning that are felt to be reliable (Denessen, 2000, cited in (Tondeur, et al., 2016). In line with Denessen (2000), Pajares (1992, p. 314) claimed that "all teachers hold beliefs, however, defined and labelled, about their work, their students, their subject matter, and their roles and responsibilities".

A teacher's core beliefs are the most durable. Consequently, it is challenging to adjust them as they have strong bonds with other ideas and faiths (Richardson, 1996). Ertmer (2005) claimed that teachers' core beliefs regarding teaching and learning are immune to reform as they have been developed over several years of teaching experience and backed by strong consensus; whereas, beliefs that are freshly developed are more dynamic and more comfortable to break (Fives & Gill, 2014).

Kagan (1992) stated that teachers' pedagogical beliefs work as a scanner through which new experiences are examined for consistency. This applies to experiences related to digital technology, as well. In turn, this implies that teachers' attitudes towards any development of their teaching techniques, including the adoption of educational technology, are shaped and influenced by their internal beliefs of effective teaching and learning (Ertmer & Glazewski, 2015).

Tondeur et al. (2008) defined teachers' educational beliefs as teachers' understandings, premises or propositions about education. Tondeur et al. (2008) investigated teachers' use of digital technologies based on their educational beliefs, including their planning, decision-making and behaviour in the classroom. The authors argue that "teachers are likely to adopt practices with computers that are in line with their beliefs about teaching" (2008, p. 3).

In terms of digital technology-based learning, Tondeur et al. (2008) identified two different educational beliefs: *traditional teaching* usually referred to teacher-centred approach and *constructivist teaching that* embraces a student-centred approach. According to Tondeur et al. (2008), differences in teachers' beliefs lead them to use digital technology in different manners. The authors argue that teachers with traditional beliefs do not use digital technology substantially in their teaching, in contrast to teachers believing in constructivist beliefs, who are described as regular users of digital technologies.

Ertmer et al. (2015) stated that teachers who have constructivist beliefs are active users of digital technology. Becker (2000) claimed that teachers with constructivist beliefs, not only they use digital technology more often than teachers with traditional beliefs, but also they employ it in more student-centred approaches, allowing students to build their own knowledge and develop their understandings. This claim is supported by Ananiadou and Claro (2009, p. 7), who stated that teachers with constructivist beliefs encourage their students to "apply knowledge and skills in key subject areas and to analyse, reason, and communicate effectively as they raise, solve, and interpret problems in a variety of situations". However, Tondeur et al. (2008), argue that some teachers may hold both pedagogical beliefs, constructivist and traditional. These teachers often have a broader range in their beliefs, enabling them to use digital technologies diversely and effectively.

Tallvid, 2014, cited in (Salavati, 2016), studied the cause of teachers' reluctance for adopting digital technology in the learning process. The findings of the study suggested five different dimensions that can justify teachers' reluctance to using digital technologies in the classroom. The first dimension is the lack of technological competence. The second dimension is the prejudice that digital technology does not improve learning significantly. Thus, it does not worth the time and effort consumed by teachers for preparation. Third, by moving away from the course textbook towards digital learning, teachers face difficulties to find the required digital material on the Internet or any other virtual learning platform. Therefore, Tallvid 2014, cited in (Salavati, 2016) suggested providing teachers with well-structured, organised, consecutive educational practice so that teachers can admit the necessity for digital technologies. The fourth dimension was concerned with keeping the class in control. With the presence of digital technology, some teachers believe that it would be challenging to maintain students' concentration during the lesson. The fifth dimension was the lack of time. Some teachers claim that they do not have adequate time to plan their lessons using digital technologies.

Procedures Considered in This Study to Minimise the Influence

To minimise the influence of teachers' personal pedagogical beliefs on this study, several procedures were considered.

First, meetings were held with the involved teachers in this study. During these meetings, both components of this study digital and non-digital technology-based learning were discussed with these teachers, including the pedagogical dimensions (P1 to P4) and the kinds of the curriculum (C1 to C3) required to be implemented in both components as well as the level of integration with digital technology (T1 to T5) in the case of digital technology-based learning.

Second, the involved teachers were provided with YouTube videos related to the implementation of the pedagogical dimensions, such as collaborative, constructive and cognitive learning. These videos were watched and discussed during the same meetings.

Third, to guarantee the same personal pedagogical attitude towards teaching and learning, including educational technology beliefs, in each case of this study, both components of each CPT strategy, digital and non-digital technology-based learning, were implemented by the same teacher. Thus, a teacher’s personal attitude and effect on teaching, learning, students, assessments, and marking would appear in both situations. Nevertheless, some teachers could favour one approach rather than the other, which is considered a limitation of this study. For a detailed discussion of this limitation, please refer to chapter 7.

Finally, a description of Webb's depth of knowledge levels and Bloom's taxonomy stages was shared and discussed with the teachers involved in this study. As such, teachers could judge the complexity levels of the contents delivered and the cognitive levels of the exams conducted in both cases, digital and nondigital technology-based learning, refer to section 3.17.5.

3.8 THE RESEARCH DEVELOPMENT PROCESS

One of the main difficulties the researcher faced since the beginning of this study was related to the lack of literature reviews. As this study presents a new research area; dealing with education using a mathematical perspective to investigate and predict the impact of using digital technology on students’ attainment (quantitatively). The author can affirm that none of the previous research papers (see for example Mishra and Koehler (2005a; 2006; 2008)) dealt with this research area mathematically, using a statistical model that can predict the improvement in students’ attainment as an outcome of using educational technology. Another difficulty that had been faced, was based on teachers' records (mark books). Not all teachers archive their records, notes and scores that date one or two years back, so when the previous records were needed in this study, only a few teachers were able to fulfil the request.

The pilot study took place in the period between September 2014 and October 2015 in two schools that belong to IAT. The main study or the broad investigation of this study (stages two and three) took place in the period between January 2016 and October 2017 in the same schools that belong to IAT. The progress of this research is shown in Table 9.

Part of the study	**Areas of research**	**Instrument**	**Subjects**	**Academic year**
A pilot study (exploration)	i) Teachers' thoughts and beliefs towards the use of digital technology in learning. ii) The relationship between the use of digital technology in learning and students' attainment.	i) Informal meetings. ii) Questionnaire. iii) Teachers' previous records (mark books).	Teachers	Between September 2014 and October 2015
Main study / in-depth investigation (interpretation and construction)	i) The impact of using educational technology on students' attainment. ii) The relationship between the content of the curriculum, digital technology and pedagogy. iii) The validity of the developed model, which maps the relationship between the content of the curriculum, digital technology and pedagogy to predict the improvement in students' attainment.	i) Students were examined with regard to the nondigital technology-based learning in different subjects related to humanities and science. ii) The students were examined with regard to digital technology-based learning in the subjects that were tested in the previous point. iii) The collected data (students' attainment with regard to nondigital and digital technology-based learning) were compared statistically to verify the impact of using educational technology on students' attainment. iv) The expected and observed improvements were compared statistically to check the validity of the developed model of this study.	Students (were examined by teachers)	January 2016 and October 2017)

Table 9. Research timeline.

3.9 METHODOLOGY

McGregor and Murnane (2010) claimed that the term methodology is a branch of knowledge that deals with general concepts, such as philosophical assumptions that underlie any natural, social or human science study. Jonker and Pennik (2010, p. 21) in their study stated, “terms such as ‘methodology’ and ‘method’ are often used arbitrarily. This can lead to a sort of methodological potpourri”. Kothari (2004) argued that the term *methodology* refers to philosophies that show how the research was conducted and to the process of gathering, discovering and analysing the data and building knowledge systematically. While the term *methods* in specific, refer to data gathering techniques and the instruments used to gather these data, such as interviews, questionnaires or observations. In other words, methods can be considered as tools and techniques used in research to obtain the data. Therefore, it can be viewed as a component of the methodology (Kothari, 2004).

According to Willington (2000), methodology discusses and justifies why specific methods were used to collect the data. Based on ontological and epistemological beliefs, the term methodology can be divided into two types of research: quantitative and qualitative. The quantitative research is based on numerical values and aims always to generate numbers such as percentages of a specific kind of people in a society or a community (for example the portion of the PhD holders within a particular city). Quantitative research is used to answer questions like how many, how much, by which factor; these questions can be answered using different methods, such as experiments, questionnaires and observations. Jonker and Pennink (2010) in their study, stated that quantitative research is often conducted for purposes related to scientific, justifiable and precise facts. Conversely, the second type of methodology is the qualitative research, which is usually used to answer questions related to people’s thoughts, ideas, experiences or attitudes or to answer questions like what, how or why, using various methods, such as questionnaires, interviews, and case studies. Qualitative research is often conducted to investigate ambiguous cases that do not belong to the scientific field and do not follow a definite structured plan (Jonker & Pennink, 2010).

Kothari (2004) suggested that quantitative research is concerned with measuring quantities or specific characters related to aspects that can be expressed in terms of numbers. On the other hand, qualitative research is based on aspects related to quality or kind. For instance, investigating human behaviour.

In this research, data were collected from teachers and students (refer to sections 3.12.3 and 3.17). During the pilot study, qualitative research was conducted; informal meetings were held with some teachers. Participating teachers were informed that the researcher was trying to understand their thoughts and attitudes towards educational technology to develop a questionnaire. These informal meetings were followed by the developed questionnaire, which was distributed to teachers to check their awareness of digital technology-based learning.

Based on the findings of the pilot study, I could build the hypothesis of this study about the integration of digital technology and education. The hypothesis of this study was focused on: i) the effect of educational technology on students' attainment, ii) the relationship between the content of the curriculum, digital technology and pedagogy, iii) the positive impact of using educational technology on students' attainment. However, another question emerged regarding the use of educational technology, if the hypothesis is correct and there is a positive effect of using educational technology on students' attainment, then by which factor it can improve students' attainment?. To answer this question, there was a need for stages of in-depth investigation, which required quantitative research. Therefore, the methodology of this conducted research is considered as a mixed methodology as it uses both quantitative and qualitative methods.

3.9.1 Sampling

This section discusses the sampling and the rationale for choosing the investigated samples.

Before the studies began, an official letter was sent from the supervisory team in Nottingham Trent University (Appendix 2 - Consents) to the Institute of Applied Technology (IAT) to obtain the authorisation to commence the research; the permission was granted.

Prior to the main study, there were arranged meetings between the researcher and involved teachers to discuss the strategy of collecting data, the amount of content knowledge that would be integrated with digital technology, how many pedagogical dimensions will be used to deliver the content and how many types of curriculum will be used which might be theoretical, practical and interactive.

The samples that were selected and recruited in this study can be described as purposive sampling. Babbie stated that it was “appropriate to select a sample on the basis of knowledge of a population, its elements, and the purpose of the study” (Babbie, 2002, p. 178).

Nevertheless, Creswell (2012) argued that purposive sampling should be used more in research related to qualitative studies. This type of sampling was suitable for this research, being aware that the methodology of this research uses both quantitative and qualitative methods. Particular samples were required to answer the research questions. Therefore, I confirm that the sampling process in this study was purposive sampling and was not a convenient sampling.

This study (the pilot and the main study) took place in two schools (one school for boys and one school for girls), both of these schools belong to the Institute of Applied Technology, which has fourteen schools distributed in the United Arab Emirates.

Further information related to the samples of the pilot and main studies is mentioned in sections 3.12.3, 3.17.1 and 3.17.2

3.9.1.1 ***The Rationale for Choosing the Samples***

Many reasons can justify the rationale for selecting these schools. First of all, the researcher works in this institution as a physics teacher, which implies that the researcher knows the samples’ abilities and skills of using digital technology efficiently, which serve the purpose of this research. The second reason is related to a sociocultural aspect, since all students in this institution are citizens mono-cultural/mono-ethnic (Mistry & Sood, 2013), and as long as the research was conducted in the United Arab Emirates, therefore it would be the best to study citizen students (the permanent residents). Thirdly, this academic institution is the only institution in the United Arab Emirates that provides each student with a laptop, iPad and an email since the moment they join the school so that there was a guarantee that students will be able to use digital technology for purposes of studying, communicating and doing the exams. Likewise, each classroom is provided with many technological tools, such as a projector, wireless internet connection, smart whiteboard and smart-pen (IAT, 2018a); unlike other schools where the use of digital technology is limited due to the lack of technological tools.

Eventually, IAT has various supportive tools for the use of educational technology, such as iBooks, multiple data analysis software used in the science laboratories to ensure that even the practical side of learning can be done using digital technology, in addition to a learning management system (a virtual learning platform), which makes communication between the members of the learning process more comfortable, delivering the content, sharing and exchanging experience effectively. Furthermore, teachers and students in this institution are familiar and well-trained in using digital technology, which ensures efficient use of educational technology.

METHODOLOGY OF THE PILOT STUDY

3.10 AREAS EXPLORED IN THE PILOT STUDY

The pilot study in this research investigated teachers' thoughts and beliefs towards the content knowledge, pedagogy and the use of educational technology in learning. Based on the teachers' previous records (mark books), the impact of using educational technology on the students' attainment had been investigated as well. Qualitative and quantitative methods were used in the pilot study to analyse the collected data.

During the pilot study, two approaches were used. The first was a subjective approach, which was used to check the teachers' thoughts about educational technology, pedagogy and content; this approach was achieved by the direct interaction with the teachers (the participants).

> In the research that are related to social studies, readers cannot be convinced easily by analysis and results based on observations only, for this reason, there should be a space for questions that are related to subjectivity. (Bryman, 2012, p. 287)

The second approach was an objective approach where percentages of improvement in students' attainment after using educational technology were measured using some teachers' mark books, which had been analysed using various statistical functions to check the validity of the collected results.

The findings of the pilot study could answer the **initial questions of this study**:

1. Based on the teachers' experience in education, to what extent educational technology, pedagogical dimensions and curricula are essential for learning?
2. Is there a relationship between the use of educational technology and students' attainment?

The answers to these questions are shown in the data analysis and discussion chapter (refer to chapter 4).

3.11 PILOT STUDY PLAN

The pilot study consisted of two parts: informal interviews and a questionnaire. It commenced by informal interviews with some teachers followed by a questionnaire. The significance of the conducted interviews (meetings) was to realise teachers' thoughts about the main topic, which is the integration of teaching and learning with digital technology. I could employ these thoughts and opinions to formulate the questionnaire, refer to Appendix 4 – Teacher's Questionnaire.

Based on the informal interviews with the teachers and after grasping the teachers' thoughts, I could point out the main components of the questionnaire as follows: i) teacher's self-acknowledgement using ICT (digital technology), ii) digital technology integration using mobile devices, such as the iPad and iii) teacher's educational process including the curriculum and the pedagogical dimensions. The rationale for investigating these three areas was an attempt to form an initial framework for the relationship between content knowledge, digital technology and pedagogy.

3.12 RESEARCH METHODS AND INSTRUMENTS OF THE PILOT STUDY

Selecting the most appropriate instruments and methods to gather the data in an interpretive study is a crucial need. However, using these methods and techniques to collect as many results as possible is a more critical aspect of interpretive research (Creswell, 2003). In this study, the design of the tools that were used to gather the data was influenced by three factors: the kind of data the researcher intended to collect (Alberta Health Service, n.d.), the guidance of the supervisory team of this research in Nottingham Trent University and some suggestions from educators working in IAT.

During the pilot study, informal interviews were conducted, and a questionnaire was used to collect the data from teachers, which helped in creating the core ideas of this research and answering the initial research questions. Twenty teachers responded to the questionnaire, thirteen teachers from the science department, and seven from the humanities department**.** The ethical issues were taken into consideration (BERA, 2018) (refer to section 3.19). Participants were aware of their rights in this study, and they were informed that they could withdraw at any time (refer to section 3.19). All participants were full-time, employed teachers. The age range of the participants was 30 to 50 years old. The participants were teachers of the following subjects: Physics, French, Chemistry, English and Mathematics (for more details about the samples refer to section 3.12.3).

3.12.1 The First Instrument of the Pilot Study – Focus Group (Informal) Interviews

The focus group interview is a technique of interviewing that comprises at least four interviewees, unlike the individual interview, which involves one interviewee (Bryman, 2012).

Hughes and DuMont (1993, p. 776) identified focus groups as group interviews: " Focus groups are in-depth group interviews employing relatively homogenous groups to provide information around topics specified by the researchers". Kreuger (1998) cited in (Smithson, 2000, p. 104) defined it as group discussions: "a carefully planned discussion designed to obtain perceptions on a defined environment". Beck et al. (1986), cited in (Wilkinson, 1999, p. 221) described it “at its simplest” as an informal discussion between selected people about particular topics.

In terms of comparison, focus group and individual interview, Fern (1982) claimed that in a free-listing task, focus groups contributed 60–70% fewer ideas than individual interviews. Furthermore, ideas presented in focus groups were found to be of lower quality. In line with Fern (1982), Heary and Hennessy (2006) found that individual interviews produced more relevant and innovative ideas than focus groups. These claims were supported by Rat et al. (2007), who stated that individual interviews generated more beneficial details to social domains than the focus groups. In contrast, Griffin and Hauser (1993) and Coenen et al. (2012) claimed that focus group interviews addressed more significant categories than individual interviews. In terms of cost and time consuming, Aldag and Tinsley (1994) contended that focus groups demanded approximately half of the time and cost of individual interviews. Janis, 1982, cited in

(Bryman, 2012), claimed that, when a group shares a particular point of view, the group members do not think of it critically.

Unlike individual interviews, Wilkinson (1998) stated that focus groups are challenging to organise as the researcher needs to agree with several participants and also persuade them to turn up at an appropriate time. However, it is typical, as Wilkinson (1998) claimed, for participants not to turn up. Therefore, it is a traditional practice in the focus group to recruit new participants. According to Wilkinson (1998) and Bryman (2012), communication, arguments and disagreements represent natural characteristics of the focus groups compared to individual interviews. However, these characteristics add levels of complexities to the data analysis process (Onwuegbuzie, et al., 2009).

In a qualitative context, participants' viewpoints, beliefs and attitudes are essential factors to build hypothesis and draw conclusions. Focus group interviews, as a qualitative approach, are based on the interaction and discussion between an interviewer and interviewees and interviewee to interviewee (Gavora, 2015; Wilkinson, 1998). Consequently, it grants the researcher the possibility to understand how people make sense of a specific phenomenon (Stalmeijer, et al., 2014). Accordingly, Wilkinson (1998) claimed that focus group interviews could exhibit participants' constructed understanding and their beliefs, which can be viewed as more naturalistic than individual interviews.

In focus group interviews, the moderator has less control over processes than with individual interviews (Wilkinson, 1998). Some writers on focus groups interviews regarded this as a disadvantage, while other writers in the same domain perceive it as an advantage (Bryman, 2012). For instance, Kamberelis and Dimitriadis 2005, cited in (Bryman, 2012), claimed that surrendering control of a focus group to its participants grants them ownership of the interview; hence, various aspects related to the research area emerge. However, Wilkinson (1998, p. 114) stated that "this shift in the balance of power can, in fact, expose researchers to harassment and abusive behaviour from their research".

In focus groups, some problems related to group effects can be encountered, which does not apply to individual interviews (Wilkinson, 1998). For instance, some interviewees are hesitant and reserved speakers, and there are others who "hog the stage" (Bryman, 2012, p. 518). To overcome this problem, Mack et al. (2005) suggest that the moderator needs to announce that all participants' views are required and also actively encourage reticent participants.

In terms of group effects, according to Smithson (2000), during the focus group, participants may be more inclined to revealing culturally anticipated views than in individual interviews. Morgan 2002 indicates the case of research in which focus group interviews "with boys discussing relationships with girls were compared with individual interviews with them on the same topic" cited in (Bryman, 2012, p. 518). During the individual interviews, boys showed a degree of sensitivity that was not shown in the group interviews. This implies, within the group context, the boys were influenced by the patterns of each other. However, Bryman (2012, p. 518) argues that "this does not render the group interview data questionable, because it may be precisely the gulf between privately and publicly held views that is of interest". In line with Morgan 2002, Smithson (2007) claims that in some situations, focus groups may not be suitable, as it may cause embarrassment amongst participants. For instance, when private details need to be revealed and discussed, participants may feel discomfort in each other's presence. In such circumstances, individual interviews are expected to be preferable. This was summarised by Michell (1999), who stated that Individual Interviews could be useful for discussing delicate or sensitive details while focus groups are a proper forum for discussing common perspectives.

According to Kvale (1996), the goal of using the focus group interview in qualitative research is to describe the essential themes of the subjects' lifeworld. The interviewer's main mission is to understand the interviewees' ideas and responses. Kvale and Brinkman (2005) stated that the dialogical interviews in themselves are considered useful tools and emancipating since participants are given the opportunity to express their opinion freely.

However, it is essential to note that participants do not always express their real opinions freely in interviews, especially if they are recorded, for the reason that it will be documented and cannot be kept anonymous. Therefore, people might have many restrictions and fears when they participate in an interview (Bryman, 2012). For example, they fear to say an opinion against the policy of their employer, which is related to "micro-political senses" (refer to section 3.19) (Morrison, 1993, cited in (Cohen, et al., 2005, p. 43). Therefore, I kept the interviews friendly and informal as far as possible. Interviews were not recorded based on participants' request. As a result, everybody could feel that this is a typical conversation between teachers.

Many factors can affect the respondent's answers during the interview, such as:

> Characteristics of interviewers (and respondents) may affect the answers that people give […] it has been suggested that characteristics such as ethnicity, gender, and the social background of interviewers may combine to bias the answers that respondents provide. Obviously, since there is no interviewer present when a self-completion questionnaire is being completed, interviewer effects are eliminated. (Bryman, 2012, p. 233)

Based on the previous quote, the researcher in this study and the supervisory team decided to use the questionnaire to collect the data instead of the interviews in order to minimise any influence that can impact the validity of the collected data negatively.

3.12.1.1 The Rationale for Conducting Informal Interviews

Interviews can offer participants the opportunity to express themselves freely using their own words (Kvale, 2006). McNamara (1999) claimed that conducting interviews during research would be very useful and helpful for the researcher to understand the story behind a subject's experiences.

At the beginning of this research, several informal meetings with teachers were held. The purpose of these informal interviews was not to collect data, but it was the researcher's need to discover and understand, the main areas of interests for teachers that are related to educational technology so that it can be included in the questionnaire. Based on these interviews, I was able to design a reasonable and factual questionnaire, which discussed the main aspects of learning from interviewees' points of view. Moreover, based on these interviews, I could highlight the frame and boundaries of the study. Using the informal interviews in this study, I could gain a better understanding of teachers' thoughts and beliefs towards educational technology. For instance, if they can use it effectively to implement learning and if they believe that it is useful or not.

3.12.1.2 The Design of the Informal Interviews

The informal interviews were based on precise, simple questions that belong to the open and closed format questions; a clear and uncomplicated language was used in the questions. The primary goal of these informal interviews was to understand teachers' thoughts and beliefs about educational technology, which could be used as a basis for the teachers' questionnaire. Therefore, the researcher kept the conversation clear and straightforward; participants were given enough time to speak their minds and express their opinions freely without any interruption.

Questions asked to participants were derived from the researcher's experience as a teacher, and the supervisory team's guidance and recommendations. The issues that were discussed and addressed, mainly the pedagogical and technological aspects related to teachers' work as follows: What technological devices do you use in your teaching? How are new technologies essential to you? Have you tried to integrate digital technology into the curriculum in your classroom? What do you know about pedagogy? What areas do you suggest to including in the questionnaire?. These questions were the main ideas in the meetings; the teachers' responses formed the primary areas of the questionnaire, which were then arranged appropriately to create a well-structured and comprehensive questionnaire.

As long as the conducted interviews were informal and were not used to collect data, the researcher affirms that these questions were not structured or prepared in advance, as the majority of them were generated spontaneously during the friendly conversations with the participants.

3.12.1.3 Implementation of the Informal Interviews

Twenty teachers were interviewed, teachers were divided into groups; each group consisted of five teachers; each interview was planned to last between twenty to thirty minutes. Even though the meetings were informal and were not recorded (the interviews were not recorded at the interviewees' request), for ethical perspective participants were aware of their rights in this study, and they were informed that they could withdraw at any time, all participants were full-time employed teachers. The participants were teachers of the following subjects: Physics, French, Chemistry, English, and Mathematics. Teachers were given a full chance to express their opinions and beliefs.

The researcher of this study would justify the decision of making these interviews informal rather than formal by the following points. Firstly, participants requested not to record the interviews. It would be difficult for the researcher to collect the data from not recorded interviews. Secondly, the researcher and the supervisory team decided to collect the data using a questionnaire (refer to section 3.12.2), for several reasons, such as confidentiality, anonymity, and non-traceability which offers participants a high level of freedom to express their thoughts (Cohen, et al., 2005), as the influence of the micro socio-political sense would be minimised (refer to section 3.19). Finally, the researcher's point of view about the purpose of these informal interviews, which was to understand the main areas of interests for teachers to construct a reasonable and factual questionnaire.

3.12.2 The Second Instrument of the Pilot Study - Questionnaire

During the pilot study, there was a need to investigate the main area of the research, which is the impact of educational technology on students' learning. Based on the researcher's understanding of the concept of qualitative research and the interpretive paradigm, the researcher and the supervisory team decided to collect the initial data of this study using a questionnaire to be answered by teachers. (Appendix 4 – Teacher's Questionnaire).

3.12.2.1 The Main Areas of the Questionnaire

The questionnaire used in the pilot study aimed to check three areas related to teachers: i) the teacher's self-acknowledgement using ICT (digital technology), ii) digital technology integration using mobile devices, such as the iPad and iii) the teacher's educational process including the content of the curriculum and pedagogical dimensions (these elements will be discussed in detail in sections 3.12.2.5 and 4.1.1). These areas were used in the questionnaire to form an initial understanding of the relationship between content knowledge (curriculum), digital technology and pedagogy, which participated in creating the theoretical framework of this study (Figure 17) so that the in-depth investigation could take place.

3.12.2.2 The Rationale for Using the Questionnaire

For Cohen et al. (2003), the questionnaire as a tool in any interpretive paradigm is a useful and affordable tool for data collection. Creswell (2003) claimed that questionnaires are used mostly in quantitative and social studies. Even though the questionnaire can offer multiple truths and a rich source of data, which can be considered as an advantage, it requires considerable time and effort to be designed in an accurate manner, which is one of the major disadvantages. The questionnaire as an instrument to collect the data is relatively quick to obtain information. In some cases, the process of designing a questionnaire, applying it and analysing the collected data can be time-consuming (Harvey, 1998). However, as a result of distributing a precise questionnaire, reliable results can be collected (Creswell, 2003). Moreover, the questionnaire offers a substantial opportunity for people to express their opinions and state the truth the way they see it since the respondent remains anonymous (Stromer, 2004).

> It is important to include in the questionnaire, perhaps at the beginning, assurances of confidentiality, anonymity, and non-traceability, for example by indicating that they need not give their name, that the data will be aggregated, that individuals will not be able to be identified through the use of categories or details of their location. (Cohen, et al., 2005, p. 259)

One of the reasons that encouraged the researcher to use the questionnaire in the pilot study of this research was the desire to collect teachers' real thoughts and opinions in many topics related to learning without inconveniencing teachers. Even though the questionnaire consists of twenty questions, it could be answered in less than half an hour, as stated by some respondents. In contrast, if the researcher collected the teachers' opinions using the same questions through interviews instead of the questionnaire, it would have taken at least twenty hours to collect the data from participants. Therefore, a questionnaire can offer rich and reliable data in a short time compared with other instruments, which makes it a rich source of knowledge for an interpretive paradigm (Stromer, 2004). Moreover, the questionnaire might be more honest and reliable than the interview since the participants' identities are hidden, i.e., the influence of the micro-political senses would be minimised, which implies that the participants can express their thoughts freely (refer to section 3.19) (Morrison, 1993, cited in (Cohen, et al., 2005, p. 43).

Teachers were encouraged to do the questionnaire since there is confidentiality. Teachers were not requested to write their names or any other personal details so that they felt safe to answer the questions without fearing that their answers might be exposed later.

3.12.2.3 Questionnaire's Design

In general, the design of the research instruments, including the conducted questionnaire was based on the kind of collected data, which was controlled by the research area, the literature review and the research questions.

The main area of this research is related to educational technology and the implementation of technology integration, which includes pedagogical dimensions. Therefore, the questionnaire was designed to investigate many areas, such as the teachers' thoughts and beliefs towards educational technology, their skills in using digital technology, the pedagogical design used in classrooms and how often they use digital technology in the learning process to deliver the content?

Cohen et al. (2003) claimed that the successful questionnaire should not have any mysterious or ambiguous question. Therefore, in this study, to ensure that the extracted results from the questionnaire are valid and reliable, the questionnaire was designed to consist of actual and real concerns with direct and clear questions related to education. In 1970 Davidson stated that an ideal questionnaire should be "clear, unambiguous and uniformly workable" cited in (Cohen, et al., 2005, p. 250).

A few teachers asked for clarification of some questions related to the pedagogical dimensions. This was provided and where necessary questions were discussed and rephrased verbally for the participants. Embarrassing or complicated questions were avoided.

The majority of the questions used in the questionnaire were multiple-choice questions, but in order to give the participants a space of freedom in case they have a different point of view or a different answer not mentioned in the choices, participants were informed that they could add their answers if it did not exist among the stated responses. None of the participants had to do this, which indicates that the questionnaire was likely suitable for participants.

3.12.2.4 Types of Questions

As indicated previously, the questionnaire in this study has used two kinds of questions: closed format questions and open format questions.

The closed format questions, which can usually be answered by yes or no, were used to ask about information that is related to participants such as i) the experience, ii) if they use digital technology in their teaching or no, iii) if they have their website to communicate with students or no.

On the other hand, the open format questions were used to ask about information that is related to learning processes, such as the participant's opinion of educational technology, the applied technology, and pedagogical dimensions. The answers for the open format questions usually depends on the participant's thoughts and beliefs, such as the teachers' thoughts about the pedagogical dimensions or the digital technology used to deliver content. Therefore, this kind of thoughts cannot be generalised since each participant has his/her own point of view (Phillips, 2017).

The length of the questionnaire and the time it needs to be answered were taken into consideration. If the questionnaire is too long and requires a great deal of time to be answered by participants, then the validity and reliability of the collected data will be affected negatively. Therefore, the length of the questionnaire in this study was reasonable; it did not require a long time from participants to be completed which encouraged them to do it, at the same time the quality of the questionnaire was kept and considered. These claims were confirmed by the respondents.

3.12.2.5 Questionnaire's Content

The questionnaires' content focused on three main areas related to participants and the learning process:

i) Teacher's self-acknowledgement using ICT.
ii) Digital technology integration using mobile devices and applications in the classroom and the influence on learning.
iii) Teacher's educational process, including the content of the curriculum and pedagogical dimensions used to deliver the content.

The first part of the questionnaire focused on teachers' level and skills in using digital technology, their familiarity with it and their way of dealing with technological tools. The second part focused on educational technology, including teachers' perspectives and beliefs about the use of digital technology in the classroom, how important these new technologies are for their jobs as teachers and how helpful it is for their students. The third part investigated the teachers' pedagogical design in the classroom to deliver content knowledge.

Four different pedagogical dimensions were included in the questionnaire: i) Cognitively active learning. In this type of learning, cognitive exercises, such as creating the relationships between elements or variables, are given to students to engage them with the subject they study, so students will be shifted from the stage of being passive learners to the stage of being cognitively active learners (Mayer, 2004). Therefore, a teacher is no longer, the main provider of knowledge but a facilitator for students' learning process (Schallert & Martin, 2003); ii) Constructive learning. A teacher who applies constructivism believes that students can build their knowledge through the interaction with their environment. Therefore, a teacher should create a suitable environment, which motivates students to interact with it, in order to lead them to construct new knowledge. (Schallert & Martin, 2003); iii) Social learning. A teacher who applies the social collaborative learning believes that creating the social interaction environment can motivate students to exchange knowledge and ideas which might lead to improving their education (Schallert & Martin, 2003). Finally, iv) Direct teaching which is described as the traditional method of teaching where a teacher is the main knowledge provider and the centre of the learning process (Lin, et al., 2012). For more details about these pedagogical dimensions, please refer to sections 2.3, 2.9.1 and 2.9.2.

3.12.2.6 Piloting and Implementation of the Questionnaire

The questionnaire was piloted on twenty male and female teachers teaching different subjects in IAT schools. The taught subjects were divided into two separate categories: science and humanities. Results were collected and analysed using Microsoft® Excel.

While distributing the papers to the teachers general and brief information about participants was written on the corner of each distributed copy in terms of codes. These codes included the gender and the taught subject's category so that participants could be divided into two groups (categories), humanities subjects and science subjects. Therefore, the researcher coded each distributed copy of the questionnaire by one of the following: SMT science male teacher, SFT science female teacher, HMT humanities male teacher and HFT humanities female teacher.

Bryman (2012) and Cohen et al. (2003) claimed that the development process of a questionnaire should pass through three stages of evaluation. During the first stage, short, limited and simple questions should be asked for the participant. In the second stage, the responses should be used to point out the main areas of research and to construct the completed questionnaire. In the third stage, the final draft of the questionnaire can be revealed after it was polished and modified in the first and second stage, including content, time, length and layout.

In this study, the development of the questionnaire passed through three stages: the first stage of development was through informal interviews with some teachers in IAT schools. These informal interviews helped the researcher to form an initial image of the questionnaire's main areas and to gain a better awareness of teachers' beliefs and thoughts regarding educational technology.

The second stage of development was allocated to building the questionnaire, using the formulated ideas from the previous stage, and in the last scene, the questionnaire was revised, modified and polished after considering the recommendations of the supervisory team. For instance, some questions required more clarification, and some needed rephrasing. Furthermore, new terms, such as mobile technology devices, were defined in the questionnaire, and more choices were added to the questions to ensure that teachers would find a suitable category to place their responses. Eventually, the completed version of the questionnaire was revealed.

To ensure that teachers will respond to the distributed questionnaire appropriately and that they do understand the questions that are included in the questionnaire. Photocopies of the questionnaire were distributed to teachers, participants were offered the assistance in anything they need in the survey such as clarifications, and further explanation for some questions and they were given enough time to complete the questionnaire.

Before completing the questionnaire by different teachers, I provided the respondents with some clarifications related to the questionnaire parts. For instance, the terms used in question seven in the questionnaire, it was explained to teachers numerically, based on the percentage of the learning objectives. The phrase, always use, means that the teacher uses the stated pedagogical dimension to implement all the learning objectives, i.e., 100 % of the learning objectives are achieved using the stated pedagogical dimension. The phrase, mostly use, means that 80 % of the learning objectives are performed using the stated pedagogical dimension. The phrase, use about half of the time means that approximately 50 % of the learning objectives are implemented using the stated pedagogical dimension. Regarding the phrase, sometimes use, was stated as 20 % and regarding the term, never used, means that the teacher never applied the stated pedagogical dimension to implement any learning objective. Please see Table 10.

The Phrase	**The percentage of the learning objectives**
Always use	100 %
Mostly use	80 %
Use about half of the time	50 %
Sometimes use	20 %
Never used	0 %

Table 10. The equivalent percentages for the phrases used in question seven

3.12.3 The Pilot Study's Samples

During the pilot study, questionnaire papers were distributed to teachers. Twenty teachers were selected according to the subject they teach (science and humanities). To ensure that the selection of these teachers was random, the researcher used to go to teachers' staffrooms in different times and to give the papers of the questionnaire to whoever was found there or to give it to science or humanities teachers were met while walking in the corridor.

In this study, I covered subjects related to science and humanities; other subjects were excluded, based on this fact, teachers were selected as random as possible within science and humanities departments, the selected teachers were as follows: Physics (6 teachers), French (2 teachers), Chemistry (4 teachers), English (5 teachers) and Mathematics (3 teachers). Regarding the French teachers, they were not working in IAT schools, but they were working as full-time French teachers in an International school. Table 11, Table 12, and Table 13 provide some details about the participants of the pilot study: gender, subject taught, teaching experience in years.

Gender **Category**	**Male**	**Female**
Science teachers	11	2
Humanities teachers	5	2

Table 11. The category (science or humanities teachers) and the gender of the participants in the questionnaire.

	Teachers' response	**%**	**Teachers' response**	**%**
Teaching experience in years	5-9 years	40%	10-15 years	30%
	More than 15 years	30%		
The number of taught courses	2 courses	30%	3 courses	50%
	4 courses	10%	5 courses	10%

Table 12. Participants in the questionnaire, years of experience and the number of taught courses.

Subject **Category**	**Physics**	**Mathematics**	**Chemistry**
Science	6 teachers	3 teachers	4 teachers
Humanities	**French**	**English**	
	2 teachers	5 teachers	

Table 13. Participants in the questionnaire and their taught subject.

3.13 DATA ANALYSIS PROCEDURES OF THE PILOT STUDY

The data analysis stage in this study was one of the most critical scenes of the research, as it made the connection between the raw data, which was collected using the research instruments, the hypothesis and the conclusions of this study. This section presents the procedures that were implemented to analyse the collected data during the pilot study.

Marshall and Rossman, in their study, claimed that the "data analysis is the process of bringing order, structure, and interpretation to the mass of collected data. It can be a messy, ambiguous, time-consuming, creative and fascinating process", cited in (Manaf, et al., 2011, p. 173). The data analysis process can be defined as "a set of procedures or methods that can be applied to data that has been collected in order to obtain one or more sets of results" (AED/TAC-12, 2006, p. 19). In other words, data analysis consists of methods of dealing with the data to support the research study including the goals and plans.

The data analysis process of the pilot study could achieve several goals, such as: identify the relationship between educational technology and students' attainment and the relationship between the main areas of this research: digital technology, pedagogy and the content of the curriculum. This allowed the researcher to put forward ideas and draw conclusions.

Four informal interviews were conducted with four groups of teachers; each group consisted of five teachers, to discuss many areas related to educational technology, such as:

i) The impact of using educational technology on students' behaviour and attainment.
ii) What devices are used to integrate content knowledge with digital technology?
iii) The teachers' experiences in educational technology.
iv) The teachers' experience in the pedagogical dimensions.
v) The pedagogies used to deliver the content.

vi) The learning management system used to deliver the content.

These teachers' thoughts and ideas were formed and shaped by questions to build the questionnaire. Not all teachers who were involved in the interviews were included in the questionnaire, as the random perspective was considered in all stages of the study.

A questionnaire is a rich source of knowledge, as it provides a massive amount of data in a relatively short time compared with other instruments, such as interviews and observations (Stromer, 2004). The questionnaire that was implemented in this study did not require a long time to be distributed, filled and collected back, but it required a relatively long time to be designed, rephrased and developed until it took its final form and was revealed.

The questionnaire aimed mainly to explore the teachers' thoughts and beliefs regarding educational technology including their skills of using digital technology, and the pedagogical dimensions, using a sample of teachers of different subjects that belong to humanities and science.

To ensure that participants would have enough time to read the questions thoroughly and to answer them accurately, they were informed that they have two days to give it back. Most of the teachers (14 out of 20 teachers) answered the questions and returned the questionnaire on the same day.

Before analysing the completed questionnaire, the returned copies of the questionnaire were checked to be sure that all of the questions were answered. Furthermore, there was a brief conversation with some participating teachers to make sure that the questions were well understood. There were positive feedback and confirmation from the teachers that the questions were clear and factual. While checking the returned questionnaires, it was noticed that one of the teachers left a branch of question unanswered since the questionnaire was anonymous, it was not possible to trace the teacher, so the answer had been left blank in the questionnaire and the data analysis. There were no reasons that might affect the validity of the returned questionnaire. Therefore, no returned questionnaire was excluded.

In the next stage of the questionnaire analysis, the questions were divided into three parts: i) Teacher's self-acknowledgement using ICT, ii*)* Digital technology integration using the mobile devices and applications, iii) Teacher's educational process and the pedagogical dimensions. At this stage, it had been decided by the researcher and the supervisory team to use Microsoft® Excel as it can offer the statistical analysis, such as representing the collected data by graphs (bar charts), and several statistical tests (refer to Appendix 1 – Statistical Functions).

According to the results of the questionnaire (shown and discussed in detail in section 4.1.1), participants agreed that there is a positive impact of using educational technology on students' learning (qualitative methodology). Therefore, the research approaches were developed, to a new challenge, which is how to predict the impact factor (the improvement in students' attainment due to the use of educational technology) using quantitative methodology. Therefore, teachers were asked about the percentage of improvement in students' attainment due to the use of educational technology (based on their previous records in their mark books) and the percentage of the content that was integrated with digital technology. Unfortunately, not all the participants had previous records to answer these questions; as a matter of fact, only three teachers (physics, mathematics and English), including the researcher could answer these two questions.

The researcher acknowledges that this is a small sample, and it should be more extensive to be able to run statistical functions, such as P-value and Pearson correlation factor. However, at that time, this sample was the only available sample, and the researcher's target was to form an initial understanding of the effect of educational technology on students' attainment. Therefore, this sample was used to form the core idea of this research, with a plan to test all findings during the in-depth investigation (the main study).

The previous records were collected from teachers, P-value and Pearson correlation factor were used to check the strength of the relationship between two elements: the amount of the material, which is integrated with digital technology and the impact factor (for more details refer to section 4.1.2).

METHODOLOGY OF THE MAIN STUDY (IN-DEPTH INVESTIGATION)

3.14 THE CONNECTION BETWEEN THE PILOT STUDY AND THE MAIN STUDY (THE TRANSITION FROM QUALITATIVE TO QUANTITATIVE METHODOLOGIES)

In the first stage of this study (the pilot study), teachers' thoughts regarding the use of educational technology were investigated using a questionnaire (Appendix 4 – Teacher's Questionnaire). Some teachers' previous mark books were used to check the effect of educational technology on students' attainment. The data collected from the questionnaire and the teachers' previous records (based on their mark books) showed that there is a positive effect of using educational technology (refer to section 4.1). Therefore, the research scope was promoted to investigate the impact of using educational technology on students' attainment quantitatively instead of qualitatively, i.e., the study approaches were developed. A new challenge emerged: how to predict and measure the improvement in students' attainment as an outcome of using educational technology, which is referred to in this study as the predicted *impact factor*. Figure 20 shows the stages of development of the pilot study.

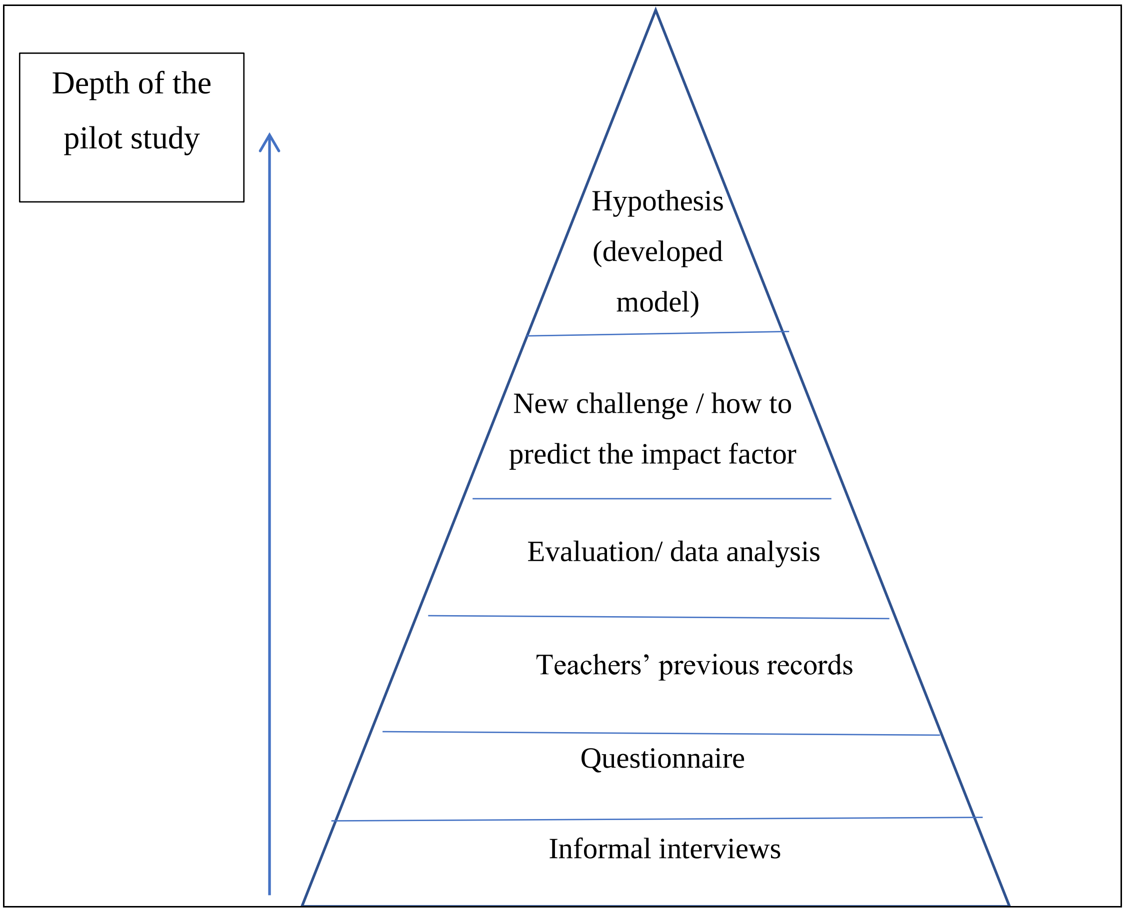


Figure 20. The stages of development of the pilot study.

I suggested the term *impact factor* to express the percentage of improvement in students' attainment due to the use of educational technology.

I do acknowledge that measuring and predicting the impact factor requires significant samples (large scale) and many assessments to be conducted. However, in that period (pilot study), I had to use the available data obtained from the participants to form the core and initial idea of the developed model of this study, which was tested and verified during the in-depth investigation (stages two and three) using more extensive samples and different subjects. After building the core idea of the developed model in this study (CPT model) using the findings of the pilot study (questionnaire and teachers' mark books), there was a need to check the new findings in terms of reliability and validity. Thus, the second and third stages were conducted to test the developed model and check the validity of the new equations that are related to it. For more details about the CPT model, please refer to section 5.

Note: please refer to Figure 21, which shows the stages of development of the main study along with the Pilot study.

3.15 THE MAIN STUDY (IN-DEPTH INVESTIGATION) METHODOLOGIES

"All progress is born of inquiry. Doubt is often better than overconfidence, for it leads to inquiry, and inquiry leads to invention" this famous quotation by Hudson Maxim shows the significance of research and how research can lead to the invention, cited in (Kothari, 2004, p. 5). The findings of the pilot study could give the researcher an initial understanding of the relationship between educational technology and students' attainment. However, there was a crucial need to test the validity and reliability of these findings, which took place during the main study (stages two and three) which focused on measuring the improvement in students' attainment as an outcome of using educational technology, i.e., to measure and predict the impact factor. Students were assessed many times in different subjects that belong to science and humanities, the collected data (students' attainment) were analysed in these stages using a range of statistical methods (refer to section 3.17.6 and Appendix 1 – Statistical Functions).

In each case in stages two and three, the content of a lesson or section was divided into two parts, with the condition that these two parts must have the same level of complexities. Webb's (Mississippi Department of Education, 2009) and Florida's (Cpalms.org, 2019) depth of knowledge (DOK) levels were employed to review the contents' level of complexities in both scenarios, refer to section 3.17.5.1. The two parts of the content were taught to the selected group of students. The first part of the content was taught using nondigital technology-based learning; the students were examined, marks were registered. The second part of the content was taught for the same group of students using digital technology-based learning (digital technologies were integrated with the taught content, including simulations, iBook Author, online resources, external articles and movies related to the content), students were examined, exams were marked, and the marks were recorded. As agreed with the involved teachers, the assessments conducted in the first and second situations should have the same level of complexities. Bloom's Taxonomy was used to review the exam's level of complexities, please refer to section 3.17.5.2. Consequently, the impact of digital technology could be distinguished by the difference in students' attainment in both situations.

Five instruments were used to collect primary data in stages two and three: i) planned learning outcomes to be implemented in the classroom without the use of digital technology (teachers prepared it), ii) paper-based assessment tool prepared by teachers, iii) planned learning outcomes to be implemented using digital technology. iv) paper-based and technology-based assessment tool, v) exams were marked in both cases, the marks were recorded and compared to check the impact of digital technology (positive or negative) and to calculate the observed impact factor as well.

It was agreed with the teachers who were involved in the study to create a positive learning environment (technological facilities – iPads, laptops, learning management system, various pedagogical dimensions, a positive and clean environment, a positive and friendly relationship with the students), as this kind of environment facilitates students achieving their goal and learning. Teachers were encouraged to create a positive learning environment in both learning scenarios, digital and nondigital technology-based learning. However, digital technology was used in the case of digital technology-based learning only.

Different learning management systems were used in these stages, such as Plato (the former learning management system of IAT), which was replaced by another learning management system: D2L (Desire to Learn) alongside Showbi platform system.

It was agreed with the involved teachers to include the following criteria in their assessments:

i) The assessments must integrate the theoretical and practical sides of the subject/material, especially in the science subjects.
ii) Assessments must cover different categories of questions such as short response, problem-solving and conceptual questions.
iii) Assessments must include at least three different levels of questions according to Bloom's Taxonomy to be suitable for the whole range of students, such as comprehensive, application and analysis (different levels of complexities) (Teaching Learning Center, 2015; bloomstaxonomy.org, 2018).
iv) Students must be given enough time to answer the questions of the exam.

Developing the model (the CPT model), the teaching, assessment, and collecting the data were administered in the period between January 2016 and October 2017. Different subjects were included in stages two and three, physics, mathematics, biology, social studies and English language. The researcher of this study and the supervisory team decided to choose subjects related to science and humanities and avoid other subjects, such as art, physical education and extra curriculum activities (ECA), due to the fact that the content of these avoided subjects is ambiguous (no clear curriculum documents that include academic learning objectives, which might affect the validity and reliability of the collected data negatively). Furthermore, at the level of primary and secondary schools, the content of these avoided subjects is not delivered using digital technology, especially in the case of physical education and ECA.

During the study, students interacted positively with the use of digital technology in learning and towards the use of mobile technology, such as the iPad, to create a personalised learning experience outside the classroom. Students became involved more in their learning, and they could learn at any time and any place. However, I do confirm that all graded tasks or assessments during this study were implemented inside the classroom. The researcher and the supervisory team made this decision for several reasons are discussed in the limitations of this study, please refer to chapter 7. Figure 21 shows how the study (pilot and in-depth investigation) was developed.

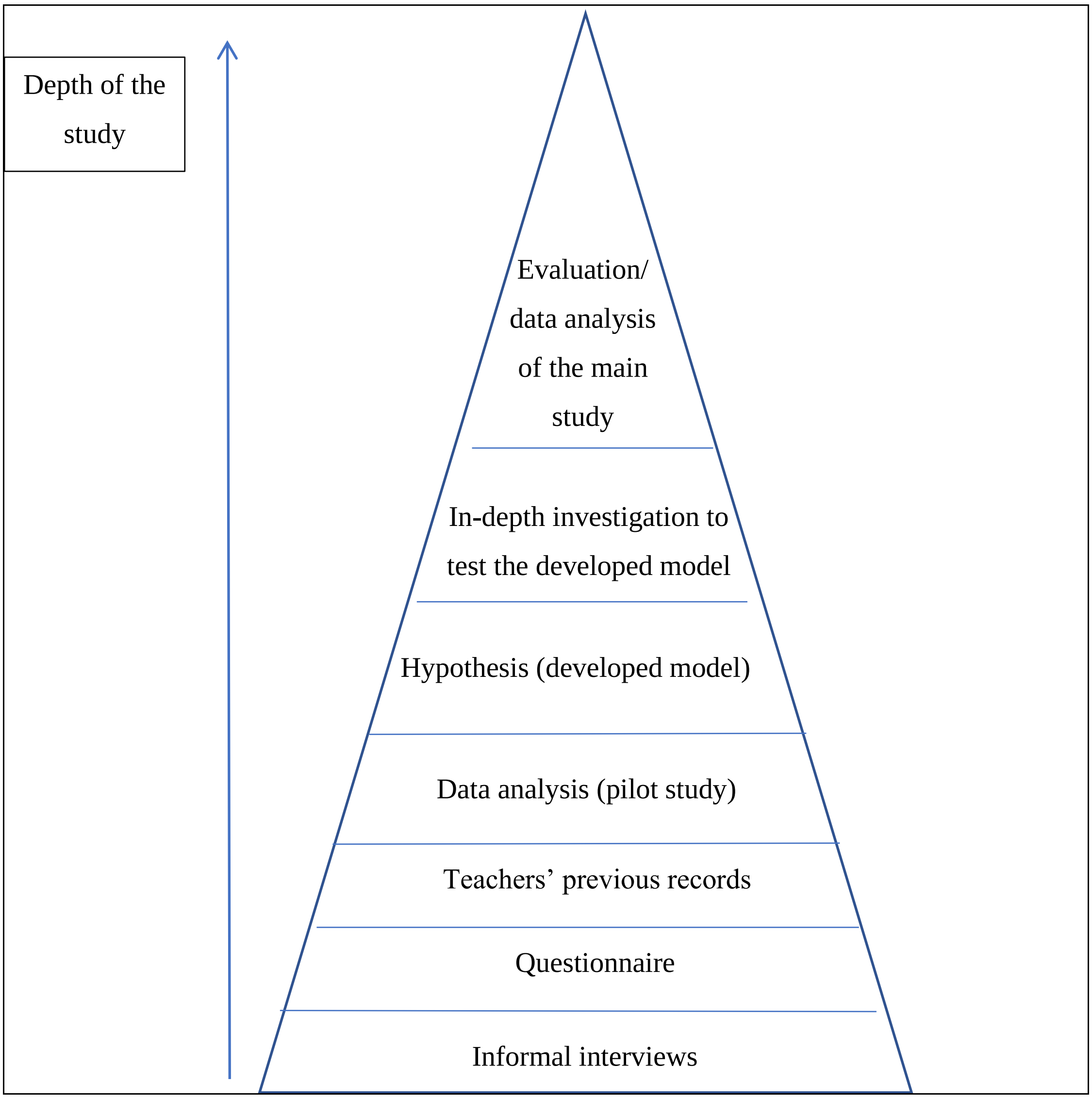


Figure 21. The stages of development of the study (Pilot study and in-depth investigation).

3.15.1 Main Study Plan

The findings of the pilot study were investigated during the main study (stages two and three) using a more extensive range of samples and subjects (two hundred seventy-eight students were examined in different subjects related to science and humanities). The main study played a vital role in testing and validating the pilot study's findings. This part of the study (stages two and three) could answer the research questions (refer to section 1.4) by digging more in-depth in the research areas.

Before conducting the main study (stages two and three), meetings were held with the participating teachers to discuss the policies of the study, such as the goal of the study, samples confidentiality and the mechanism of collecting the data. Participating teachers knew and understood their role in this study. Students' attainments with and without using educational technology were checked and investigated by assessing them after each case. These collected data were compared and tested using a range of statistical functions: Pearson correlation factor, chi-square test, T-test, P-value and effect size (refer to section 3.17.6 and Appendix 1 – Statistical Functions).

3.16 EQUIPMENT AND RESOURCES THAT WERE USED IN THE MAIN STUDY

1. The involved teachers had access to MacBook Pro laptops and iPads, provided by IAT. These devices come with packages of software and applications (Apps) meeting the expectations of digital technology integration plan and the curriculum requirements.
2. Classrooms, workshops and laboratories are equipped with projectors, audio systems and smart boards (digital technology to serve the curriculum outcomes).
3. Learning resource centre (LRC) has many multimedia resources to support curriculum implementation and promote students' literacy and research skills.
4. Electronic resources were provided, such as iBooks, academic animation movies and PDF files.
5. Learning management systems (Plato and desire to learn (D2L) (Farah, et al., 2016).

Note: this equipment and all resources exist in all IAT schools.

3.17 THE MAIN STUDY SAMPLES

Regarding the main study (stages two and three), the researcher can claim that the participants, the groups of students, were selected randomly from the specific population, which was intended to investigate (two IAT schools out of fourteen schools). Hanlon and Larget (2011) defined a simple random sample as a chosen sample in a manner that each participant within the sample has the same chance of being selected.

This agrees with Kothari (2004) who claimed that the random sampling grants each member in a population an equal opportunity of being chosen to participate in a conducted study.

To ensure equal chances for the samples to be selected, the researcher wrote the grade and section titles for all grades in the schools, such as grade 11 sections 1 and 2 (G11.01, G11.02) on separate pieces of papers, folded each paper, placed them into pots (all sections of each grade in a separate pot) and then random papers from each container were picked. As such, not all sections of grade 11 were involved in the study, random sections of grade 11 were selected, and the same goes for other grades, which means that not all sections of one grade were selected, but that each section had an equal opportunity of being selected.

The selected samples in stages two and three of this research were chosen randomly; these samples can be considered as a representative sample of the specific population, which the researcher studied in IAT schools.

> Random sampling ensures the law of statistical regularity, which states that if on an average the sample chosen is a random one, the sample will have the same composition and characteristics as the universe. This is the reason why random sampling is considered as the best technique for selecting a representative sample. (Kothari, 2004, p. 60)

However, the author would claim that the findings of this study can be generalised to this particular population only (IAT schools), but there is no guarantee that it can be generalised to other external populations. The following points describe the selected samples:

i) The samples that were investigated have the same characteristics as the population, especially that the students are Emirate citizens (permanent residents). Based on sociocultural and geographical perspectives, the students who were involved in the study came from different places (more than ten villages). Therefore, it can be said that the study covered various geographic areas and diverse layers of the society, which might reduce the margin of error, so that it can be considered as a broad layer, though not necessarily representative of the entire population of United Arab Emirates.

ii) The participants were randomly selected from the specific population, which was intended to investigate (two IAT schools).

iii) To represent the population of IAT schools, participants in the study were both male and female students.

Another aspect that was taken into consideration, the socio-economic status (SES) of the students involved. SES is an essential factor in any educational technology research, see section 3.6.

I confirm that all students who participated in the in-depth investigation were able to use the laptop and iPad at any time and any place, regardless of their socio-economic status (SES), as IAT provides freely every student with an iPad, a laptop and access to the required software, such as a learning management system, iBooks and simulation applications (Apps). Therefore, the participating students could access these tools in school and from home freely. For more details about the socio-economic status (SES), please refer to section 3.6

3.17.1 Samples of the Second Stage (In-depth Investigation) – Students

In the second stage (in-depth investigation), ninety-eight students were involved. School authorities' permission was received to use students' work and marks in this research. The students were aware of their rights, and they were informed that they could withdraw at any time. The participants had a mean age of sixteen years. All participants had to be examined twice; the first exam was conducted after nondigital technology-based learning (pre-test), and the second exam was after using digital technology-based learning (post-test). Table 14 below shows details about the participants and the taught subject in the second stage of this study.

Case #	**Grade**	**Age-ranges of students in years**	**Students' ethnicity/ citizenship**	**Gender**	**No of students**	**Subject**
1	Grade 09	15	Arab/ UAE	Male	35	Physics
2	Grade 10	16	Arab/ UAE	Male	28	Physics
3	Grade 11	17	Arab/ UAE	Male	35	Physics

Table 14. Participants in stage two of this study.

3.17.2 Samples of the Third Stage (In-depth Investigation) – Students

In the third stage (in-depth investigation), one hundred and eighty students (participants) from ten different classes were involved, as shown in Table 15 and Table 16. The school authorities' permission was received to use students' work and marks in this research. For ethical consideration, the students were made aware of their rights, as per ethical guidelines. The participants' ages were between 14 and 17.

Table 15 and Table 16 show the classes and the number of students that were examined many times in different subjects during stage three of this study.

Case #	Grade	Age-ranges of students	Students' ethnicity/ citizenship	Gender	No of students	Subject
1	Grade 10	16	Arab/ UAE	Male	17	Biology
2	Grade 08	14	Arab/ UAE	Female	20	Biology
3	Grade 11	17	Arab/ UAE	Male	20	Biology
4	Grade 10	16	Arab/ UAE	Male	20	Biology
5	Grade 08	14	Arab/ UAE	Female	20	Biology
6	Grade 09	15	Arab/ UAE	Male	16	Maths
7	Grade 10	16	Arab/ UAE	Male	14	Maths
8	Grade 11	17	Arab/ UAE	Male	20	Maths
9	Grade 11	17	Arab/ UAE	Female	18	Physics
10	Grade 09	15	Arab/ UAE	Female	20	Physics
11	Grade 11	17	Arab/ UAE	Male	18	Physics
12	Grade11	17	Arab/ UAE	Male	21	Physics

Table 15. Participants in stage three in the science subjects.

Case #	Grade	Age-ranges of students	Students' ethnicity/ citizenship	Gender	No of students	Subject
1	Grade 09	15	Arab/ UAE	Male	16	English
2	Grade 09	15	Arab/ UAE	Male	16	English
3	Grade 11	17	Arab/ UAE	Male	20	English
	Grade 11	17	Arab/ UAE	Male	25	English
4	Grade 09	15	Arab/ UAE	Female	20	Social Studies
5	Grade 11	17	Arab/ UAE	Male	15	Social Studies
6	Grade 09	15	Arab/ UAE	Male	27	Social Studies

Table 16. Participants in stage three in the humanities subjects

All students, who participated in stages two and three, are Emirate citizens and have the same ethnicity being aware that the IAT policy states that the applicant (student) must be a UAE national. Mistry and Sood (2013, p. 44) described such population as a “mono-cultural/ mono-ethnic” population.

3.17.3 Main Study Data Analysis Procedures (Stages Two and Three)

Prior to the data collection process, there were meetings conducted with the teachers involved to discuss the study and their role in this stage of the study. The discussion with teachers aimed to agree about the teaching strategies which should be applied (teaching strategies were derived from the developed model of this study). These strategies include the pedagogical dimensions that would be used to deliver the content, the types of curriculum that would be used during the content's delivery process (theoretical, practical and interactive). Likewise, the amount of material to be integrated with digital technology, which was calculated using the number of learning objectives that were integrated with digital technology. For instance, if a content consists of five learning objectives and a teacher integrated three learning objectives out of five with digital technology, then it should be considered that 60% of the content was integrated with digital technology. It was agreed with the involved teachers that the learning objectives should have equal weight (approximately). The equivalent percentage for each learning objective can be found using the following formula:

Equation 1

The equivalent percentage (the amount of material integrated with digital technology) =

$$\frac{\text{The number of learning objectives integrated with digital technology}}{\text{Total number of learning objectives}}\ x\ 100\%$$

Note: I developed the above formula, so it would be easier to calculate the amount of material which is integrated with digital technology

Table 17 shows a few examples that illustrate the calculation of the equivalent percentage of the integrated content with digital technology.

Total number of learning objectives	**The number of learning objectives integrated with digital technology**	**The equivalent percentage (**the amount of material integrated with digital technology)
2	1	50 %
4	4	100%
5	3	60%

Table 17. The equivalent percentage of integrated content with digital technology.

In the process of developing the research methodology, prior to the main study commencement, in some classes, I used an alternative technique to calculate the percentage of content integrated with digital technology. This technique was based on the amount of time during the lesson where digital technology was used. However, the researcher found that this technique was not a valid method, for a simple reason that this time can be dissipated inefficiently while chatting with students in some external topics not relevant to the lesson or while the teacher is trying to control the class so that the integration with digital technology in such a case will be pointless. As a matter of fact, it will be just counting minutes without efficacy, or inefficient use of digital technology, which may not lead to any improvement. As stated by the office for standards in education (Ofsted, 2002, p. 4) “the effective application of ICT across subjects that needs to improve most”. Hence, I decided to consider the amount of material integrated with digital technology to be calculated based on the number of learning objectives that are combined with digital technology, as shown above in Table 17.

3.17.4 The Use of Pre and Post-tests in the Main Study

The scope of this research is to compare students’ attainment in two teaching-learning scenarios: digital and nondigital technology-based learning applied to two different contents within the same subject. Webb’s (Mississippi Department of Education, 2009) and Florida’s (Cpalms.org, 2019) depth of knowledge (DOK) levels were employed to review the contents’ level of complexities in both scenarios. It was agreed with the involved teachers that both contents should have the same depth of knowledge. Same pedagogies and kinds of the curriculum were applied in both situations. The only difference between both situations is related to the existence of educational technology (digital technology) in one of them and the absence of it in the second one. As such, I could observe how much educational technology could add to students’ attainment based on their results in the pre and post-tests.

Each student in each CPT strategy of this study was examined twice, once after being taught without using educational technology, which was considered the pre-test, and another exam took place after being taught using digital technology (educational technology), which was considered the post-test. In each case, the results of both exams were subtracted, which showed the observed (actual) difference that educational technology had on students' attainment. The differences in students’ attainment in both cases, pre and post-tests, i.e., the observed impact factors were compared with the predicted impact factors that are calculated using the CPT model equations.

Knapp (2016), Marsden and Torgerson (2012) in their research addressed a group of factors that could be considered as a threat to the pre and post-test findings’ validity, such as maturation, the content of the test itself, the test design and the marking process. To avoid these threats and increase the validity of the pre-test (based on nondigital technology-based learning), and the post-test (based on digital technology-based learning), the following actions were considered in this research. Firstly, students' maturity level was considered, as the pre and the post-test for each group of students were conducted within a short period (little time passed between them). Secondly, the pre-test and the post-test were based on different contents so that both tests were not the same and nothing common between them, else the level of complexity, as it was agreed with the involved teachers that the pre and post-tests should have the same level of complexities, refer to section 3.17.5. Finally, the teachers who marked the pre-test were the same teachers who marked the post-test, so it was ensured that the same procedures of marking were followed in both situations.

Regarding the generalisability of the pre and post-tests' findings, the selected samples in this research can be considered as a representative sample of the specific population investigated in IAT schools. Therefore, results could be generalised to this particular population only, but there is no guarantee that it can be generalised to any other external population.

The road map to the pre and post-tests in the main study

The main study (in-depth investigation) was conducted in two stages: the second and third stages. These stages were used to test and validate the findings of the pilot study. The main subjects in these stages were students, and the purpose of these stages was to measure the improvement in students' attainment as an outcome of using educational technology (the impact factor).

Students were assessed in different subjects; the collected (observed) results were compared with the predicted results or the expected improvement in students' attainment that were calculated using the equations of the developed model (the CPT model), which was designed on the basis of the findings of the pilot study. The collected data were analysed using diverse statistical functions: Cohen's D to calculate the effect size, Pearson Correlation Factor to check the strength of the relationship or the correlation between the variables (the use of educational technology and students' attainment), T-test to compare the means of data from two related samples, Chi-square test and P-value were used as well (refer to section 3.17.6 and Appendix 1 – Statistical Functions).

In each case in stages two and three, the following road map was considered:

i) The content was divided into two parts with the stipulation that these two parts must have the same level of complexities.

ii) The selected groups of students were taught the first part of the content using nondigital technology-based learning; students had to use traditional tools, such as pens, pencils notebooks and textbook. The teacher mainly used the traditional whiteboard (non-interactive) and textbook to explain the content.

iii) Students were examined based on nondigital technology-based learning. Students' only source of knowledge was the teacher, notebooks and the textbooks;

iv) The exam was marked, and the results were recorded.

v) Digital technology-based learning was applied to the second part of the content (new technologies were integrated with the taught content, such as simulations, iBook Author (interactive book), online resources and external articles).

vi) Students were examined under digital technology-based learning, and results were registered.

vii) To be able to determine the impact of using educational technology, positive or negative impact: students' marks in both situations (without and with educational technology) were compared; the comparison showed that in most of the cases there were improvements in students' attainment. Cohen's D to calculate the effect size and the Pearson Correlation Factor were used in this step. (Please refer to sections 3.17.6, 6.1 and 6.2).

viii) To be able to determine if the developed model (CPT model) is valid as a predictive model or not, the actual improvements (the observed impact factor) were compared with the expected improvements (the expected impact factor), which were calculated using the equations of the developed model (CPT model, please refer to chapter 5). T-test, Chi-square test and P-value were used in this step. (Please refer to sections 3.17.6, 6.1 and 6.2).

A description of Webb's depth of knowledge levels and Bloom's taxonomy stages was shared and discussed with the teachers involved in this study. As such, teachers could judge the complexity levels of the contents delivered and the cognitive levels of the exams conducted in both cases, digital and nondigital technology-based learning, refer to section 3.17.5

The in-depth investigation could determine the impact of using educational technology if it has a positive or negative impact and to check if the CPT model is valid as a predictive model for the improvement in students' attainment (in advance). Figure 22 shows a summary of the steps that were followed to collect the data in stages two and three.

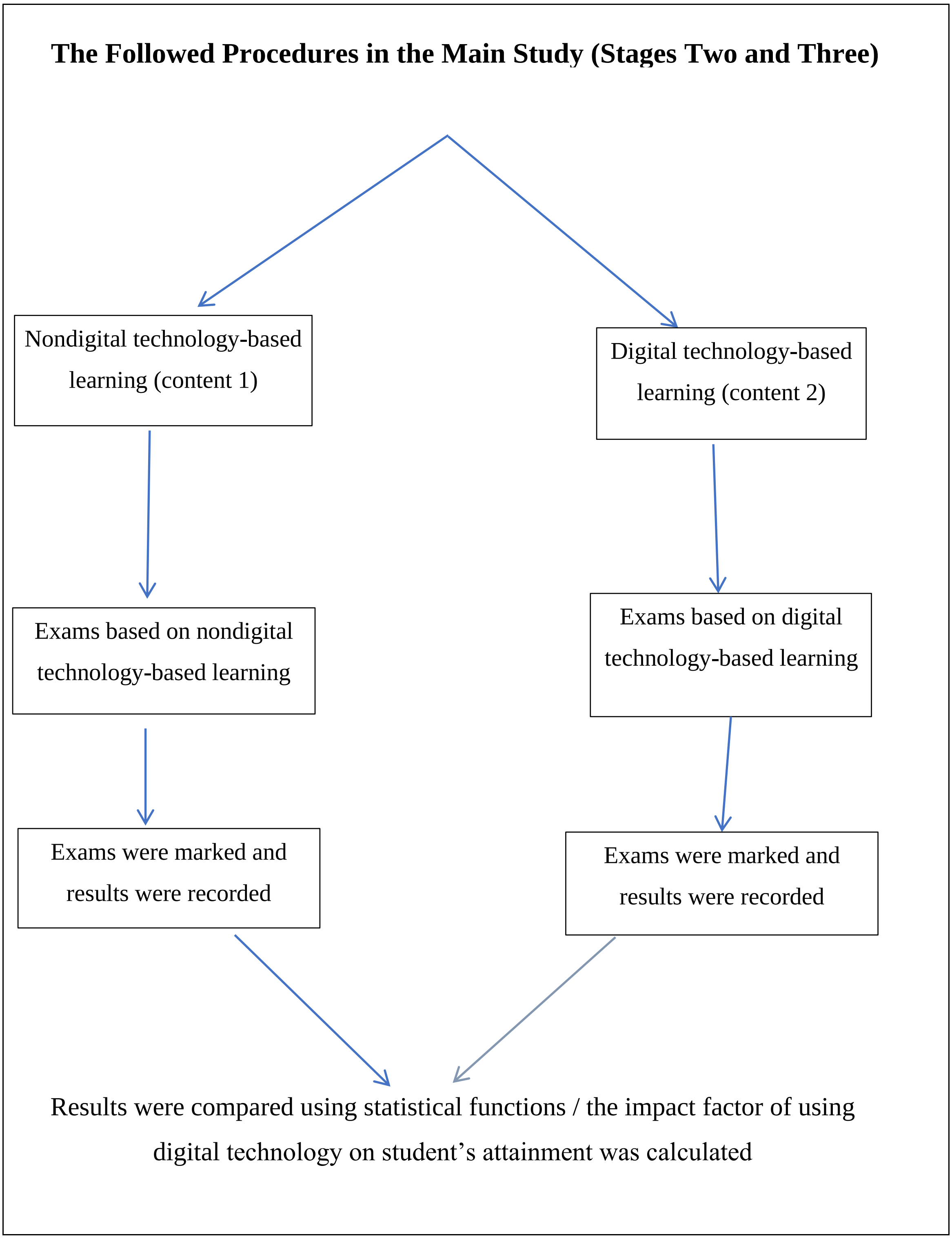


Figure 22. The strategies that were followed in each case in stages two and three to collect the data.

3.17.5 The Validity of Comparisons Relating to Integration and Non-integration of Digital Technology

This section outlines the validity of comparisons relating to integration and non-integration of digital technology, as it describes the content complexity based on Webb's depth of knowledge levels and compares the cognitive levels of the exams conducted after nondigital and digital technology-based learning, using Bloom's taxonomy, please refer to Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons, Appendix 8 – Samples of the Exams Conducted During this Study, including Table 20, Table 21, Table 90, Table 93, Table 114, Table 136, Table 137, Table 139 and Table 140.

3.17.5.1 Content Cognitive Complexity / Depth of Knowledge (DOK) levels

Two different approaches were discussed and shared with the involved teachers to review the content cognitive complexity, Florida’s original depth of knowledge (DOK) Levels and Webb’s four-level DOK. It was agreed with the involved teachers to use these approaches to judge the content complexity and ensure that both contents delivered, through digital technology or without, have the same level of complexity.

In 1997, Webb developed a four-level depth of knowledge (DOK) model to review the content complexity and its cognitive demand (Mississippi Department of Education, 2009). According to Hess et al. (2009, p. 4), depth of knowledge describes “the complexity of both the content (e.g., interpreting literal versus figurative language) and the required task (e.g., solving routine versus non-routine problems)”.

Florida’s standards for Mathematics and English Language Arts & Literacy described the content cognitive complexity or the depth of knowledge using three different categories, low, moderate and high content complexity (Cpalms.org, 2019). According to Cpalms.org (2019), Webb’s four-level DOK can be matched with Florida’s DOK levels as follows:

Level 1: Recall. According to Florida’s DOK Levels, this level is described as low cognitive complexity.

Level 2: Basic application of skills and concepts. This level is equivalent to the second level of Florida’s DOK, moderate complexity.

Level 3: Strategic thinking and complex reasoning.

Level 4: Extended thinking and complex reasoning.

Levels 3 and 4 are sketched against the same level of Florida’s DOK, high complexity content. The essential difference between both levels, 3 and 4, is that DOK of Level 4 comprises the application, analysis and synthesis of Level 3 knowledge, but students work over more extended time as students may need to conduct extensive research using various learning resources (Hess, et al., 2009; Cpalms.org, 2019).

The following description of the content complexity (DOK) of Humanities, Mathematics and Science subjects is based on the research of Hess et al. (2009), Florida State University (Cpalms.org, 2019) and Wisconsin Department of Public Instruction (2016).

The description, of Webb’s and Florida’s DOK levels, was shared and discussed with the involved teachers. It was confirmed that both contents in both situations, digital and nondigital technology-based learning, must have the same depth of knowledge and cognitive complexity.

Levels of Content Complexity for Humanities subjects, such as English language and social studies

Level 1: Recall / Low complexity

Standards and activities at this level expect students to recall facts, concepts, theories and the use of basic skills, such as oral reading. Students’ learning at this level is surface learning. This level generally requires students to “recall who, what, when and where” (Cpalms.org, 2019). Activities that ask students to describe and explain could be listed at Level 1 or 2 (basic application of concepts and skills) depending on the task’s level of complexity. For instance, activities that require students to recognise, describe and explain particular data included in simple graphics, are generally level 1. Students might be asked to extract information from a given map, locate places, use a dictionary to define a word, order some events in the text and quote from the text.

Level 2: Basic Application of Concepts and Skills / Moderate complexity

This level requires the engagement of some mental processing beyond recalling facts. Students are requested to analyse the text but not in a sophisticated manner. Skills and concepts that are required in Level 1 are applied in level 2 as well. At this level, students can summaries the text, create connections between different elements in the text and state the main idea of the text.

Generally, this level requires students to distinguish or compare characters, places, stories and thoughts; order items into meaningful divisions. For example, students may be asked to describe the historical background of a specific city or outline the roles of a government's branches.

Level 3: Strategic Thinking and Complex Reasoning / High complexity

At this level, students are requested to understand the text, explain, create connections and draw conclusions. Reasoning, employing evidence, and higher-order thinking skills are required at this level. At this level, students should be able to support and justify their thinking. The cognitive demands of this level are more complex and abstract than the previous levels (1 and 2). For example, students may be asked to:

- "Determine the author's purpose and describe how it affects the interpretation of a reading selection.
- Identify causal relationships in a text.
- Assess the extent to which the reasoning and evidence in a text support the author's claims". (Cpalms.org, 2019)

Level 4: Extended Thinking and Complex Reasoning / High complexity

"High levels of complexity through analysis and synthesis characterise both levels 3 and 4. What distinguishes the two is that a level 4 standard or test item will entail a significant effort over time, multiple resources, and documents" (Cpalms.org, 2019). Level 4 requires higher-order thinking and in-depth knowledge. At this level, students need to apply the gained knowledge to a new task or situation. Students may also be asked to perform complex analysis or develop hypotheses. For example, students may analyse and synthesise knowledge using various learning resources. And also to examine and demonstrate alternative perspectives to specific matter using external learning resources.

Levels of Content Complexity for Mathematics

Level 1: Recall / Low complexity

This level requires students to show a rote response. It involves the recall of fundamental knowledge, such as a law, definition, or a basic procedure, as well as applying a simple formula. For example, students at this level are expected to multiply and divide numbers less than 100 and recognise the variables shown in a two-dimensional graph, such as the Cartesian coordinates.

Level 2: Basic Application of Concepts and Skills / Moderate complexity

The standards of this level require students to make some decisions that can lead to solving a problem. For instance, students at this level are expected to measure volumes and masses of different objects in grams (g), kilograms (kg), and litres (l). Convert a unit to another unit, such as kilograms to grams and the vice versa. Use prefixes to express the standard base units, such as Giga (10^9) and pico (10^{-12}). Add and subtract rational numbers. Interpret data from a simple graph and produce a graph using a given data. Moreover, to “graph proportional relationships, interpreting the unit rate as the slope of the graph” (Cpalms.org, 2019).

Level 3: Strategic Thinking and Complex Reasoning / High complexity

The standards of this level require a higher level of thinking skills, such as analysis, synthesis, reasoning and planning. At this level, students need to support and explain their thinking. Students at this level may deal with complex, abstract problems that can have more than one possible answer. Students need to find the most suitable response and justify their decision. For example, formulate a problem using a real-world situation, interpret data collected through experiments or observations, defend and criticise a solution to a problem.

Level 4: Extended Thinking and Complex Reasoning / High complexity

This level “involves the application of level three processes and skills over an extended period” (Cpalms.org, 2019). Students at this level may incorporate other content domains, such as physics, biology and art, to support a mathematical argument that represents a real-world situation. For example, to derive a sophisticated mathematical equation using different concepts of physics, such as using the equations of motion in physics to derive a second-order differential equation that can describe the motion of an object. Furthermore, students at this level may develop a mathematical model that can explain a specific phenomenon or conduct extensive research to support a theory.

Levels of Content Complexity for Science subjects, such as Physics and Biology

Level 1: Recall / Low complexity

At this level, students are requested to recall knowledge, such as a fact, definition, or theory, and the ability to perform a simple science process. This level requires students to show a rote response, use general formulas, follow well-organised steps. For example, students are expected to remember a concept, describe in words or charts a scientific relationship or process, and perform simple measurements.

Level 2: Basic Application of Concepts and Skills/ Moderate complexity

The standards of this level require students to move beyond recalling facts. The content knowledge involved is more complicated than the content in Level 1. The activities at level 2 involve interpreting collected data from observations and experiments. Displaying the collected data in tables and graphs, as well as interpreting data from simple diagrams. Define and illustrate the relationship between variables; recognise variables in an experiment.

Level 3: Strategic Thinking and Complex Reasoning/ High complexity

The standards of this level require a higher level of thinking, such as analysis, synthesis, reasoning and planning. At this level, students are required to support and explain their thinking. Students at this level deal with complex, abstract activities and problems that can have more than one possible answer. Students need to find the most suitable response and justify their decision. For instance, students at this level may investigate real-world situations, draw conclusions through observations and experiments, defend and criticise their findings. And also use different concepts to solve non-routine problems.

Level 4: Extended Thinking and Complex Reasoning/ High complexity

The standards of this level require the same high cognitive demand as Level 3 with an essential difference that students, at this level, work over an extended time and efforts. Students need to create connections between different concepts within the same subject and other subjects, such as physics, mathematics and biology. Students at this level are expected to perform complex analysis, synthesis, investigate, search, support their thinking and state the limitations of their work. Students may be asked to look for evidence using various learning resources to support a theory; solve problems that need the application of various concepts of mathematics or write a detailed report of a conducted experiment in the laboratory.

> It is important to reiterate that the extended time period is not a distinguishing factor if the required work is only repetitive and does not require the application of significant conceptual understanding and higher-order thinking. For example, an activity that calls upon a student to measure the water temperature from a river each day for a month before constructing a graph would be classified as a level 2. On the other hand, an activity that calls upon a student to conduct a complex river study that requires taking into consideration a number of variables would be a level 4 (Cpalms.org, 2019).

During this study, the application of level 4 was limited by the activities that were implemented inside the classroom (inside the school), as there were no activities implemented outside the classroom, which was considered as part of the limitations of this study, please see chapter 7

Bloom’s taxonomy was used to check the validity of comparisons relating to integration and non-integration of digital technology, as it compares the cognitive levels of the exams conducted after nondigital and digital technology-based learning, please refer to sections 3.17.5.2 and 3.17.5.3 and Appendix 8 – Samples of the Exams Conducted During this Study.

3.17.5.2 The Assessments in the Main Study and Bloom’s Taxonomy

Gensee and Upshur (1996) claimed that assessment is concerned mainly with improving instruction as well as students’ learning. According to Wiliam (2011) and Popham (2008), assessments are focused on how learning is progressing and shows how well learners have grasped what they had been taught. These claims were supported by Popham (2008), who stated that “Assessment-elicited evidence of students’ status is used by teachers to adjust their ongoing instructional procedures or by students to adjust their current learning tactics". In turn, this implies that assessments are designed to achieve two essential functions. Firstly, to certify that students have grasped the delivered knowledge during the course (Cauley & McMillan, 2010; Leahy, et al., 2005). The assessments used to determine students' understanding on the completion of a course are referred to as summative assessments (IAT, 2018; Popham, 2008). Students' results in the summative assessments can be used for progression. For instance, based on these results, students might be raised to higher-grade levels. Therefore, Salvia and Ysseldyke in 2007 defined a summative assessment as "a process of collecting data for the purpose of making decisions about individuals and groups" cited in Vanderbilt University (2011, p. 2).

Secondly, assessments are used as tools for adjusting the on-going education, including teaching and learning. This type of assessment is known as assessments for learning (AFL) (Partnership Management Board, 2007). In the case of an AFL, the feedback itself is an essential tool, as it guides students and teachers to meet the expectations (Cauley & McMillan, 2010; Leahy, et al., 2005; Sadler, 1989). Usually, AFL is referred to as formative assessments (Jabbarifar, 2009; Cauley & McMillan, 2010).

Biggs (2003) suggested that the assessment needs to be aligned with the course objectives. Hence, an assessment's outcomes can be considered as reliable tools to determine if students have or have not achieved the expected learning outcomes.

According to Liljedahl (2010), Dumit (2012) and Wylie (2008), assessment's purposes can be summarised as follows:

i) Give learners the motivation to continue learning and achieve more progress.

ii) Cover the majority of the learning objectives to check students' understanding.

iii) Provide students with feedback on their progress and performance.

iv) Provide teachers and decision-makers with feedback (based on students' results) about the validity and reliability of the curriculum, the learning process, students' academic level and the actions that should be considered to make any required reforms.

v) The assessments can be taken as evidence of learning taking place and an indication of whether students' performance meets or exceeds the expectations.

According to Morris et al. (1996), learners can have a strong passion for learning, if they receive appropriate instructions or a clear plan. The appropriate instruction can be created once the teacher addresses students' needs through an effective assessment. In line with Morris et al. (1996), Surgenor (2010) and Reutzel and Cooter (2007) claimed that teachers use the outcomes of assessments to create the intervention plans that support students' learning.

The assessments that were used in this study can be broken down into formative and summative assessments.

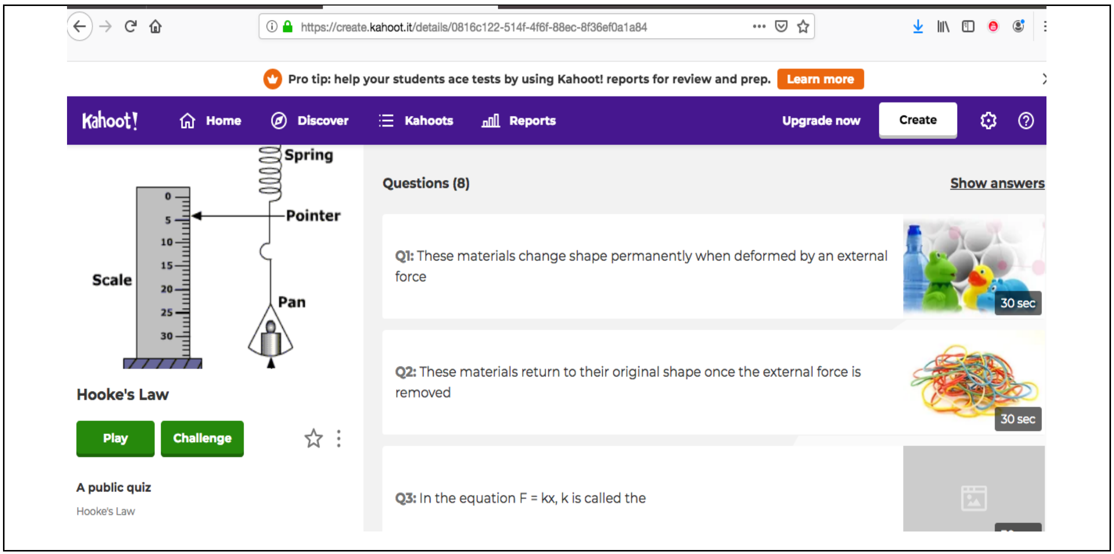
Garrison and Ehringhaus (2010) stated that formative assessment is a vital section of the instructional process. When consolidated into classroom usage, it provides the required information to modify teaching and learning while they are taking place. In this sense, formative assessment notifies both teachers and students about the learning status at a specific point. Therefore, appropriate adjustments can be made. These adjustments ensure that students attain targeted learning outcomes within a set time frame (Sadler, 1989).

Flippo (2003) claimed that formative assessment encompasses informal and formal procedures. Therefore, Flippo (2003) described the formative assessment as an ongoing process involving multiple forms and shapes, such as observations, work specimens and information about students' interests and skills.

The formative assessments that were applied to this study took several forms, such as oral questions and answers during the lesson, discussion between teachers and students and students among themselves, the teacher's observations, problem-solving activities and quick online tests, see Figure 23. According to Surgenor (2010)

> Formative assessment does not form part of the student's final grade or mark. It is used to provide constructive feedback to improve learning and understanding. The product of formative assessment may never be quantifiably recorded on a grade sheet. (Surgenor, 2010, p. 2)

In line with Surgenor (2010), the formative assessments in this study, informal assessments, were not considered in the data analysis of this study. The researcher and the supervisory team decided to consider the summative assessments, formal assessments, as the main assessments and their results to be considered in the data analysis of this study.



https://create.kahoot.it/details/0816c122-514f-4f6f-88ec-8f36ef0a1a84

Pro tip: help your students ace tests by using Kahoot! reports for review and prep.

Hooke's Law

A public quiz

Hooke's Law

Questions (8)

Q1: These materials change shape permanently when deformed by an external force

Q2: These materials return to their original shape once the external force is removed

Q3: In the equation F = kx, k is called the

Figure 23. Online formative assessment created using Kahoot platform. https://create.kahoot.it/details/0816c122-514f-4f6f-88ec-8f36ef0a1a84

The summative assessment “takes place after the learning has been completed and provides information and feedback that sums up the teaching and learning process. Typically, no more formal learning is taking place at this stage, other than incidental learning which might take place through the completion of projects and assignments” (Northern Illinois University, 2006, p. 2). This assessment is designed to judge the student’s understanding and overall performance. Most likely, this kind of assessments is to be considered as a judge of whether the learning process has succeeded or failed (Surgenor, 2010).

During this study, the summative assessments (pre and post-tests) took place at the end of each selected lesson, which includes both cases: nondigital and digital technology based-learning. The difference between students’ attainment in both scenarios (with and without using digital technology) represents the observed impact factor or the observed percentage of improvement in students’ attainment as an outcome of using educational technology. Please see the included examples of the summative assessments in this thesis, refer to Appendix 8 – Samples of the Exams Conducted

During this Study. For more details about the pre and post-tests in this study, please refer to section 3.17.4.

Regarding the sequencing and timing of the implemented exams during the main study. The second stage assessments took place during term one (September to December) in the academic year 2016/2017. The third stage was divided into two parts: science and humanities subjects. The assessments related to science subjects were conducted during term two (January to March) in the academic year 2016/2017. The humanities assessments were done during term three (April to July) in the same academic year. It was left to teachers to determine the exact dates during these terms as they have many other commitments related to their jobs else this study. In all conducted exams, Bloom's taxonomy was used to compare the exam's complexity in both situations. Please see section 3.17.5.3 and the included examples of the summative assessments conducted in this study, refer to Appendix 8 – Samples of the Exams Conducted During this Study.

Bloom's Taxonomy

It was agreed with the involved teachers that the assessments conducted in both situations (learning with and without digital technology) should have the same level of complexities. To ensure as identical as possible level of complexities, the exams conducted in both cases were constructed according to Bloom's taxonomy (see the included examples of the summative assessments in this thesis Appendix 8 – Samples of the Exams Conducted During this Study). Hence, the impact of digital technology could be distinguished by calculating the difference in students' attainment in both situations.

Bloom's taxonomy ranks the complexity of a task as it estimates the task's depth of knowledge (Forehand, 2011). According to Dunham et al. (2015), the assessment, which is designed according to Bloom's Taxonomy consists of questions with different levels of complexities; therefore, all students regardless of their academic level can find questions suitable for them and compatible with their academic level. Forehand (2011) claimed that this framework helps teachers to design the assessments in a professional manner that produces constructive feedback on students' understanding.

Bloom's Taxonomy is divided into six different cognitive levels; knowledge, comprehension, application, analysis, evaluation and synthesis. According to Dunham et al. (2015) the first two cognitive levels, knowledge and comprehension, are described as low order cognitive skills (LOCS), while levels three and above, application, analysis, evaluation and synthesis, are deemed as high order cognitive skills (HOCS). In this sense, Dunham et al. (2015) claimed that assessments that require high order thinking skills require a greater level of critical thinking and reasoning, which justify students' poor performance in HOCS tests unlike those requiring only LOCS.

Bloom's Taxonomy levels/stages

The following summary of Bloom's stages is based on the following research projects: Dunham et al. (2015), Karamustafaoglu et al. (2003), bloomstaxonomy.org (2018) and Teaching Learning Center (2015).

Note: The following summary of Bloom's stages was shared and discussed with the teachers involved in the main study.

- Bloom's Level 1 - Knowledge

In this level, students need to remember fundamental knowledge and basic concepts of the previously learned subject. The main keywords to distinguish this level from other levels: *tell, list, describe, relate, locate, write, find, state, name, ex: how many...? Make a list of the main events.*

- Bloom's Level 2 - Comprehension/understanding

In this level, students are requested to interpret their understanding of the material and answer questions that rely on the understanding of the facts and concepts stated in the subject. The main keywords for this level: *classify, contrast, demonstrate, translate, explain, extend, illustrate, outline, relate, rephrase, interpret, summarise, show, and compare.*

- Bloom's Level 3 - Application

In this level, students need to apply the ideas and knowledge, which they acquired previously to solve problems related to known ideas but in new situations, forms and shapes. The main keywords for this level: *apply, build, construct, develop, make use of, organise, utilise, model, identify, solve, show, create, complete, examine,* *classify.*

- Bloom's Level 4 - Analysis

In this stage, students have to draw connections between ideas and topics. The main keywords for this level: *analyse, distinguish, examine, compare, contrast, investigate, categories, identify*.

- Blooms Level 5 - Evaluation

In this stage, students have to be able to justify, argue and defend the facts by building up the judgments about these facts. The main keywords for this level: *decide, defend, determine, dispute, evaluate, judge, justify, measure, rate, appraise, interpret, support importance, prove, disprove, influence, perceive, value, estimate, deduct, argue, and judge*

- Bloom's Level 6 - Synthesis

In this stage, students have to add up knowledge in a different shape, by combining ideas in a new form and creating alternative solutions and new justifications. The main keywords for this level: *combine, compile, compose, construct, create, design, develop, estimate, formulate, imagine, invent, makeup, originate, plan, predict, propose, suppose, discuss, modify, change, improve, adapt, minimise, maximise, theorise, design.*

Table 18 and Figure 24 show summary of Bloom's taxonomy stages.

Level	The cognitive level	The learner's expected action/ response	The main activity to be trained on.
1	Knowledge	Recall fundamental knowledge	Multiple-choices questions, facts and statistics, stating theories, rules and definitions.
2	Comprehension/ understanding	Students interpret their understanding of the material, to answer questions that rely on their understanding of the facts and concepts stated in the subject.	The explanation, interpretation of the meanings, solving problems, creating examples.
3	Application	Apply the knowledge which has been acquired previously to solve new problems built on the known ideas but in new situations or forms.	Form a combination of the acquired facts, illustrate the observations, and solve a problem.
4	Analysis	Students have to make a connection between several ideas to justify a new idea.	Construct the parts and functions of a concept or group of concepts, or de-construct / breaking down a concept or process for many elements.
5	Evaluation	Justification, arguing defending and judging.	Justifying the facts, to be able to recommend ideas and reject others
6	Synthesis (create/ build)	Inventing a new model or idea	Developing new ideas

Table 18. Bloom's Taxonomy levels (Teaching Learning Center, 2015; California State University, 2018)

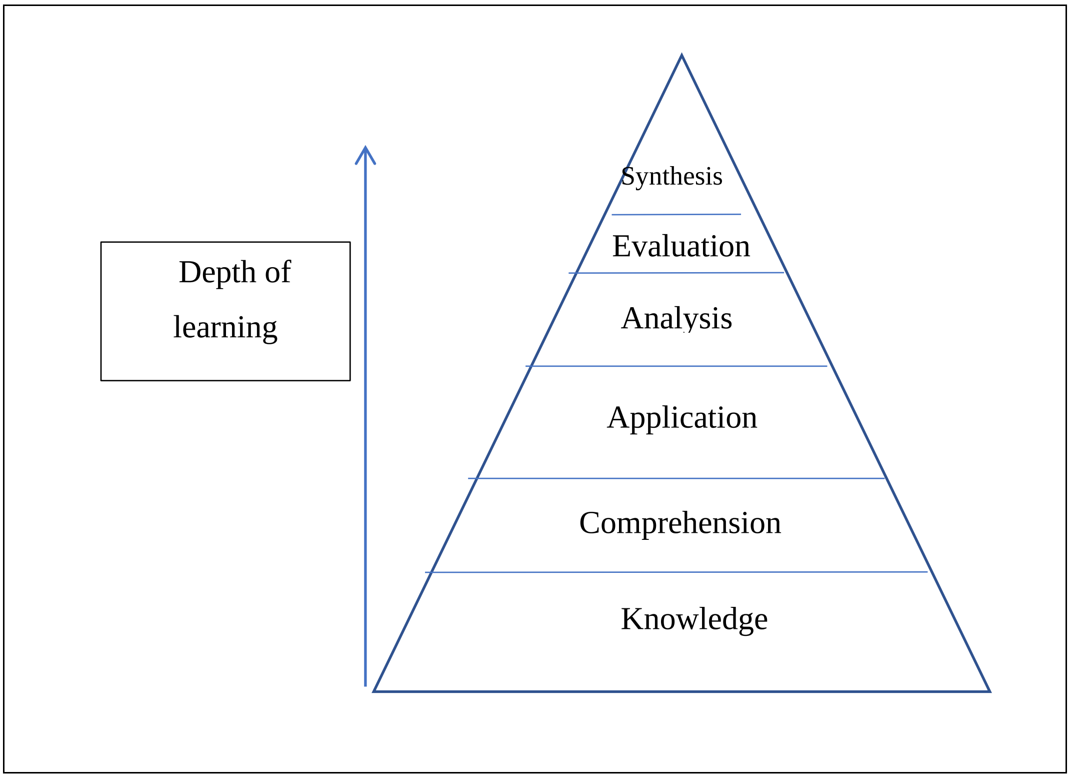


Figure 24. Bloom's Taxonomy stages represent different cognitive levels

Note. Figure 24 is based on the author's understanding of Bloom's taxonomy.

3.17.5.3 Sample of Comparison of the Conducted Exams During the Main Study – Physics subject

The following description is for two physics exams conducted following two physics lessons implemented in this study to find the impact factor of the C3, P3, T4 scenario (please refer to Appendix 8 – Samples of the Exams Conducted During this Study). Exams' results (students' attainments in the pre and post-tests) were used to measure the observed (actual) impact factor and to compare it with the predicted impact factor, which was calculated by the CPT model's equations. Being aware that the first lesson, simple harmonic motion, was delivered using digital technology-based learning, while the second lesson, Newton's second law, was delivered without using digital technology, nondigital technology-based learning. Newton's first and third laws were included as well, but the main focus was Newton's second law.

Table 19 shows the description of the parts that were included in both exams: Newton's second law and simple harmonic motion.

Lesson Title	**Part number**	**Category**	**The weight of each part out of 100 %**	**The number of questions in each part**
Both lessons, Newton's second law and simple harmonic motion.	I	Multiple choices questions	36 %	9
Both lessons, Newton's second law and simple harmonic motion.	II	Figure's analysis	51 %	3
Both lessons, Newton's second law and simple harmonic motion.	III	Conceptual questions	13 %	3

Table 19. The main parts included in each exam

Table 20 and Table 21 show the cognitive level, Bloom's taxonomy stage, of the included questions in each part of the conducted exams. Table 20 is related to the simple harmonic motion exam, and Table 21 is related to Newton's second law exam.

Cognitive level / **Part number**	**Knowledge**	**Comprehension**	**Application**	**Analysis**	**Evaluation**	**Synthesis**
Part I		2 questions	4 questions	3 questions		
Part II			1 question (several branches)	2 questions (several branches)	1 branch (question 10 C)	
Part III		1 question		2 questions		

Table 20. The cognitive levels of questions included in the simple harmonic motion exam, please see the included exam in this thesis 0.

Cognitive level / Number of questions in each part	Knowledge	Comprehension	Application	Analysis	Evaluation	Synthesis
Number of questions in part I		2 questions	5 questions	2 questions		
Number of questions in part II			1 question (several branches)	2 questions (several branches)	1 branch (question 10 C)	
Number of questions in part III		1 question		2 questions		

Table 21. The cognitive levels included in Newton's second law exam, please see the included exams in this thesis, Appendix 8 – Samples of the Exams Conducted During this Study.

Note: the cognitive level of each question is shown in the exams themselves, please refer to Appendix 8 – Samples of the Exams Conducted During this Study.

Table 20 and Table 21 show the cognitive levels of the questions included in each exam. In both exams, Part I comprises two out of nine questions focus on Low order cognitive skill (LOCS): Comprehension; while seven out of nine questions required high order cognitive skills (HOCS): Application, Analysis, and Synthesis.

Part II in both exams comprises questions that are deemed as high order cognitive skills (HOCS): Application, Analysis and Evaluation. Part III in both exams includes questions that belong to both orders, high and low cognitive skills, which comprises Comprehension and Analysis — being aware that the weight (out of 100%) of each part, in both exams, is equal. For instance, the total mark for part I in both exams is 36 %, and so on for parts II and III, see Table 19. Based on Table 20 and Table 21, it can be stated that the weight of the questions related to HOCS is equal in both exams, and the same goes on for the questions related to LOCS. Therefore, I would claim that both exams have approximately the same level of cognitive complexities. Please refer to Appendix 8 – Samples of the Exams Conducted During this Study.

The Marking Procedures

The following procedures were considered during the correction process of the exams conducted in the main study, which includes all investigated subjects:

i. The main corrector and reviewer should mark each exam paper.
ii. The reviewer needs to make sure that no question is left uncorrected. He/she also needs to double-check the addition of marks.
iii. The main corrector uses a red pen, and the reviewer uses green.
iv. If the reviewer found any mistake in the answer key or the exam itself, he/she needs to report it to the main corrector and the researcher so that the necessary action could be considered.

These procedures were discussed and shared with the teachers involved in the main study. The main correctors were the teachers of the subjects, who taught both contents using digital and nondigital technology-based learning. The reviewers were selected randomly from the teachers involved. Please see samples of students' responses in Appendix 9 – Samples of Marked Exams – Students' Responses.

For other examples related to comparing the cognitive levels of the exams conducted after nondigital and digital technology-based learning, please refer to Appendix 8 – Samples of the Exams Conducted During this Study.

3.17.6 The Rationale for Using the Statistical Functions

The observed improvements (observed impact factor) were collected using the data of two hundred and seventy-eight students in different subjects: mathematics, physics, biology, English and social studies. Various statistical tests were used to compare the observed data accurately with the expected data, to check the null hypothesis of this study and the validity of the developed model of this study (the CPT model).

Effect size offers researchers an opportunity to move away from the simple statistical description towards an interpretable, quantitative description of the magnitude of an effect (Fritz, et al., 2011). Cohen’s D or the effect size was used in this study to measure the difference between the two means, i.e., to estimate the distance that the means of two groups of data, the students’ marks with and without using educational technology, have shifted from each other (Borenstein, et al., 2009) as shown in Figure 25 (Coe, 2002, p. 2), so that the comparison at the level of groups could be made accurately. Calculating the effect size allowed the researcher of this study to judge how significant is the effect of using educational technology on students’ attainment (large, medium or small effect) (Coe, 2002).

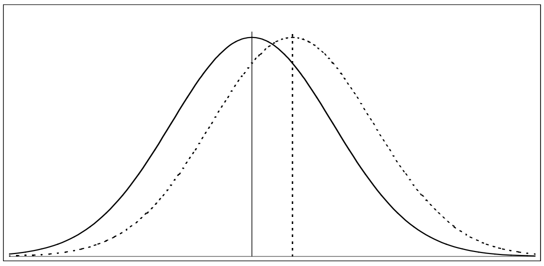


Figure 25. The effect size depends on the overlapped area and how the results spread. (Coe, 2002, p. 2).

An effect size is an objective measure of the magnitude of the observed effect on a sample (Field, 2005). In 1969 Cohen described an effect size of 0.2 as small and provided to explain it, the case of the difference between the heights of 15-year-old and 16-year-old girls in the US. An effect size of 0.5 is represented as medium and is large enough to be noticeable to the naked eye. A 0.5 effect size resembles the difference between the heights of 14-year-old and 18-year-old girls. Cohen illustrated an effect size of 0.8 as grossly visible and, therefore, large and compares it to the discrepancy between the heights of 13-year-old and 18-year-old girls. As a further example, he stated that the difference in IQ between holders of the PhD degree and typical college first-year students is comparable to an effect size of 0.8 (Cohen, 1988; Coe, 2002).

The Pearson Correlation factor was calculated to check the existence and strength of a relationship between the variables. This statistical function is used to check how the collected data are related to each other (Mukaka, 2012). In this study, the Pearson Correlation factor was applied to explore the strength of the relationship between the use of educational technology and students’ attainment, which was achieved by checking the relationship between students' marks with and without using educational technology.

The correlation coefficient (factor) ranges from -1 to +1, "depending on whether the slope is positive or negative (correlation or anti-correlation)" (Hall, 2015, p. 2). If a correlation factor is considerably close to 0, but either positive or negative, it indicates a weak or no relationship between the two variables. If a correlation factor is close to +1, it implies a positive relationship between the two variables, with a rise in one of them being associated with increases in the other one. If a correlation factor is close to -1, it implies a negative relationship between the two variables, with a rise in one of them being associated with a decrease in the other one (University of Regina, n.d.).

A t-test was used in this study to compare the means of data from two related samples (the means of observed and predicted improvement in student's attainment).

The t-test enabled the researcher of this study to decide whether the mean of the expected improvement in students' attainment is really different from the mean of the observed improvement in students' attainment, being aware that the data collected represent a paired-samples t-test (refer to Appendix 1 – Statistical Functions). According to Kothari:

> In case two samples are related, we use paired t-test (or what is known as difference test) for judging the significance of the mean of difference between the two related samples. It can also be used for judging the significance of the coefficients of simple and partial correlations. (Kothari, 2004, p. 196)

The chi-square test (X^2) relates to the P-value. In particular, the chi-square test compares the observed frequency in each group to the frequency which would be expected, which can be called a comparison between a categorical data (variables) (Ugoni & Walker, 1995). (X^2) Test can be used as a test of goodness of fit; as it allows the researcher to check how well the theoretical (predicted) distribution fits the observed (actual) data. Each value of (X^2) should meet a P-value. In the specific table, if the calculated value of (X^2) is less than the table value at a certain level of significance, then the fit is considered to be a good fit, which means that there is no significant difference between the observed and predicted frequencies (Kothari, 2004).

On the other hand, if the calculated value of (X^2) is greater than its table value, then the fit is not considered to be a good one (Kothari, 2004). “Chi-square test is based on chi-square distribution and as a parametric test is used for comparing a sample variance to a theoretical population variance” (Kothari, 2004, p. 196). This agrees with Maben (2018, p. 1) who stated: “The chi-square test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories”.

Calculating the (X^2) value and comparing it against a critical value at a specific level of significance using (X^2) statistical distribution table allowed the researcher of this study to assess if the observed improvement in student’s attainment is significantly different from the expected improvement in student’s attainment or not.

Measuring the P-value enabled the researcher to check how much of the observed data disagrees with the null hypothesis of this study. In other words, the P-value was employed in this study to measure the strength of the evidence against the null hypothesis by estimating the probability of obtaining an equally extreme or more extreme result than what was observed, if the null hypothesis is correct.

Being aware that the null hypothesis (H_0) of this study states that there is no significant difference between the means of predicted and observed impact factors, which implies that the CPT model is a valid and reliable predictive model for the improvement in students’ attainment as an outcome of using educational technology.

Note: for more conceptual details about the statistical functions that were used in this study, please refer to Appendix 1 – Statistical Functions.

3.18 VALIDITY AND RELIABILITY

In this study, the validity and reliability issues were taken into consideration in all the methods that were used to collect the data during the pilot study and the in-depth investigation.

There are two subtypes of validity that have an essential role in conducted research, internal validity and external validity. The internal validity of research is concerned with the ability to measure what was intended to measure. The external validity of a study is concerned with the ability to generalise the research findings to external populations (Kothari, 2004). Regarding the internal validity, the author would claim that this study has internal validity as it could measure what was intended to measure since the beginning of this research. For instance, this study could investigate the impact of educational technology on students' attainment (positive or negative), map the relationship between digital technology, pedagogy and the content of the curriculum to develop a new predictive model (the CPT model) that could predict the impact factor of using educational technology on students' attainment.

Regarding the external validity, the researcher would suggest that the findings of this study can be generalised only to the specific population that was studied in IAT schools, but there is no guarantee that it can be widespread to external populations. Polit and Beck stated that:

> The goal of most qualitative studies is not to generalise but rather to provide a rich, contextualised understanding of some aspect of human experience through the intensive study of particular cases. (Polit & Beck, 2010, p. 1)

Okoro in 1994, and Bello in 1998 (cited in John (2015), considered reliability as the degree of consistency between two measures of the same thing or the accuracy, trustworthiness or consistency of a measuring instrument.

> Reliability is concerned with repeatability. For example, a scale or test is said to be reliable if repeat measurements made by it under constant conditions will give the same result. (Taherdoost, 2016, p. 33)

Many steps had been taken into consideration to enhance the reliability of the study, such as the stages of development that the piloted questionnaire passes through during the pilot study stage. Starting from informal interviews to understand teachers' thoughts and points of view, then building the initial structure of the questionnaire, then many stages of discussion with the supervisory team followed by the required and recommended modifications so that the questionnaire could be completed, revealed and distributed.

Lipson et al. (1999) claimed that authenticity is the study's level of accuracy, fairness and reliability. The researcher of this study may claim that authenticity parameter was enhanced by taking into consideration several procedures. For instance, during the stages of developing the questionnaire, the questionnaire was reviewed by the supervisory team who provided the researcher with some recommendations, such as rephrasing some questions to raise the level of accuracy and make it easier for participants. The pilot study (the first stage), was conducted on a small sample of teachers, enhanced the authenticity of the study, the findings from the pilot study were tested using more extensive samples of students in stages two and three which enhanced the findings' accuracy, validity and reliability. Furthermore, different samples of students from different grades were selected randomly, and two categories of taught subjects (humanities and science subjects) could sustain the accuracy and maintain the fairness level of this study as well.

Cohen et al. (2003) argue that educational research is considered reliable if it gives similar answers repeatedly with the same group of participants. Therefore, the majority of the CPT strategies that were applied during the in-depth investigation were trialled twice to check the reliability of the results.

The use of different instruments, samples, subjects to collect data in this study improved validity and reliability. Comparing the observed results with the expected ones could enhance the validity and reliability of this study.

The reliability of the results that were collected during the main study (stages two and three) was determined through different statistical functions. Outcomes were extracted using these functions and compared with critical statistical values: for instance, comparing the effect size value with the critical values could demonstrate the kind of effect of using educational technology on students' attainment. And the same goes on for P-value, T-test, chi-square, and Pearson correlation factor.

Creswell (2009) argued that the validity of a study is determined by the significance of the used instruments and the ability to transform the collected data using the instrument to form productive findings. The valid instrument is the method, which measures what was intended to investigate and measure in the research (Lodico, et al., 2010). Kimberlin and Winterstein (2008) explained the valid instrument using the accuracy of the results that are produced.

Trochim (2006) described several sorts of validity, such as face and content validity; the most applicable to this study is content validity. Trochim stated that content validity is based on the accuracy of an established instrument in a conducted research that covers all aspects of the investigated area that was intended to be covered. According to Wozney et al. (2006), the technology implementation questionnaires should have content validity, for the reason that researchers are consulting and collecting ideas from experienced educators and other researchers.

In order to enhance the content validity in this study, many aspects related to educational technology had been covered, starting from the pilot study which focused on teachers as the main subjects of the study, their thoughts towards educational technology, pedagogy as well as the relationship between digital technology, pedagogy and curriculum, which was investigated thoroughly during the main study.

3.19 ETHICAL ISSUES

One of the most critical areas in any educational research is related to ethical issues. In general, a researcher needs to make sure that the collected data will stay confidential and will not be used outside the research area. Furthermore, the researcher needs to make sure that his studies cause no harm to any participant. Beauchamp and Childress (1983) stated that the ethical considerations in educational research must involve four principles: respect the rights of each participant, offer a positive contribution to learning, do not cause any harm and finally apply the justice especially the equality among participants.

The author would affirm that the above principles were kept and considered in all stages of the research. Prior to completing the questionnaire, each participant was provided with a consent letter to fill it (please refer to Appendix 3 – Teacher’s Consent Letter). All participants were aware of their rights, and they were informed that they could withdraw their responses from the collected data at any time. Permission was granted from the IAT schools to commence the studies using samples within the schools; the studies were kept confidential and caused no harm. Moreover, the findings of this research can be employed to serve the learning process and enhance the students' academic performance.

Furthermore, in this study, the ethical guidelines that were stated by the British educational research association, which is the home of educational research in the United Kingdom (BERA, 2018) were followed. The participants agreed voluntarily to participate in the study. Participants received a full explanation of the purpose of the research and its potential impact on learning; participants were given the opportunity to ask any questions about the study. It had been discussed with participants, why their participation was essential to the research, and how it would be employed and to whom it would be reported.

The participants were informed clearly that their participation would be analysed and used in the research and were informed that they could withdraw from the research at any time they decided. Moreover, all the collected information is being kept strictly confidential and used only for this research without any individual identification of participants, which was mentioned explicitly on the first page of the questionnaire and the consent letters (refer to Appendix 3 – Teacher's Consent Letter and Appendix 4 – Teacher's Questionnaire).

An official letter was sent from the supervisory team at Nottingham Trent University to IAT schools (see Appendix 2 - Consents). Therefore, permission from the IAT schools was obtained to use students' work in this research. Furthermore, there were no incentives or rewards offered to participants in this study to encourage them to participate in the research.

Confidentiality, privacy and anonymity are essential for the participants to respond to conducted studies (Jones, 1997). During all of the stages in this study, privacy was considered. The confidentiality of the collected data and the participants' anonymity were taken into consideration; no real names were required or requested from participants, which encouraged teachers to respond to the questionnaire, and motivate students to participate in the in-depth investigation since no students' names were used in the data gathering and analysing. Students in each class were numbered (student 1, student 2, and so on).

The chosen methods and instruments in this study are fit with the purpose of the study, caused no harm to any participant. This study has been recognised by two publications (see Appendix 10 – List of My Publications), so that part of the findings are placed in the public domain (the confidentiality of the collected data and the participants' anonymity were considered and respected). To ensure that the participants' privacy is respected the collected data will be kept for two years only after the date of the viva to be deleted after that.

The socio-political dimension has been considered in this study. This dimension was divided into macro and micro-political senses. The macro-political sense is related to funding arrangements of the study and its consequence on making the decisions during the research. The researcher states that this dimension did not have any impact on the study, as the researcher is self-funded. Regarding the micro-scale sense, which is related to the participants of research, Morrison described it as:

> The case in evaluative research, where an evaluation might influence prestige, status, promotion, credibility, or funding. For example, in a school a negative evaluation of one area of the curriculum might attract more funding into that department, or it might have the effect of closing down the department and the loss of staff. (Morrison, 1993, cited in (Cohen, et al., 2005, p. 43)

The researcher states that during this study, participants were not asked about their attitudes towards the policy of IAT, and were not placed under any pressure, being aware that they were informed of their rights as participants in this study (BERA, 2018). Therefore, the researcher would claim that the influence of this sense was minimised.

3.20 SUMMARY OF THE CHAPTER

This chapter has described the theoretical framework of the conducted research, which shows the frame of the main investigated areas in this research, the research paradigm and the study approaches and plan. It has also demonstrated the progress of this research in three stages starting from the pilot study to the in-depth investigation stages including the methods and instruments that were used to collect the data, the design of each instrument and sampling was presented as well. The data analysis procedures were presented in this chapter, including the main statistical functions that were used to check the validity and reliability of the collected data. The last part of this chapter was allocated to the reliability and validity of the collected data and finally, the ethical issues that were considered during the three stages of this study.

Summary of the Pilot Study's Methodology

The primary goal of the pilot study (the first stage) in this research was to investigate teachers' thoughts and beliefs regarding educational technology. Based on the findings from the initial study this goal was promoted and modified to predict and measure quantitatively the impact of using educational technology on students' attainment using the teachers' previous records (mark books).

The pilot study consisted of two parts; it began with informal interviews with some teachers, followed by a questionnaire. The significance of the conducted informal interviews (meetings) was to understand the interviewed teachers' beliefs and thoughts about the main area of this research, which is educational technology. These thoughts and opinions have played a considerable role in building the structure of the questionnaire since they were reformulated as questions to be asked through the questionnaire that was distributed to teachers.

The teacher's questionnaire was used as a key method of collecting data in this study. The questionnaire aimed to check: i) teacher's self-acknowledgement about using ICT (teachers' level of using educational technology, their familiarity with the technical equipment and their own perspective towards the use of educational technology), ii) digital technology integration using mobile devices such as the iPad and iii) teacher's educational process, including the content of the curriculum and pedagogical dimensions used to deliver the content. The rationale for choosing these areas to be investigated was to form an initial understanding of the relationship between content knowledge (the content of curriculum), digital technology and pedagogy. Based on the questionnaire's findings, the theoretical framework of this study was developed, as shown in Figure 17. Thus, an in-depth investigation could take place.

Summary of the In-depth Investigation Methodology

Stages two and three of this research (the in-depth investigation) focused on students, intending to measure the improvement in their attainments as an outcome of using educational technology. Students were assessed several times; the collected data were analysed in these stages using a range of statistical functions (Appendix 1 – Statistical Functions).

In each case of stages two and three, in order to maintain fairness and achieve reliability, the content of each lesson was divided into two parts, with the condition that both of them must have (approximately) the same level of complexities. The two parts of content were taught to the selected group of students: the first part of the content was taught using nondigital technology-based learning, students were examined, and marks were recorded. The second part of the content was then taught for the same group of students using digital technology-based learning; new technologies were integrated with the taught content, such as simulations, iBooks, online resources, external articles, videos related to the content and learning management systems. Students were examined, the exams were marked, and the marks were registered. It was agreed with the participating teachers that the exams held in both situations should have the same level of complexity so that the impact of digital technology (the impact factor) could be distinguished by measuring the difference in the students' attainment in both situations.

Note: the impact factor is a suggested term by the researcher of this study, for the purpose of this thesis; the definition of the impact factor is the percentage of improvement in students' attainment as an outcome of using educational technology.

The next chapter focuses on the data analysis and discussion of the findings of the pilot study.

CHAPTER FOUR – Data Analysis and Discussion of the Pilot Study

4 DATA ANALYSIS AND DISCUSSION OF THE PILOT STUDY

INTRODUCTION

The use of educational technology in the Institute of Applied Technology has been adopted since 2005 and regarded as one of the main priorities for the plan of education development (IAT, 2018a). Therefore, this study aimed to explore the impact of using educational technology on students' attainment in this institution. This study was divided into two phases: the pilot study and the in-depth investigation. The findings of the pilot study have played a considerable role in highlighting the frame of this research, which includes the content of curriculum, pedagogy and digital technology. Thus, the theoretical framework of this study had been formed, as shown in Figure 17 (refer to section 3.2).

This chapter presents the data analysis and discussion of the collected results during the pilot study, including the questionnaire and the teachers' previous records.

4.1 THE FINDINGS OF THE PILOT STUDY

During the pilot study, qualitative and quantitative methods were used to analyse the collected data from the questionnaire and the teachers' previous records (mark books). Two approaches were used. First, a subjective approach was achieved by the direct interaction with teachers to find out what their thoughts about educational technology are. Second, an objective approach represented by the measured percentages of improvement in students' attainment as an outcome of using educational technology. These percentages were measured using three teachers' mark books and had been analysed quantitatively using a range of statistical functions to check the validity of the collected data (refer to Appendix 1 – Statistical Functions). The findings of the pilot study allowed the researcher to form the core ideas of this research and answer the initial research questions (section 3.10).

4.1.1 Teachers’ Questionnaire Findings and Discussion

The questionnaire’s content focused on three main areas related to participants’ (teachers’) experience and the learning process, including the use of digital technology and pedagogy. These areas were represented in the questionnaire by the following components:

i) Teacher’s self-acknowledgement using ICT (digital technology).

ii) Digital technology integration using mobile devices and applications in the classroom and the influence on learning.

iii) Teacher’s educational process, including the content knowledge and pedagogical dimensions used to deliver the content.

As indicated previously, the rationale for investigating these areas was an attempt to form the theoretical framework for the relationship between content knowledge (the content of curriculum), pedagogy and digital technology.

4.1.1.1 Statistical Descriptive Analysis

This part of the questionnaire focused on educational technology, including the teachers’ familiarity with digital technology equipment and their own perspective towards the use of digital technology. Table 22 shows general information about the participants in the questionnaire.

The question in the survey	**Teachers’ response**	**in %**	**Teachers’ response**	**in %**
Teaching experience in years	5-9 years	40%	10-15 years	30%
	More than 15 years	30%		
Number of courses taught	2	30%	3	50%
	4	10%	5	10%

Table 22. General information about participants.

Based on Table 23 below, the questionnaire showed that 20% of the participants (4 out of 20) described themselves as advanced (very good and excellent) users of digital technology and the rest of the participants (16 out of 20) rated themselves as good and less than good users of digital technology, none of the participants described themselves as fair users. Respondents themselves judged their ability to integrate ICT (digital technology) with education. Three out of seven humanities teachers described themselves as advanced users (43%); only one out of thirteen science teachers described himself (his questionnaire was coded as SMT, which stands for science male teacher) as advanced user of digital technology, one out of thirteen science teachers accounts for 8 % of the total, as shown in Table 23 and Figure 26. For more details, please refer to Appendix 5 – Teachers' Responses/ Raw Data.

The user's level	**13 science teachers (6 physics, 4 chemistry, 3 maths)**	**7 humanities teachers (5 English, 2 French)**
Advanced users	8 %	43%
Good or less than good users	92%	57%
Fair users (poor users)	0%	0%

Table 23. Participants' self-acknowledgement as ICT users.

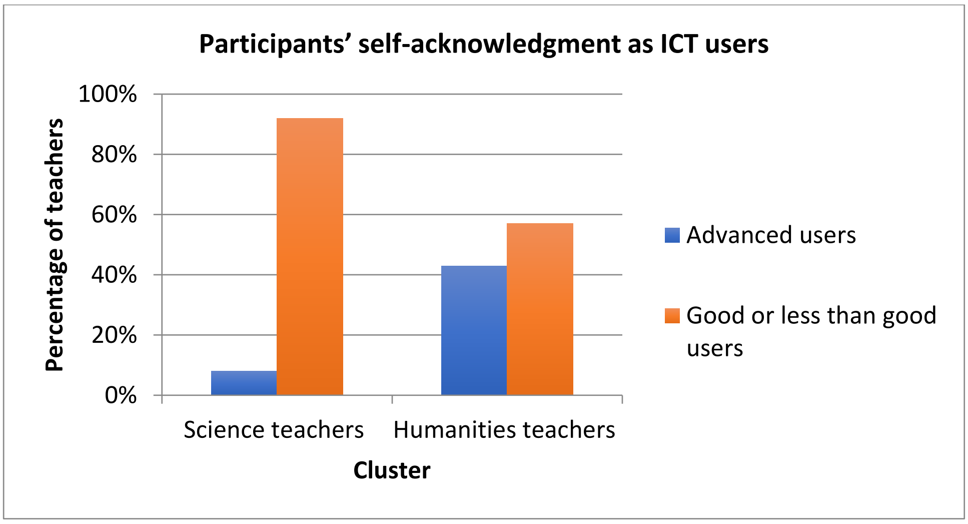


Figure 26. Participants' self-acknowledgement as ICT users.

Humanities teachers ranked their own proficiency in using ICT higher than the science teachers. This can be explained by the fact that the proficiency level in ICT for science teachers consists of many criteria and categories that are not applicable or required for humanities. For instance, science teachers need to conduct some experiments and analyse data, which might involve creating a software code (program) using specific computer software, such as Fortran, Matlab, C^{++}, to deal with the raw data and to draw conclusions, which means that the science teachers should have a background in programming. Therefore, because of the high standards that are required to integrate digital technology with the science subjects, it might be difficult for science teachers to consider themselves as an advanced level in using digital technology, unlike the humanities teachers. Hence, their criteria are different, and the idea of what is very good is different.

Indeed, at the level of primary and secondary schools, the technology techniques required to deliver the content of humanity subjects usually are not sophisticated and does not need programming; usually, no data analysis is necessary. This fact might lead to conclude that it is easier for humanities teachers to rank themselves as advanced users than it is for science teachers.

Table 24, Table 25, Table 26, Table 27 and Table 28 show the teachers' responses to the questions related to educational technology in the questionnaire. Teachers' responses were based on their thoughts, experiences and opinions.

The question in the survey	**Teachers' response**	**in %**	**Teachers' response**	**in %**
Integrating digital technology with curriculum	Yes	100%	No	0%
Importance of digital technology in teaching and learning.	Very important	40%	Important	40%
	Neither important nor unimportant	20%	Not important	0%

Table 24. Teachers' responses to the digital technology section of the questionnaire.

As can be seen in Table 24, the majority of participants have positive thoughts regarding the use of educational technology and its significance and contribution to learning as 100 % of the participants declared that they integrate digital technology with learning. Eighty per cent of the participants in this questionnaire believe that digital technology is significant and a crucial need to implement learning since 40 % of the participants stated that digital technology is very important and 40 % stated that it is important. This finding goes in line with Deaney et al. (2003) who declared in their study that educational technology is an essential element in the learning process as it provides teachers with effective tools, software and hardware that can promote their technical and pedagogical skills. On the other hand, 20 % of the participants could not decide if digital technology is essential for learning or not (Neither important nor unimportant).

As shown in Table 25, it seems that there is a strong correlation between teachers' thoughts about educational technology and their thoughts about the positive impact of educational technology on their students' attainment and academic performance, inside the classroom including participation, engagement and behaviour. This is supported by Roschelle et al. (2000), Kimmel and Deek (1995) who claimed in their studies that educational technology has a positive impact on learning if it is used effectively. Many researchers could recognise the potential impact of educational technology to improve teaching and learning (Bell & Bell, 2003).

The question in the survey	**Teachers' response**	**in %**	**Teachers' response**	**in %**
The improvement in students' attainment when using integrated IT lessons	Excellent	0%	Very good	35%
	Good	50%	Satisfactory	15%

Table 25. Teachers' thoughts about the improvement in students' attainment using educational technology in the classroom.

As shown in Table 25, 85% of teachers have agreed that educational technology could support their students to improve their attainment levels to a good and very good degree, those teachers' claim can be compatible with that of Groth et al. (2009) who stated that educational technology has granted teachers extensive opportunities to implement learning, which improved their students' achievements. However, 15% of teachers agreed that educational technology could offer only a satisfactory level of improvement to the students' attainment. Based on these teachers' claim, the researcher may state that educational technology could create sufficient opportunities for learning to take place, which can be supported by Kumar et al., who suggested that:

> Computers play an essential role in students' recreation and learning. It changes the way different subjects such as science is taught as IT tends to accord more closely with the way students think. (Kumar, et al., 2008, p. 604)

AlAmmary (2012) as well has confirmed that educational technology has established a positive impact on students' performance and learning.

Note: The participating teachers' description of the level of improvement, such as excellent, very good, good, is purely based on their experience, thoughts and beliefs, which implies that these statements are not quantised.

Question in survey	**Teachers' response**	**in %**	**Teachers' response**	**in %**
Using the LMS at the institution	Yes	90%	No	10%
Number of applications, software codes used in the teaching process	1	20%	2	30%
	3	30%	4 and more	20%
Created their own webpage for teaching	Yes	15%	No	85%
Use of the Internet as a tool to deliver a lesson	Every lesson	5%	Most lessons	35%
	Some lessons	60%	Occasionally/ never	0%

Table 26. Teachers' thoughts about the use of LMS and other applications in the learning process.

As shown in Table 26, 90 % of the participants use a learning management system to implement learning, which includes delivering the content, online assessments and assignments. The author would claim that the LMS facilitates the communication between learners and teachers, organises and stores the documents and personalises learning since each student will be granted a virtual learning platform (their account), which implies that a student will be more involved in learning.

Based on Table 26, 15 % of the participants only have created their webpage. The questionnaire showed that a small portion of the participants uses the Internet in every lesson. However, the majority of the participating teachers rely substantially on the LMS, which is a virtual publication platform, that allows students and teachers to post their work and communicate with each other (Jessel, 2014). Furthermore, the LMS itself consists of many resources such as textbooks (softcopy), simulations, past exam papers, external articles and projects so that these teachers might not need to use the internet frequently and might not find a time for it during their teaching since the LMS offers them everything they need from the Internet. For more information about the LMS, please refer to section 2.7

Question in survey	**Teachers' response**	**in %**	**Teachers' response**	**in %**
Effect of using mobile technology on student's performance in the classroom (participation, engagement and behaviour)	Positive	35%	Partially positive	45%
	Neither positive nor negative	10%	Partially negative	10%
Devices used to prepare the lessons	Laptop	95%	iPad	80%
	Desktop	10%	Others	20%
Devices used to deliver the lessons	Laptop	100%	iPad	85%
	iPod/MP3player	5%	Others	5%
The frequency of using mobile technology devices in classes	Per lesson	60%	Per day	10%
	Per week	25%	Per month	5%

Table 27. Teachers' responses to the use of mobile technology in learning and its effect on students.

Regarding the impact of mobile technology on students' performance inside the classroom, which includes participation, engagement and behaviour, as shown in Table 27, 80% of the participating teachers declared that the use of mobile technology has a positive or partially positive impact on their students' performance and behaviour. This implies that mobile technology could increase students' engagement and participation in learning and do not distract them. In other words, mobile technology could create an effective classroom. This matches with Tutty and White (2006) who claimed that mobile technology could create a more effective classroom environment than the traditional tools, such as chalk and board or even the lecture notes. Mobile technology devices offer learners access to additional sources of knowledge and social interaction through virtual platforms, which leads to improving learning (Pachler, et al., 2011).

On the other hand, 10 % of the participants agreed that mobile technology could affect their students' performance negatively, as it distracted them during lesson time. Ten per cent of the participants believed that mobile technology did not affect, neither positive nor negative, their students' performance (participation, engagement and behaviour).

Table 27 shows that the majority of the participants (more than 80 %) are using mobile technology devices, such as laptops and iPads, to prepare and deliver the content. Furthermore, 70 % of the participants are using it daily to implement learning, while 30 % of the participants are using it, but not every day. This finding would seem to confirm the significance of mobile technology devices to implement learning. Sarrab et al. (2012) claimed that mobile learning, which is implemented by mobile technology devices, maximises learning outcomes and improves the overall learning experience of learners and educators as mobile technology offers them the possibility to learn at any time and any place, i.e. lifelong learning.

According to the U.S. Department of Education (2014), learning can be improved and promoted when learners are involved in the following strategies: i) building their knowledge, ii) establishing the connections between the gained knowledge and models to form a united piece of knowledge, not just scattered facts, iii) exchanging knowledge through social interactions; therefore knowledge can be built upon teamwork. Mobile technology can promote the strategies above since it offers learners a range of virtual learning platforms, such as learning management systems (LMS) and many other resources for learning including the social media websites and search engines such as Google, Bing, and Yahoo. With access to numerous articles and diverse sources of knowledge, there are more possibilities for learners to develop their critical thinking and analytical ability and gain new knowledge. Hence, students will be able to gain and build new knowledge.

Question in survey	**Teachers' response**	**in %**	**Teachers' response**	**in %**
Effect of using mobile technology on student's learning	Positive	20%	Partially positive	50%
	Neither positive or negative	30%	Partially negative	0%

Table 28. Teachers' thoughts about the effect of mobile technology on students' learning.

Overall, 70% of teachers have agreed that mobile technology had a positive effect on students' learning, though, as shown in Table 28, 30% of the participants agreed that mobile technology did not affect, neither positively nor negatively, students' learning. In fact, in one of the discussions with some science teachers who do not believe in digital technology as an essential tool to develop and implement learning. These teachers stated that they believe in the traditional way of teaching and learning. They argued that most of the scientific inventions were invented at the time where no digital technology was known and by people who have never experienced mobile technology in particular or digital technology in general, such as Einstein's theory of relativity and Faraday's law for Michael Faraday and many other examples. According to these teachers, digital technology can help, but it should not be considered as a priority to implement learning or a crucial need to develop learning. As long ago as Lortie (1975) argued that teachers who teach hard sciences tend to ignore modern theories of learning as these teachers claim that science and mathematics content should be isolated from social activities.

Pedagogies Practised by Teachers

Pedagogy itself is a contested term involving activities that evoke changes within learners, educators and the learning process. Watkins and Mortimore defined pedagogy as “any conscious activity by one person designed to enhance learning” (Watkins & Mortimer, 1999, p. 3).

Lin et al. (2012) stated that pedagogy is divided into four levels or dimensions: i) Direct teaching, ii) Cognitively active learning, iii) Constructive learning and finally iv) Social (collaborative) learning.

i) **Direct teaching**: this pedagogical dimension can be described as the traditional method of teaching where a teacher is the leading knowledge provider and the centre of the learning process. A teacher who applies direct teaching “adopts traditional teaching methodology, which relies primarily on lectures, note-taking, chapter reviews and the regurgitation of facts on tests. The teaching style is strongly teacher-directed.” (Lin, et al., 2012, p. 102). The disadvantage of this pedagogy dimension is that it does not encourage students to be active learners. In fact, during direct teaching, in most cases, students are requested to be listeners only and remain silent. Gupta (2014, p. 2) described students’ situation while implementing direct teaching as he claimed, “in a traditional classroom environment, children become bored or frustrated”.

ii) **Cognitively active learning**, which is the second pedagogical dimension. A teacher at this level believes that students are active participants in learning rather than passive recipients of knowledge. “A cognitive perspective is concerned with inner mental functioning of a higher order such as thinking and reasoning and representation in memory” (Jessel, 2013, p. 17). The student emphasises understanding, analysing and application of critical thinking rather than memorisation and repetition. Cognitive exercises that involve creating relationships between elements or variables are given to students to engage them with the subject they study, so students will be shifted from the stage of being passive learners to that of being cognitively active learners (Mayer, 2004). Therefore, a teacher is no longer the main provider of knowledge, but a facilitator for students’ learning process (Schallert & Martin, 2003).

iii) **Constructive learning**: this is where students construct their knowledge on the basis of interaction with their environment. In constructivism, people build their knowledge of the world by experiencing real life, which will be reflected in their own experiences and level of understanding (Giesen, 2006). A teacher who applies constructivism believes that students can build their knowledge by interacting with their environment. Therefore, a teacher needs to create a suitable environment and motivate students to interact with it, which could lead them to construct new knowledge (Schallert & Martin, 2003).

iv) **Social (collaborative) learning**: at this level, the focus is extended to address the collaborative and social dimensions of education. A teacher believes that meaningful learning occurs when individuals are engaged in social activities. Johnson and Johnson (1991), and Johnson et al., (1991) defined collaborative learning as the use of small groups in educational activities, which might maximise students' learning and improve their academic performance. Naturally, collaborative learning is a process where knowledge, creation, experience and ideas can be shared and exchanged (Laal & Laal, 2011). In this kind of educational approach, two or more learners are interacting to create a shared understanding of a concept, discipline or area of practice that was not known previously, such as building a new model or developing new knowledge that none of them had possessed before. Johnson and Johnson (1991), and Johnson et al., (1991), suggested that collaboration needs the participation of all members to achieve the best outcome.

A teacher who applies social collaborative learning believes in creating a socially interactive environment, in which students are distributed in small groups with some assigned tasks. Students could be encouraged to use virtual platforms for learning, such as a learning management system, which enables students to respond to posts were uploaded by the teacher or other students. This promotes the exchange of ideas and experience between students which can lead to improving their learning (Schallert & Martin, 2003). Sachs (2003) argued that social interaction is essential for learners, enhancing their skills and ensuring they are always up to date. For more information about the practised pedagogies, please refer to sections 2.3.

As shown in Table 29, Table 30 and Figure 27, the questionnaire showed that the majority of the participants (70%) use direct teaching regularly (always, about half of the time and mostly use), while 30% of the participants declare that they use it sometimes (irregularly or occasionally). Moreover, 75 % of the participants are consistently using cognitively active learning, and 25% of the participants are using the cognitive pedagogy dimension sometimes (occasionally) in their teaching.

As per Table 29, Table 30 and Figure 27, 35% of respondents classified their teaching in the dimension of constructive learning; those teachers are using constructivism regularly (mostly use and about half of the time), while 60 % of the participants are using constructivism irregularly, and 5% never used it in their teaching. On the other hand, 30 % of the participants are using social learning frequently to implement learning, 10 % have never used it, and 60 % of the participants are using social learning irregularly or occasionally which implies that a small fraction of the sample sees their teaching as a more reliant process on collaboration between learners and educators or between learners themselves.

Pedagogical dimension applied by the teachers	**Percentages of the teachers within the sample (regularly use)**
Direct (traditional) teaching	70%
Cognitively active learning	75 %
Social, collaborative learning	30 %
Constructive learning	35%

Table 29. Percentages of the teachers within the sample who apply the pedagogical dimensions regularly (always, about half of the time and mostly use).

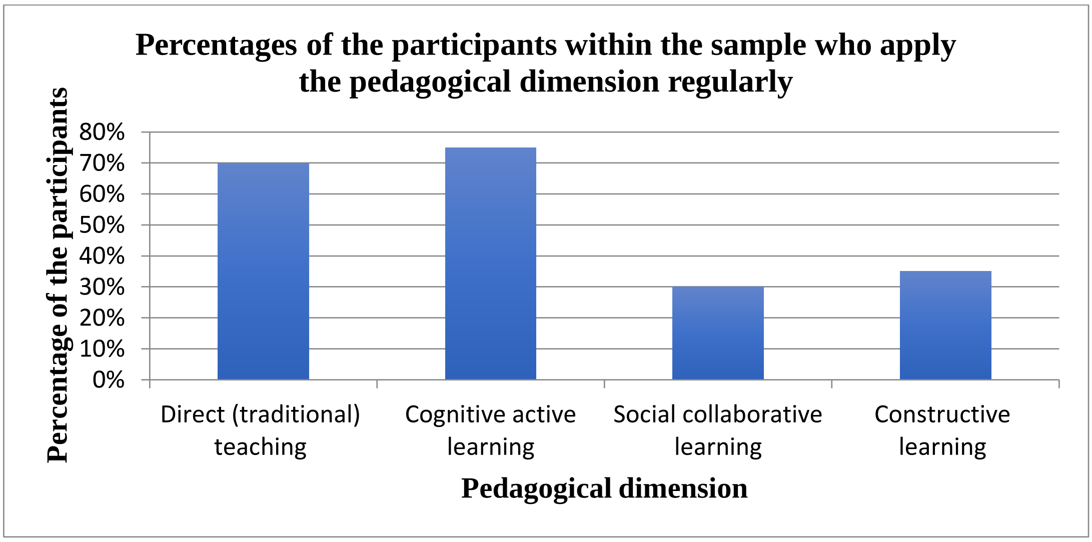


Figure 27. The applied pedagogical dimensions: direct teaching, cognitively active learning, constructive learning and social learning by teachers in the classrooms.

Looking at Table 29, it can be stated that the majority of the participants (70 %) still prefer to use the traditional way of teaching (direct teaching), where the teacher is considered as the centre of the learning process. The questionnaire showed that those teachers are using a combination of the old-school's design of learning, traditional teaching (teacher-centred), which was promoted by the behaviourism, and another element of the modern learning process that was raised by Piaget, cognitively active and constructivism learning (student-centred learning).

According to Bray and Nason cited in (Hancock, et al., 2002), the teacher-centred pedagogy that usually takes place in traditional learning can be defined as the situation where the teacher is the dominant figure or the leader who establishes and enforces rules in the classroom. Unlike student-centred pedagogy, where a student has an essential role in the learning process as an active learner, inventing, building and exchanging the new knowledge. Roth (2013) and Blickenstaff (2010) claimed that when learners are involved more in the learning process as active learners constructing their knowledge, then their critical thinking and academic performance will be enhanced.

Mascolo (2009) argued that the student-centred pedagogy originates from constructivist and cognitive developmental theory where students are the active members in the learning process, capable of building their knowledge and understanding of the surrounding world through their interaction with the world.

Table 30 shows the teachers' responses to the questions related to the pedagogical dimensions in the questionnaire (the frequency of using the pedagogical dimension to implement the learning objectives).

Question in survey	**Teachers' responses**	**in %**	**Teachers' responses**	**in %**
The frequency of using ***direct teaching***	Sometimes use	30%	Use about half the time	45%
	Mostly use	20%	Always use	5%
The frequency of using ***cognitively active learning***	Sometimes use	25%	Use about half the time	30%
	Mostly use	40%	Always use	5%
The frequency of using ***constructive learning***	Never use	5%	Sometimes use	60%
	Use about half the time	15%	Mostly use	20%
The frequency of using ***social (collaborative) learning***	Never use	10%	Sometimes use	60%
	Use about half the time	10%	Mostly use	20%
The improvement in students' attainment when using: ***Direct teaching***	Excellent	20%	Very good	25%
	Good	30%	Satisfactory	25%
The improvement in students' attainment when using: ***Cognitively active learning***	Excellent	15%	Very good	60%
	Good	20%	Satisfactory	5%
The improvement in students' attainment when using: ***Constructive learning***	Excellent	0%	Very good	50%
	Good	40%	Satisfactory	5%
The improvement in students' attainment when using: ***Social collaborative learning***	Excellent	5%	Very good	25%
	Good	35%	Satisfactory	25%
	Not satisfactory	10%		

Table 30. Teachers' responses to the pedagogy section of the questionnaire.

Note1: The participating teachers' description of the level of improvement, such as excellent, very good, good, is purely based on their experience, thoughts and beliefs, which implies that these statements are not quantised.

Note2: One respondent does not apply constructive learning; hence did not answer the question.

As shown in Table 30 and Figure 28, 75 % of the teachers agreed that the improvement in students' attainment, as an outcome of using cognitive learning in the classroom, can be described as an excellent or a very good improvement while 25 % of the participants stated that the level of improvement is good or satisfactory only.

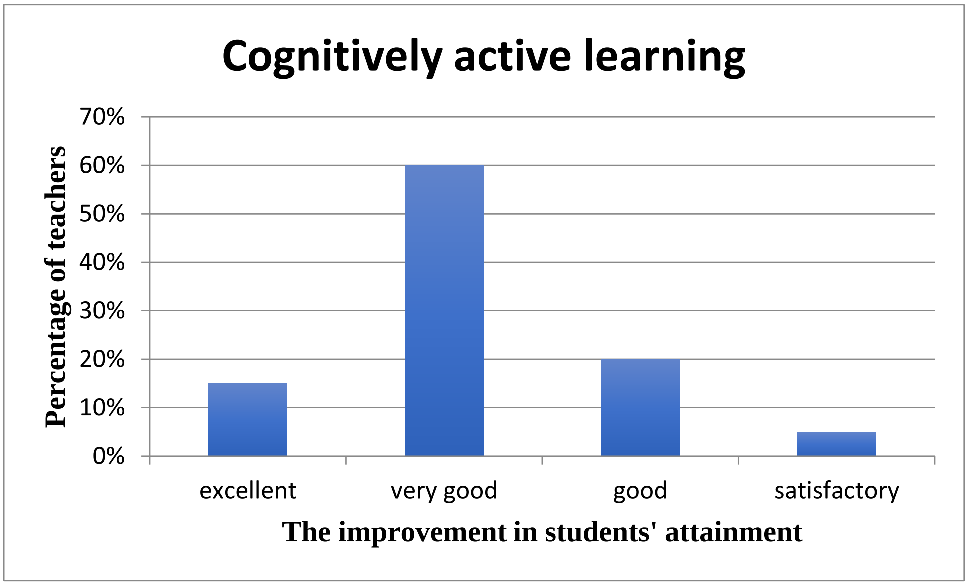


Figure 28. Teachers' thoughts about the improvement in students' attainment, which can be achieved when using cognitive learning.

Social (collaborative) learning can have a positive effect on learners since social interaction could develop the learner's personality and reinforce their trust and belief in themselves. Furthermore, learners might have the opportunities to learn more by sharing and exchanging knowledge and experience. This idea was supported by Slavin (1983; 1990), who stated that social learning had a positive impact on students' behaviour and learning efficiency as collaboration motivated them to work harder.

However, as shown in Table 30 and Figure 29, in the case of using social learning, 35 % of the participants described the improvement in students' attainment as not satisfactory and satisfactory, while 35 % described it as a good level of improvement. Only 30 % of the teachers claimed that the improvement that can be made using collaborative learning is very good and excellent. As stated by the respondents, collaborative learning is a difficult technique to implement in the learning process, especially when students do not feel any responsibility for their learning, then there is a risk that the lesson time will not be used efficiently. For instance, some students may waste the time, speaking with their colleagues in the group about topics unrelated to the lesson. Therefore, using social learning to implement a specific learning objective might need more extended time than what it takes when using other pedagogical dimensions to implement the same learning objective, bearing in mind that the allocated time for each subject is limited by few sessions a week. These disadvantages might be the reasons for some teachers' negative attitudes towards social (collaborative) learning.

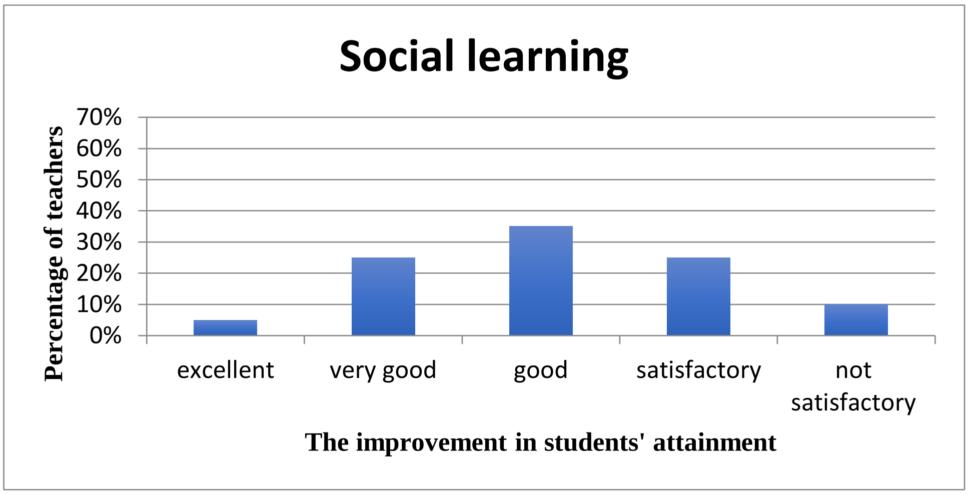


Figure 29. Teachers' thoughts about the improvement in the students' attainment that can be achieved when using social learning.

With regard to direct teaching. Although 70% of the participants admitted in the first part of this questionnaire that they are using direct teaching regularly to implement learning. However, 55% of respondents declared that the achieved improvement using the direct teaching approach would be less than the improvement that could be achieved when using the cognitive or constructive pedagogies, as they stated that the achieved improvement using direct teaching is satisfactory and good only, refer to Table 30 and Figure 30.

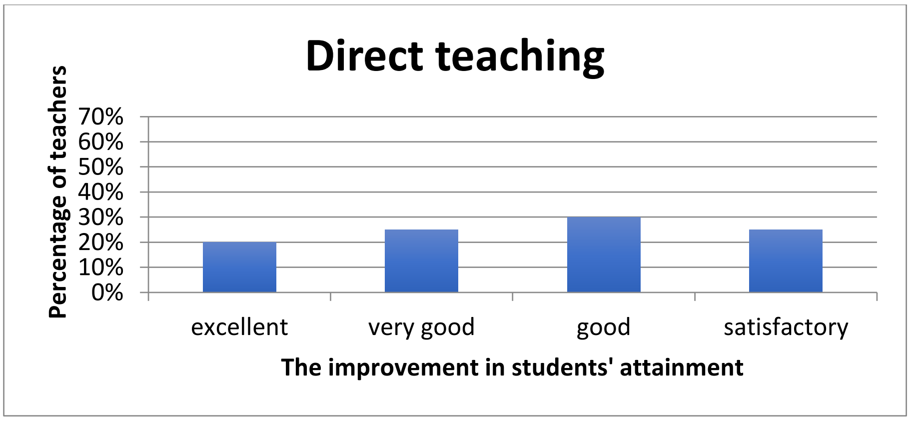


Figure 30. Teachers' thoughts about the improvement in the students' attainment that can be achieved when using direct teaching.

Finally, as shown in Table 30 and Figure 31, 50 % of the participants agreed that the achieved improvement in students' attainment as an outcome of applying constructive learning could be described as a very good improvement. However, the rest of the participants did not agree with this statement, as 50 % of the participants stated in their responses that the improvement which can be made using constructive learning is good or less than good. None of the respondents agreed that the improvement which can be achieved using constructivism is excellent.

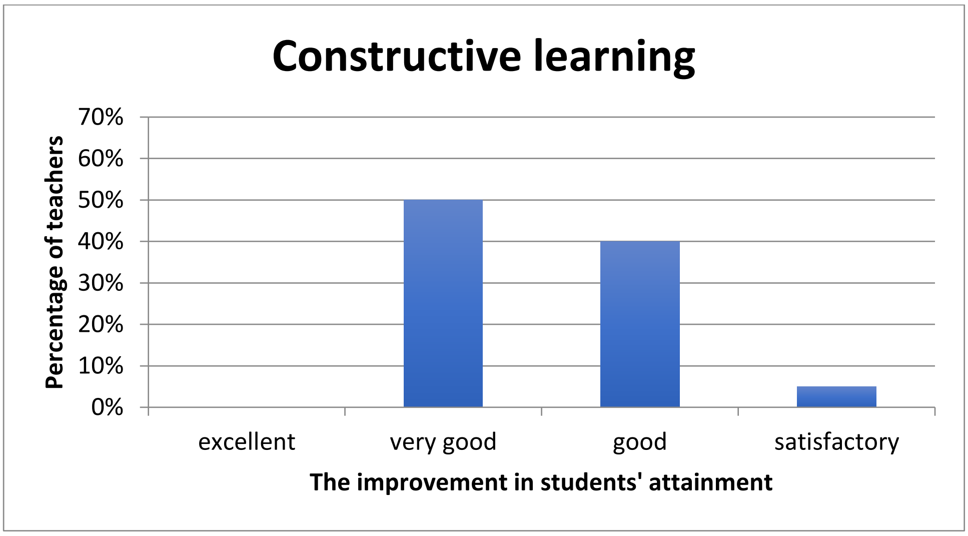


Figure 31. Teacher's thoughts about improvement in student's attainment when using constructive learning.

Okojie et al., (2008, p. 9) explored the relationship between digital technology and pedagogy and suggested, "it is important that educators perceive technology in education as part of the pedagogical process". This implies that digital technology can promote the four pedagogical dimensions that were included in the questionnaire: direct teaching, cognitively active learning, constructive learning and social learning. For instance, digital technology promotes cognitive and constructive learning, by offering the required tools, including software and hardware that provide students with a wide range of resources that can be used to gain new knowledge. Thus, learners can be shifted from the stage of being passive learners (receivers only) to another phase of being active learners (knowledge's producers or builders). Fullan claimed that the learning process relies substantially on pedagogy and digital technology since pedagogy is the driver of this process, while digital technology is the accelerator (Cited in (Chalich, 2015).

Digital technology can promote social learning as it provides learners with many virtual platforms to share their knowledge and gain new insights. The virtual platforms can be learning management systems, social media websites, communication applications and many other software tools that can be employed to exchange knowledge among learners. This idea was also confirmed by Domalewska (2014) who suggested that digital technology promotes collaborative learning by offering students various platforms for social interaction, allowing them to communicate with each other, exchange knowledge and experience, which leads to developing their skills and can be reflected in their work and their classmates work positively. For more details about the relationship between digital technology and the pedagogical dimensions, please refer to sections 2.4.1 and 2.5.2

Table 31 shows the teachers' responses to the questions related to digital technology tools that are used to deliver the content of the curriculum in the questionnaire.

As shown in Table 31, the participating teachers had been asked about the software tools they use to deliver the content, which can be introduced using three forms. Firstly, theoretical content, using the slides, textbooks and lecture notes. Secondly, practical content, by conducting experiments in laboratories or activities related to real-life applications. Finally, interactive content, using various interactive tools such as simulations, animations, videos and iBooks (Farah, et al., 2016).

The questionnaire showed that 60% of the participants agreed that the use of interactive tools, such as simulations or animations, are the most helpful tools amongst other means that can be used to improve students' learning and understanding. In their study, Ramma et al., (2017) declared that the interactive tools improve students' conceptual understanding, but cannot improve students' skills in problem-solving activities.

C, P, T	**Question in survey**	**Teachers' responses**	**in %**	**Teachers' responses**	**in %**
	How helpful are these for teaching and students: ***Lecture notes via PPT slides***	N/A or completely unhelpful	10%	Somewhere in the middle	15%
		Helpful	50%	Very helpful	25%
	Projection of Internet sites	N/A or completely unhelpful	0%	Somewhere in the middle	25%
		Helpful	55%	Very helpful	20%
	Individual or small group work using a computer	N/A or completely unhelpful	5%	Somewhere in the middle	15%
		Helpful	55%	Very helpful	25%
	Audio, video or images display	N/A or completely unhelpful	0%	Somewhere in the middle	20%
		Helpful	40%	Very helpful	40%
	Simulation/ interactive animations/ applications	N/A or completely unhelpful	0%	Somewhere in the middle	20%
		Helpful	20%	Very helpful	60%

Table 31. Teachers' responses to the questions that are related to the content of the curriculum, pedagogy and digital technology.

Interactive learning can raise the learning enjoyment level, which in turn might be reflected in students' comprehension and the effectiveness of learning. Some researchers argue that interactive learning could accelerate the rate at which students learn and improve their confidence. For instance, Sabry and Barker (2009) claimed that interactive learning enables students to navigate through meaningful activities, selecting data, responding to problems and performing challenging assignments. According to the participants, the use of audio, videos and images came at the second level in terms of significance as helpful tools to improve students' learning.

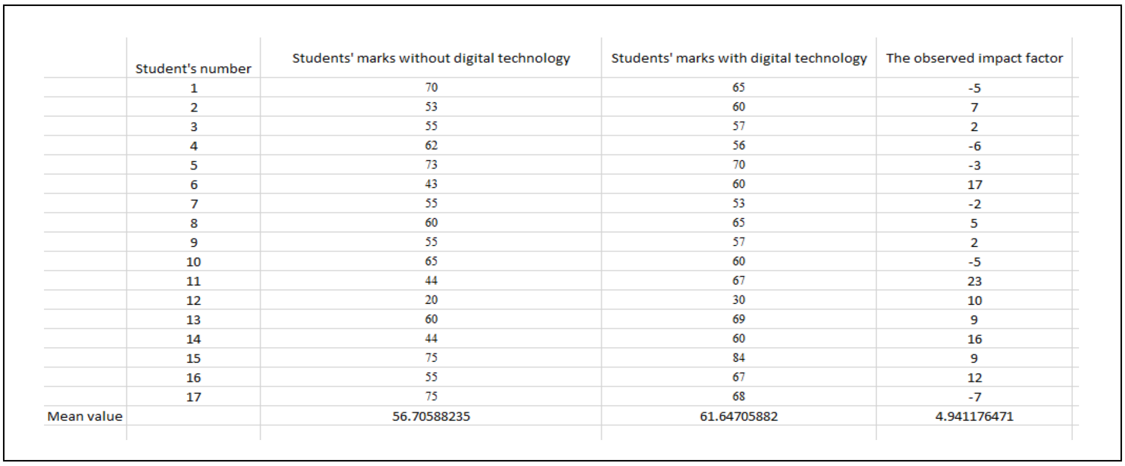
Grangeat (2008) and Cuban (2001) stated that the theoretical content must be connected with real-life applications and situations so that learning outcomes can be maximised. This connection can be created using interactive tools, such as simulations, which have the power to unite the theoretical part of the content and the practical side of life (the real-life applications). This can, in turn, lead to improving students' level of understanding, their critical thinking and enhance their learning. For instance, if students are studying about the electric motor using traditional teaching methods, as an outcome they might be capable of nominating each part of the electric motor or memorising the function of each element as well as having, perhaps, some ideas, though not necessarily accurate, about how it works. However, in the case of using simulations as a part of interactive learning, students may have a clearer understanding of the workings of an electric motor as they are having a virtual experience with a model (virtual experiment). Furthermore, using interactive tools, students will have the opportunity to check the relationship between variables related to the electric motor, such as electric current, magnetic field and torque (physics quantities), as the simulations used can offer this function (checking the relationship between the variables). This situation can be applied approximately to the video and audio files, with an essential difference that the students in the case of videos and audio files cannot navigate through the experiment or control it as in a simulation. For more information about the use of simulations and videos in education, please refer to section 2.9.2.1.

As shown in Table 31, 40 % of the participating teachers have agreed that the lecture notes, individual learning and referring students to Internet sites should be placed in the third level in terms of significance as helpful tools to improve students' learning. According to some of the respondents, in the case of using other tools, such as Powerpoint slides or a soft copy or a hard copy of the textbook only, students might not be motivated or appropriately engaged in learning, and they might be distracted quickly in the case of referring them to specific Internet websites or working independently.

4.1.2 Teachers' Previous Records

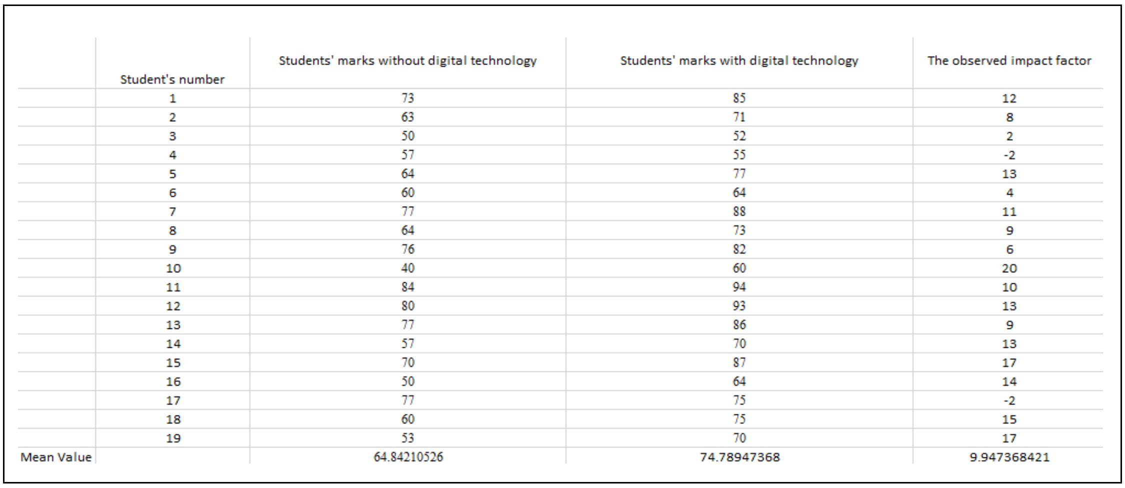
In light of the questionnaire's findings, where the majority of participants agreed that there is a positive impact of using educational technology on students' learning and attainment, I could build the theoretical framework, which consists of pedagogy, digital technology, the content of the curriculum, and the main users of these elements, teachers and students, refer to Figure 17. Once the framework was created, there was a need to study the impact factor of educational technology on students' attainment quantitatively, using some teachers' mark books (the teachers' previous records). Therefore, teachers were asked about two factors: i) the percentage of improvement in students' attainment as an outcome of using educational technology and ii) the approximate percentage of the content (learning objectives) integrated with digital technology by these teachers.

Figure 32, Figure 33, Figure 34, Figure 35, Figure 36 and Figure 37 show the teachers' previous records, students' marks with and without digital technology, in different subjects physics, English language and Mathematics. Hence, the impact of educational technology on students' attainment (the observed impact factor) could be measured. *These records are based on Grade 9 students; please refer to the Limitations chapter in this thesis.*



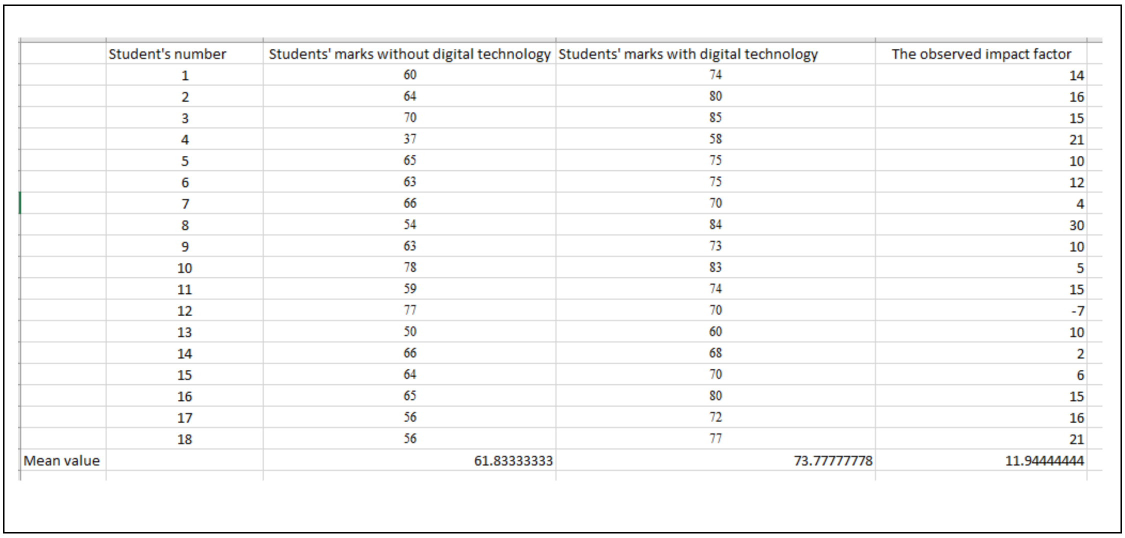
	Student's number	Students' marks without digital technology	Students' marks with digital technology	The observed impact factor
	1	70	65	-5
	2	53	60	7
	3	55	57	2
	4	62	56	-6
	5	73	70	-3
	6	43	60	17
	7	55	53	-2
	8	60	65	5
	9	55	57	2
	10	65	60	-5
	11	44	67	23
	12	20	30	10
	13	60	69	9
	14	44	60	16
	15	75	84	9
	16	55	67	12
	17	75	68	-7
Mean value		56.70588235	61.64705882	4.941176471

Figure 32. Students' marks (out of 100) in the Physics subject with and without digital technology. As stated by the subject's teacher, 20% of the learning objectives integrated with digital technology.



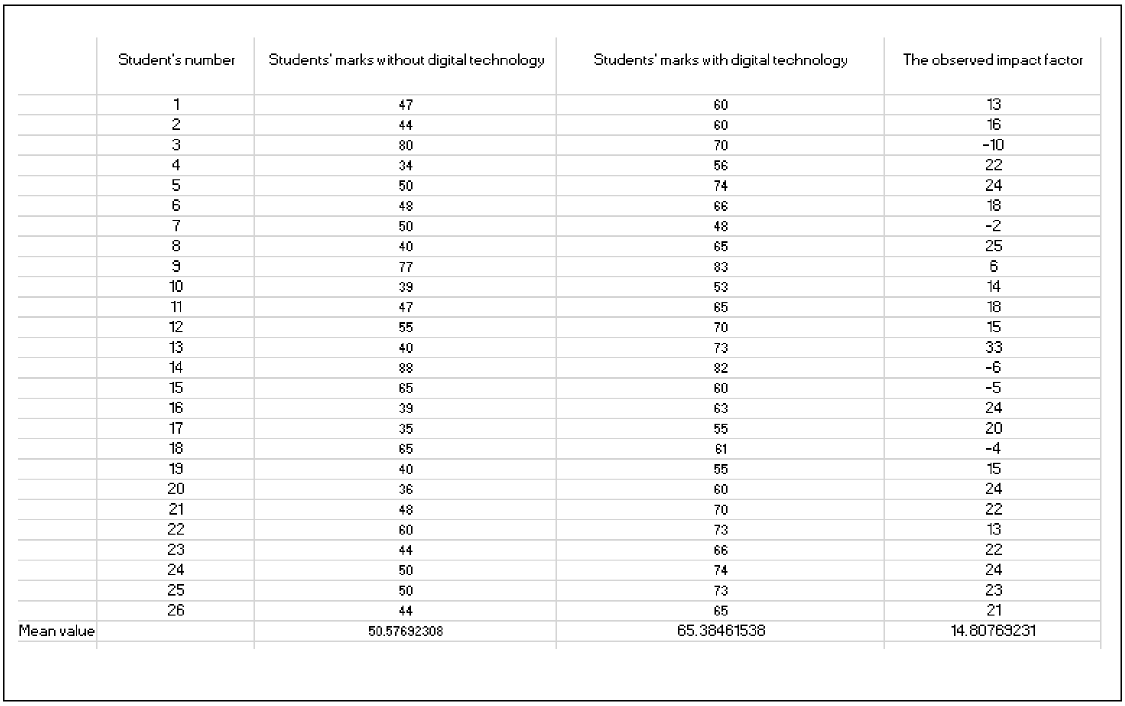
	Student's number	Students' marks without digital technology	Students' marks with digital technology	The observed impact factor
	1	73	85	12
	2	63	71	8
	3	50	52	2
	4	57	55	-2
	5	64	77	13
	6	60	64	4
	7	77	88	11
	8	64	73	9
	9	76	82	6
	10	40	60	20
	11	84	94	10
	12	80	93	13
	13	77	86	9
	14	57	70	13
	15	70	87	17
	16	50	64	14
	17	77	75	-2
	18	60	75	15
	19	53	70	17
Mean Value		64.84210526	74.78947368	9.947368421

Figure 33. Students' marks (out of 100) in the Physics subject with and without digital technology. As stated by the teacher, 60% of the learning objectives integrated with digital technology.



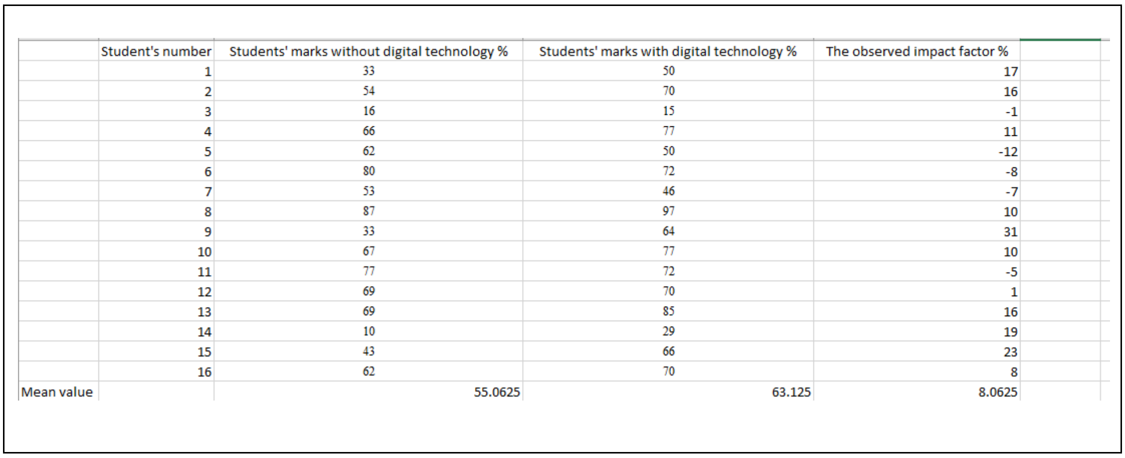
	Student's number	Students' marks without digital technology	Students' marks with digital technology	The observed impact factor
	1	60	74	14
	2	64	80	16
	3	70	85	15
	4	37	58	21
	5	65	75	10
	6	63	75	12
	7	66	70	4
	8	54	84	30
	9	63	73	10
	10	78	83	5
	11	59	74	15
	12	77	70	-7
	13	50	60	10
	14	66	68	2
	15	64	70	6
	16	65	80	15
	17	56	72	16
	18	56	77	21
Mean value		61.83333333	73.77777778	11.94444444

Figure 34. Students' marks (out of 100) in the Physics subject with and without digital technology. As stated by the teacher, 70% of the learning objectives integrated with digital technology.



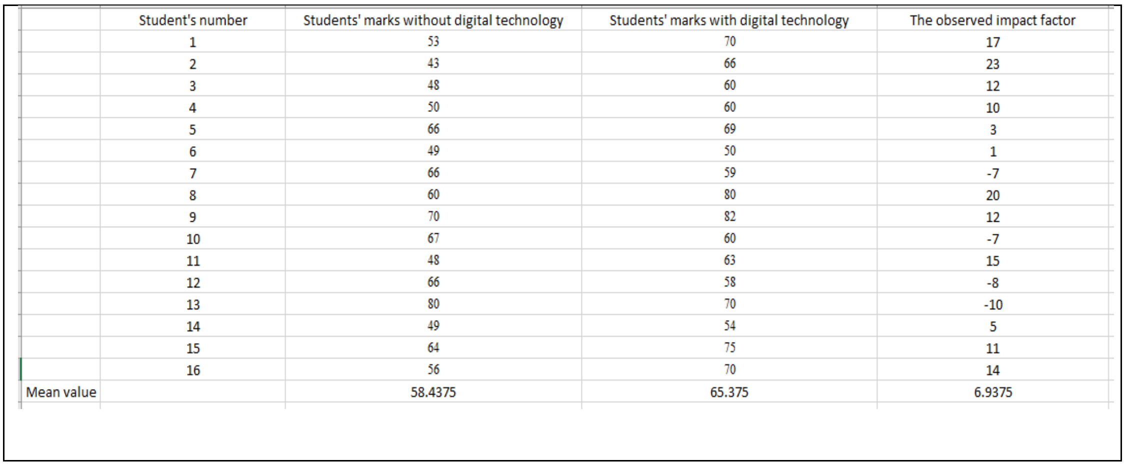
	Student's number	Students' marks without digital technology	Students' marks with digital technology	The observed impact factor
	1	47	60	13
	2	44	60	16
	3	80	70	-10
	4	34	56	22
	5	50	74	24
	6	48	66	18
	7	50	48	-2
	8	40	65	25
	9	77	83	6
	10	39	53	14
	11	47	65	18
	12	55	70	15
	13	40	73	33
	14	88	82	-6
	15	65	60	-5
	16	39	63	24
	17	35	55	20
	18	65	61	-4
	19	40	55	15
	20	36	60	24
	21	48	70	22
	22	60	73	13
	23	44	66	22
	24	50	74	24
	25	50	73	23
	26	44	65	21
Mean value		50.57692308	65.38461538	14.80769231

Figure 35. Students' marks (out of 100) in the Physics subject with and without digital technology. As stated by the teacher, 80% of the learning objectives integrated with digital technology.



	Student's number	Students' marks without digital technology %	Students' marks with digital technology %	The observed impact factor %
	1	33	50	17
	2	54	70	16
	3	16	15	-1
	4	66	77	11
	5	62	50	-12
	6	80	72	-8
	7	53	46	-7
	8	87	97	10
	9	33	64	31
	10	67	77	10
	11	77	72	-5
	12	69	70	1
	13	69	85	16
	14	10	29	19
	15	43	66	23
	16	62	70	8
Mean value		55.0625	63.125	8.0625

Figure 36. Students’ marks (out of 100) in the English language subject with and without digital technology. As stated by the teacher, 50% of the learning objectives integrated with digital technology.



	Student's number	Students' marks without digital technology	Students' marks with digital technology	The observed impact factor
	1	53	70	17
	2	43	66	23
	3	48	60	12
	4	50	60	10
	5	66	69	3
	6	49	50	1
	7	66	59	-7
	8	60	80	20
	9	70	82	12
	10	67	60	-7
	11	48	63	15
	12	66	58	-8
	13	80	70	-10
	14	49	54	5
	15	64	75	11
	16	56	70	14
Mean value		58.4375	65.375	6.9375

Figure 37. Students’ marks (out of 100) in the Mathematics subject with and without digital technology. As stated by the teacher, 40% of the learning objectives integrated with digital technology.

Table 32 and Figure 38 show the impact of using educational technology on students’ attainment, based on the records shown in Figure 32, Figure 33, Figure 34, Figure 35, Figure 36 and Figure 37 of individual teachers.

Subject	**The amount of the material integrated with digital technology (x)**	**The observed improvement in students’ attainment, according to the teachers’ records. (y)**
Physics	20 % (20% of the learning objectives were integrated with digital technology)	5% (the students’ attainment was improved by 5 % according to the teachers’ records)
Mathematics	40 %	7 %
English	50 %	8 %
Physics	60 %	10 %
Physics	70 %	12 %
Physics	80 %	15 %

Table 32. The impact of using educational technology on students’ attainment according to teachers’ records.

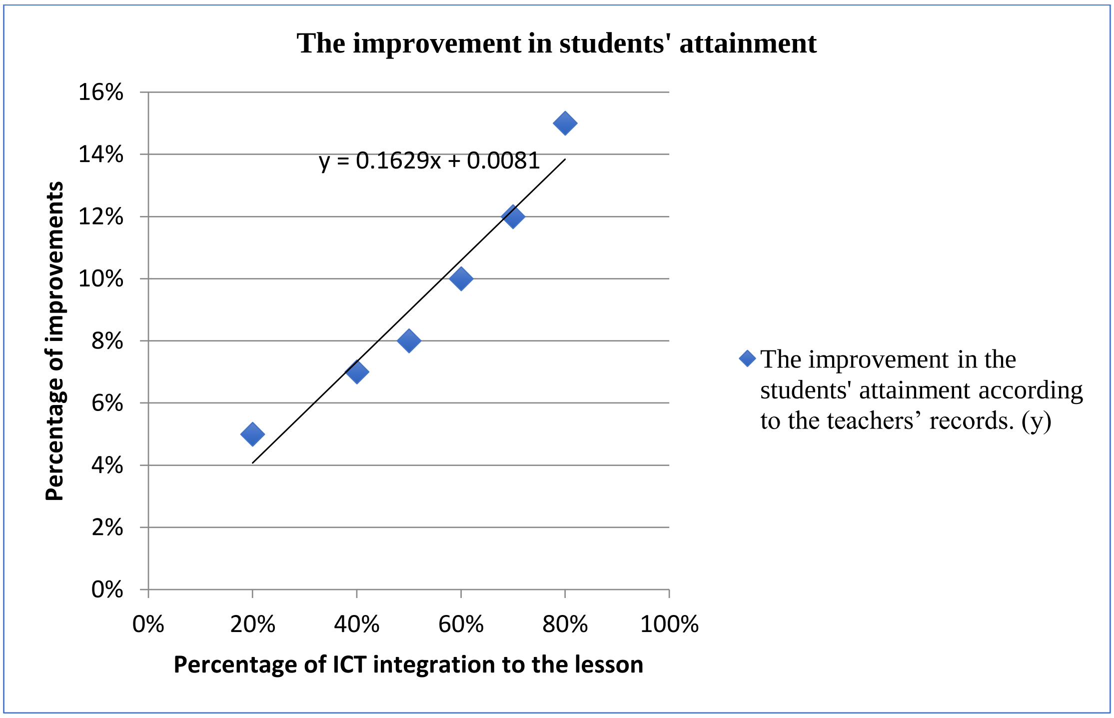
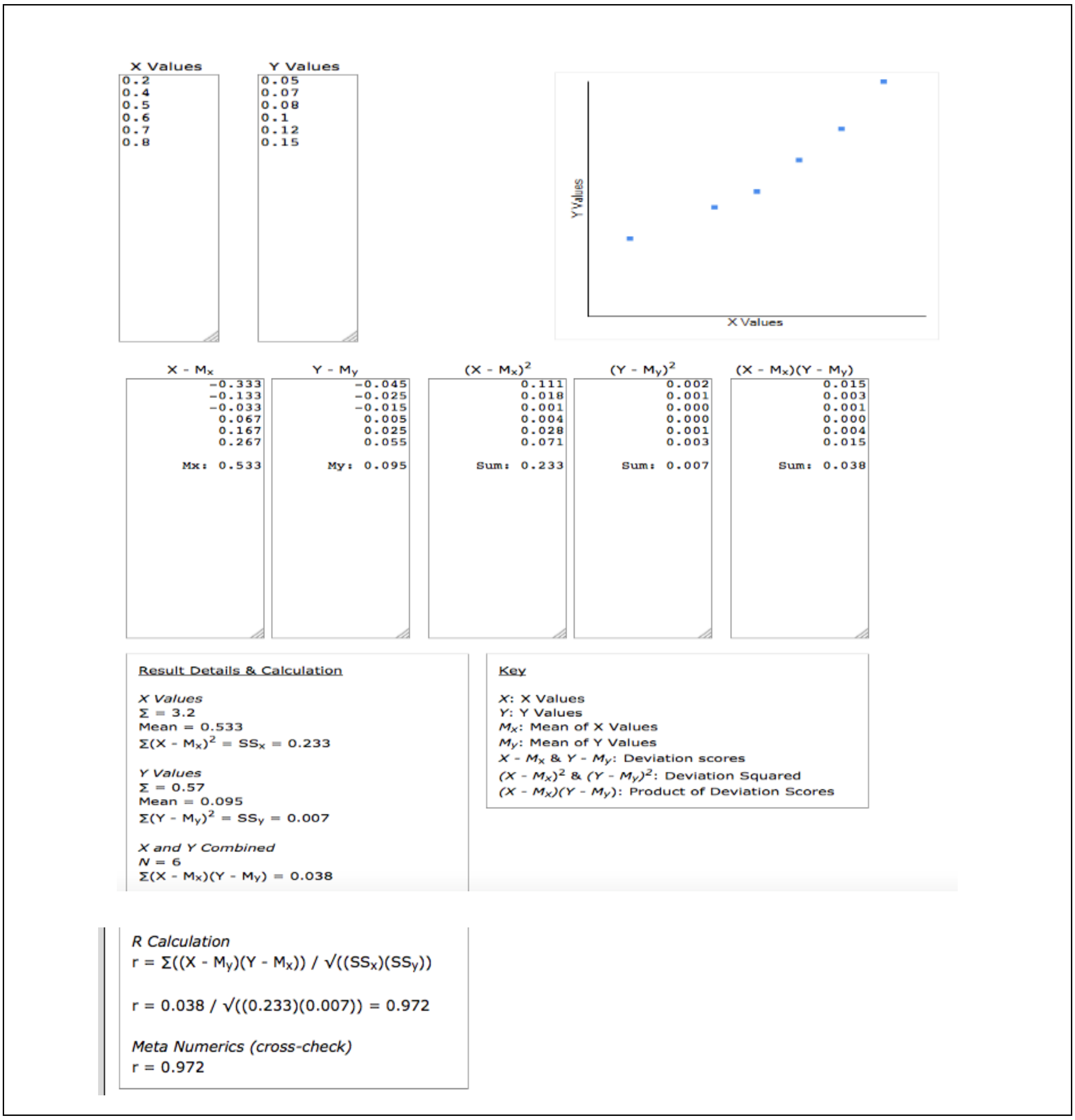


Figure 38. The relationship between the amount of the material that was integrated with digital technology and the improvement in students’ attainment according to the teachers’ records.

In an effort to test if the findings that were generated from some teachers' mark books, were an accurate reflection of the perception of respondents, and in order to find out if educational technology (the percentage of digital technology integration) and the improvement in students' attainment are correlated (dependent variables), the data were analysed using a Pearson correlation coefficient (r), as well as the P-value. The overall internal consistency of the instrument Pearson correlation coefficient (factor) was r = 0.972, and the P-value = 0.001165, which implies that the result is significant at P-value < 0.01. Table 33, Figure 39 and Figure 40 present the exact calculations of the Pearson correlation factor and P-value.



X Values	Y Values
0.2	0.05
0.4	0.07
0.5	0.08
0.6	0.1
0.7	0.12
0.8	0.15

$X - M_x$	$Y - M_y$	$(X - M_x)^2$	$(Y - M_y)^2$	$(X - M_x)(Y - M_y)$
-0.333	-0.045	0.111	0.002	0.015
-0.133	-0.025	0.018	0.001	0.003
-0.033	-0.015	0.001	0.000	0.001
0.067	0.005	0.004	0.000	0.000
0.167	0.025	0.028	0.001	0.004
0.267	0.055	0.071	0.003	0.015
Mx: 0.533	My: 0.095	Sum: 0.233	Sum: 0.007	Sum: 0.038

Result Details & Calculation

X Values
$\Sigma = 3.2$
Mean = 0.533
$\Sigma(X - M_x)^2 = SS_x = 0.233$

Y Values
$\Sigma = 0.57$
Mean = 0.095
$\Sigma(Y - M_y)^2 = SS_y = 0.007$

X and Y Combined
$N = 6$
$\Sigma(X - M_x)(Y - M_y) = 0.038$

Key

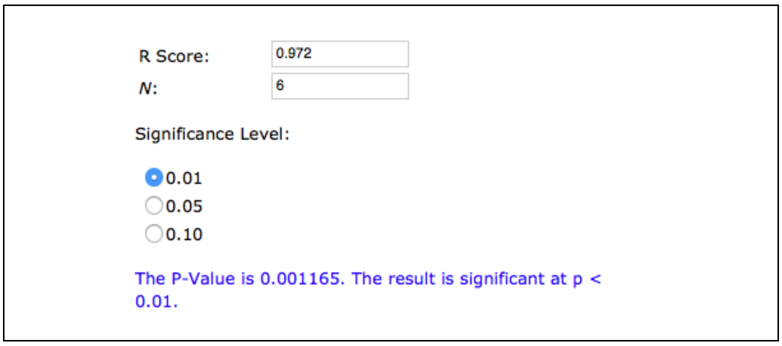
X: X Values
Y: Y Values
M_x: Mean of X Values
M_y: Mean of Y Values
$X - M_x$ & $Y - M_y$: Deviation scores
$(X - M_x)^2$ & $(Y - M_y)^2$: Deviation Squared
$(X - M_x)(Y - M_y)$: Product of Deviation Scores

R Calculation
$r = \Sigma((X - M_y)(Y - M_x)) / \sqrt{((SS_x)(SS_y))}$

$r = 0.038 / \sqrt{((0.233)(0.007))} = 0.972$

Meta Numerics (cross-check)
$r = 0.972$

Figure 39. Calculations of Pearson correlation factor r (this value was calculated using online calculator http://www.socscistatistics.com/Default.aspx).



R Score: 0.972

N: 6

Significance Level:

● 0.01
○ 0.05
○ 0.10

The P-Value is 0.001165. The result is significant at p < 0.01.

Figure 40. Calculations of P-value (this value was calculated using online calculator http://www.socscistatistics.com/Default.aspx).

Figure 39 shows that the value of r (Pearson correlation) is 0.972, which indicates a strong positive correlation and implies that high X variable scores go with high Y variable scores and vice versa (directly proportional) being aware that at this stage of the study (during the pilot study), the null hypothesis stated that there was no relationship between educational technology and students' attainment (for the developed and main null hypothesis of this study, refer to section 1.3). To measure the strength of the evidence against the initial null hypothesis, the P-value was calculated and found to be equal to 0.001165 so that the result is significant at $p < 0.01$. Therefore, the null hypothesis could be rejected, which suggests that there is a relationship between educational technology and students' attainment.

Pearson correlation coefficient (r)	**P- value**
0.972	0.00116 (< 0.01)

Table 33. The value of the Pearson correlation coefficient and the p-value

Based on these values, it can be concluded that the assumption of a positive impact of educational technology on students' attainment is valid or at least cannot be rejected. In other words, these values give some credibility to the previously described idea that integrating digital technology with education can lead to improving education and maximise the learning outcomes.

4.1.3 Summary of the Pilot Study (Procedures and Outcomes)

The pilot study was commenced by informal interviews conducted to check teachers' thoughts and beliefs regarding the integration of education and digital technology. A questionnaire was distributed to teachers to investigate three critical areas related to teachers and the learning process itself: teacher's self-acknowledgement using ICT, digital technology integration using mobile technology, such as the iPad and teacher's educational process, including the content of the curriculum and the pedagogical dimensions. These areas were investigated in the questionnaire to form an initial understanding of the relationship between the content of the curriculum, digital technology and pedagogy, which helped the researcher to design the theoretical framework of this study (refer to section 3.2).

The questionnaire showed that most of the participants are using a combination of the old school design of learning, direct teaching (teacher-centred), and another element of the modern learning process, cognitively active and constructivism learning (student-centred learning). Furthermore, most of the participants agreed that the use of educational technology, such as interactive tools, could improve students' learning and understanding which suggests the relationship between three critical elements: digital technology, the method of teaching and learning (pedagogy), and the form of content knowledge (curriculum). Therefore, the researcher would claim that the findings of the pilot study were used to form the relationship between these elements (the main research areas).

The Pearson correlation coefficient (r) and the P-value were calculated using teachers' previous records (mark books). Those values could give some credibility to the assumption as regards the positive impact of educational technology on students' attainment by improving the education process and offering extra resources.

The pilot study formed the core ideas and the frame of this research as it played a considerable role in highlighting the main areas of this research and identifying the knowledge gaps to be filled using a specific framework and methodologies (refer to sections 3.2 and 3.17.3). As a point of fact, the pilot study, helped the researcher to promote the research approaches that were initially focused on the impact of educational technology on learning (qualitatively) and were promoted to be focused on the effects of different factors: pedagogy, content of curriculum in addition to digital technology on students' attainment (quantitatively). Therefore, the framework of this research was designed to focus on the interaction between these critical factors. The next chapter introduces the CPT model, which was developed on the basis of the pilot study's findings to predict the impact of educational technology on students' attainment (predicted impact factor).

CHAPTER FIVE –
The Development of the CPT Model

5 THE DEVELOPMENT OF THE CPT MODEL

5.1 INTRODUCTION TO THE CPT MODEL

The majority of the participants in the questionnaire stated that there is an impact of using digital technology (T), the pedagogical dimension (P) and the type of the curriculum implemented (C), on students' attainment. Therefore, the author would argue that there is a relationship between these elements. This relationship was described by Mishra and Koehler (2005a; 2006; 2008) as a complex interaction that impacts students' learning. Many researchers, see for example Voogt et al. (2012), Graham (2011) and Archambault and Barnett (2010) claimed that the relationship between these elements lacks clarity as there is no clear distinctions or boundaries between these elements nor a clear definition of each element.

While the author agrees with the expressed lack of clarity in defining each element and the relationship between them, there is another perspective of clarity that needs addressing. It is focused on structuring and organising the complex interaction between C, P and T as well as mapping the most effective combination of these elements (C, P and T), to achieve effective learning, and predict the numerical impact of educational technology on students' attainment.

Mishra and Koehler (2005a; 2006; 2008) suggested that there is a common area that comprises these elements. This thesis generated a question regarding this common area. How precisely the most effective point, strategy of learning, in the common area between C, P and T, can be located? This question emerged during the pilot study stage and formed the biggest challenge.

The idea of the generated question is related to location, i.e. locating the most effective strategy of learning that can maximise learning outcomes and improve students' attainment. In terms of mathematics, locating a point in space requires using the concept of the vector space.

The application of the vector space concept organises the relationship between the elements C, P and T. In turn, this implies that these elements overlap over three-dimensional space, which is addressed in this study as the CPT space rather than, overlapping over two-dimensional plane, as demonstrated by Mishra and Koehler in their TPACK model (2005a; 2006; 2008).

Stephen Hawking stated that there must be "a single unifying equation that explains everything in the universe", cited in (Hague, 2015, p. 2). Likewise, the author believes that there must be an elegant equation that organises the CPT space. This thesis establishes the way towards this equation by using the concept of the vector space to locate the CPT vectors in the CPT space. In other words, to locate the most effective strategies of learning in this space that can enhance students' learning.

Mapping the most effective strategies of learning was achieved by calculating what is referred to in this study as ***the impact factor*** (a terminology suggested by the author). It was calculated by finding the magnitude of the CPT vector in the digital technology-based learning space (Equation 4) and the magnitude of the CPT_0 vector, i.e., the magnitude without using educational technology, as shown in Equation 5 (nondigital technology-based learning). The difference between the magnitudes of these two vectors indicates how much educational technology can add to students' attainment. In other words, the difference between these two vectors' magnitudes represents the predicted impact factor, please refer to Equation 8. The predicted impact factor (predicted improvement) was compared with the observed impact factor that was measured using the pre and post-tests. In terms of validity and reliability, the differences between both values of the impact factor, predicted and observed, were judged and checked through stages two and three of this study using a range of statistical functions (refer to Appendix 1 – Statistical Functions).

5.2 COORDINATE SYSTEM AND THE DEVELOPMENT OF THE CPT MODEL EQUATIONS

Various aspects of physics and mathematics require a representation of a location in space. For instance, the mathematical description of an object's motion needs a description of the object's position at different times. This description is achieved using the Cartesian coordinate system, in which perpendicular axes intersect at a point defined as the origin O, as shown in Figure 41. The Cartesian coordinate system is also called rectangular coordinates (Serway & Vuille, 2013).

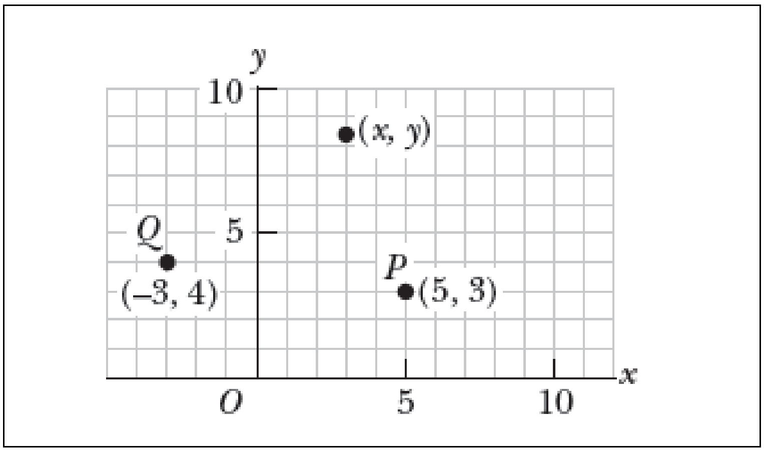


Figure 41. Selection of points in a Cartesian coordinate system, each location is identified by coordinates (x, y). (Serway & Vuille, 2013, p. 15)

Any vector in space can be represented as a sum of the primary vectors; for instance, a vector A, it would be written as:

Equation 2

$$A = A_{xi} + A_{yj} + A_{zk}$$

In physics and mathematics, vectors are expressed in component design using the unit vectors i, j and k. Each unit vector has a magnitude of one and points along the axes, x, y and z, of the Cartesian coordinate system, respectively. A_x is the x component of the vector A, and so on for y and z (Serway & Vuille, 2013).

The magnitude of vector A (|A|) is represented by its components, as shown in the below equation:

Equation 3

$$|A| = \sqrt{Ax^2 + Ay^2 + Az^2}$$

The idea of the vector space is applied to this study using new axis C, P and T instead of X, Y and Z, where C, P and T indicate curriculum, pedagogy and digital technology, respectively. Based on the argument of this thesis, the elements C, P and T should overlap over three-dimensional space and be addressed as the CPT space. Therefore, based on Equation 3, the magnitude of the resultant vector, the **CPT** vector, can be calculated using the following formula:

Equation 4

$$|\mathrm{CPT}| = \sqrt{C^2 + P^2 + T^2}$$

Where the **CPT** vector locates students' learning strategy in the CPT space when using educational technology, including different kinds of curriculum and pedagogical dimensions, i.e., digital technology-based learning.

If no digital technology is integrated into the content, the term T is omitted from Equation 4 and replaced by the term T_0. Hence, the magnitude of the new vector, $\mathbf{CPT_0}$ vector, is given by the following formula:

Equation 5

$$|\ \mathrm{CPT_0}| = \sqrt{C^2 + P^2}$$

The vector $\mathrm{CPT_0}$ locates students' learning strategy in the $\mathrm{CPT_0}$ space, without using educational technology, i.e., nondigital technology-based learning.

The difference between the magnitudes of both vectors, **CPT** and $\mathbf{CPT_0}$, indicates the digital technology-enhanced vector, which is reflected on students' attainment, or the predicted impact factor of educational technology. Based on this assumption, I define the impact factor as the improvement in students' attainment as an outcome of using educational technology (digital technology). Hence, the predicted impact factor can be expressed by subtracting Equation 5 from Equation 4:

$$\text{The predicted impact factor} = |\mathrm{CPT}| - |\mathrm{CPT_0}|$$

Equation 6

$$\text{The predicted impact factor} = \sqrt{C^2 + P^2 + T^2} - \sqrt{C^2 + P^2}$$

Note: the definition of the impact factor applies to the digital technology-enhanced vector (both terms have the same definition).

I suggested four pedagogical dimensions to be considered in this model (Pn): direct teaching, cognitively active learning, constructive learning and social (collaborative) learning; similarly, I suggested three kinds of the curriculum (Cn): theoretical, practical and interactive. Regarding the digital technology dimension (axis), I divided it into five levels of integration (Tn), starting from T1 to T5 (20% to 100%) representing the amount of content, based on the learning objectives, integrated with digital technology. Based on these assumptions, each component of the CPT vector can have several values (Cn, Pn, Tn). For instance, when n is used with C, it takes integer values (no fractions) from 1 to 3 or C1, C2 and C3 (three types of the curriculum). If n is used with P, then it can be given integer values from 1 to 4 or P1, P2, P3 and P4 (four pedagogical dimensions). Finally, when n is used with T, then n can be given values from 20 % to 100 % (five levels of integration: T1, T2, T3, T4 and T5).

To prevent the confusion between the values of (n), I would suggest renaming these components as Cnc, Pnp, Tnt rather than Cn, Pn, Tn. Thus, Equation 6 is given as follows:

Equation 7

$$\text{The predicted impact factor} = \sqrt{Cnc^2 + Pnp^2 + Tnt^2} - \sqrt{Cnc^2 + Pnp^2}$$

Where Cnc represents how many types of curriculum are applied to implement each learning objective. Cnc takes integer values from 1 to 3.

Pnp represents how many pedagogical dimensions are applied to implement each learning objective, Pnp takes integer values from 1 to 4.

Tnt represents the percentage of the learning objectives integrated with digital technology, Tnt takes one of the following percentages; 20 %, 40 %, 60%, 80%, 100%.

Accordingly, the predicted impact factor will be given the symbol R. Therefore, the final form of Equation 7 is given by:

Equation 8

$$R = \sqrt{Cnc^2 + Pnp^2 + Tnt^2} - \sqrt{Cnc^2 + Pnp^2}$$

5.2.1 The Interpretation of the Curriculum, Pedagogical, and Digital Technology Dimensions of the CPT Model.

The Curriculum Components

C – Content of the curriculum, the type of curriculum that is applied to implement each learning objective.

C 1 → purely theoretical (or any other kind of curriculum);

C 2 → theoretical + practical (or a combination of any two kinds of the curriculum);

C 3 → theoretical + practical + interactive;

The Pedagogical Dimensions

P – Pedagogy, the number of the pedagogical dimensions that are applied to implement each learning objective.

P1 → only one pedagogical dimension is applied to implement each learning objective.

P2 → a combination of any two dimensions of the pedagogy to implement each learning objective.

P3 → a combination of any three dimensions of the pedagogy to implement each learning objective.

P4 → all four dimensions of pedagogy combined to implement each learning objective.

Digital Technology Levels of Integration

T – the amount of material represented by the learning objectives integrated with digital technology, i.e., how much of the teaching-learning process (learning objectives) took place utilising digital technology in various ways, such as simulations, iBooks, external online resources and the use of a learning management system.

T1 → 20% of the learning objectives are integrated with digital technology.

T2 → 40% of the learning objectives are integrated with digital technology.

T3 → 60% of the learning objectives are integrated with digital technology.

T4 → 80% of the learning objectives are integrated with digital technology.

T5 → 100% of the learning objectives are integrated with digital technology.

Figure 42 shows the C2, P4, T5 strategy of learning, represented by three-dimensional point (2,4,1) in the CPT space. For pedagogical dimensions (P1 to P4), three kinds of the curriculum (C1, C2 and C3), and five levels of integration with digital technology, starting from level one (T1) to level five (T5) are shown in Figure 42.

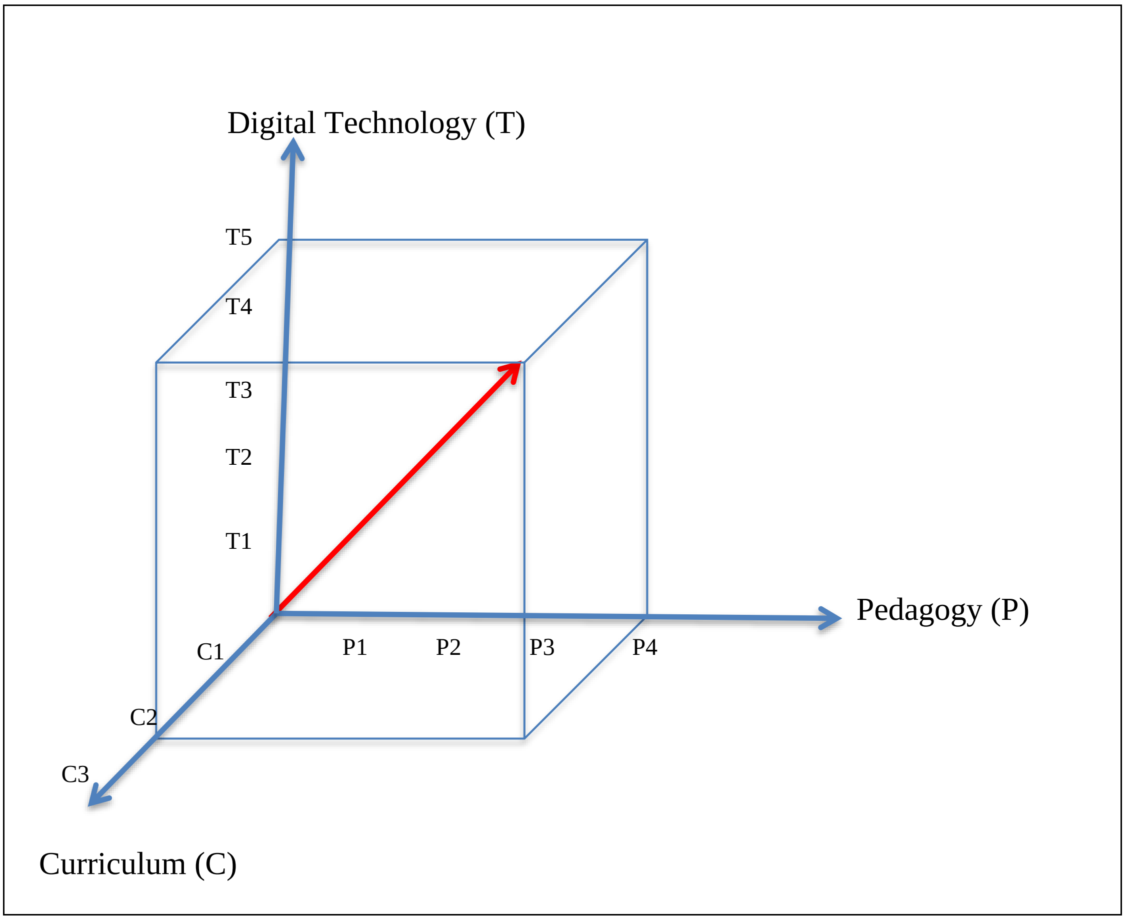


Figure 42. The CPT vector, 3D vector space used in the developed model, shows the point (2, 4, 1), which can be identified according to the CPT model as (C2, P4, T5).

For a detailed discussion on the interpretation of the pedagogical, curriculum and digital technology dimensions refer to the included examples of some lessons implemented in this study, Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

5.2.2 Mathematical Findings

As a critical mathematical finding of this study, the researcher discovered other forms of Equation 8, which is the main equation used to calculate the predicted impact factor (the predicted improvement in students' attainment). The new forms of Equation 8 could give the same results, as shown below:

$$\text{The predicted impact factor (R)} = \sqrt{Cnc^2 + Pnp^2 + Tnt^2} - \sqrt{Cnc^2 + Pnp^2}$$

The predicted impact factor, which is shown in the previous equation, can be calculated using the following formula:

Equation 9

$$R = R_o\,(N)^2$$

Where R is the predicted impact factor,

N is the digital technology integration level; it takes values from 1 to 5.

R_o is the threshold impact factor.

The threshold impact factor (improvement) takes place at the first level of digital technology integration (N=1, i.e., T1 or 20 % of the content, learning objectives, is integrated with digital technology). Thus, the threshold impact factor **(**R_o) can be calculated using the following formula:

Equation 10

$$R_o = \sqrt{Cnc^2 + Pnp^2 + 0.2^2} - \sqrt{Cnc^2 + Pnp^2}$$

As indicated previously, nc takes values from 1 to 3 (three kinds of content C1, C2 and C3), whereas np takes values from 1 to 4 (four pedagogical dimensions P1, P2, P3 and P4).

Regarding the derivation of Equation 9, I acknowledge that further research needs to be carried out to develop sustained proof of this equation. Being aware that both forms of the impact factor's equation, Equation 8 and Equation 9, produce identical results in most cases. However, there are a few cases where the results are not completely identical, though very close to one another, as shown in Table 34, with a percent error of 0.03, as will be shown in example 3, section 5.2.3. This difference would suggest that there might be undiscovered minimal differences between both equations. Therefore, an extensive mathematical investigation is required, which is considered as a future plan; please refer to section 8.6.

Table 34 below shows the predicted impact factor that was calculated using Equation 8 and Equation 9 for different CPT strategies.

Cnc, Pnp, Tnt	**The predicted impact factor (predicted improvement)** $(\mathbf{R}) = \sqrt{\boldsymbol{Cnc^2 + Pnp^2 + Tnt^2}} - \sqrt{\boldsymbol{Cnc^2 + Pnp^2}}$	**The predicted impact factor (predicted improvement)** $(\mathbf{R}) = \mathbf{R_o}\,(\mathbf{N})^{2}$
C1, P1, T1	0.014	0.014
C1, P1, T2	0.056	0.056
C1, P1, T3	0.123	0.126
C1, P1, T4	0.211	0.220
C2, P2, T1	0.007	0.007
C2, P2, T2	0.028	0.028
C2, P2, T4	0.111	0.110
C3, P3, T1	0.005	0.005
C3, P3, T3	0.042	0.042
C3, P3, T4	0.075	0.075

Table 34. The predicted impact factor calculated using Equation 8 and Equation 9.

Note: Table 34 is not exhaustive (not all possible cases are shown).

5.2.3 Theoretical Calculations Based on the CPT Model – Predicted Results

Example 1: Find the predicted impact factor in the case of using the C3, P3, T3 strategy to implement learning.

In this example, C3 means that a teacher applies three kinds of the curriculum to introduce the content, which implies that every learning objective will be implemented using three types of content: theoretical, practical and interactive. Therefore, the weight of C3 in the main equation (Equation 8) is considered to be equal to three. The same concept applies to pedagogy, as P3 means that every learning objective will be delivered using three pedagogical dimensions. Therefore, the weight of P3 in the equation is considered to be equal to three. Regarding the digital technology dimension T3, it means 60 % of the learning objectives are integrated with digital technology, which implies that not all of the learning objectives will be integrated with digital technology. Assuming that a lesson consists of five learning objectives, digital technology was used with three learning objectives out of five, then the weight of (T) can be found by dividing the number of integrated learning objectives with digital technology by the total number of learning objectives(see Equation 1): i.e. $3 \div 5 = 0.6$, or 60%, which is the weight of T3 in Equation 8. Thus, the point C3, P3, T3 is equivalent to the point (3, 3, 0.6) in the CPT space, as shown in Figure 43.

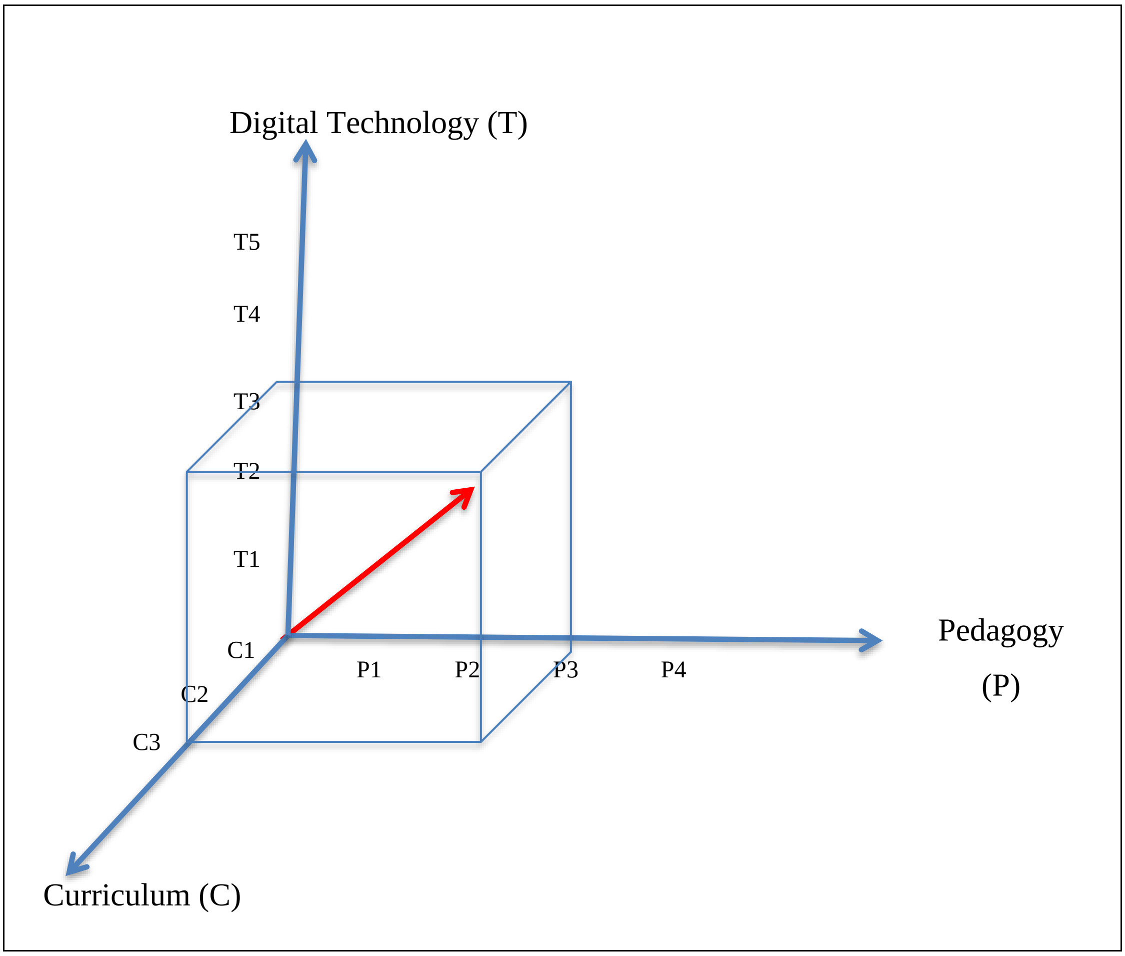


Figure 43. CPT vector shows the point (3, 3, 0.6), which is equivalent to (C3, P3, T3) in the CPT space.

The predicted impact factor in the case of using C3, P3, T3 strategy:

$$R = \sqrt{(C3)^2 + (P3)^2 + (T3)^2} - \sqrt{(C3)^2 + (P3)^2}$$

$$R = \sqrt{3^2 + 3^2 + 0.6^2} - \sqrt{3^2 + 3^2}$$

$$R = 0.042 \quad \text{(The predicted impact factor)}$$

The same result could be calculated using Equation 9 and Equation 10, as shown below:

$$\text{The threshold impact factor: } R_o = \sqrt{C3^2 + P3^2 + 0.2^2} - \sqrt{C3^2 + P3^2}$$

$$R_o = \sqrt{3^2 + 3^2 + 0.2^2} - \sqrt{3^2 + 3^2}$$

$$R_o = 0.0047 \text{ (The threshold impact factor)}$$

$$R = R_o (N)^2$$

Regarding the value of (N) or the digital technology integration level, as long as 60% of the content (learning objectives) is integrated with digital technology, then N = 3,

$$(R) = 0.0047 \text{ x } (3)^2$$

Hence, the predicted impact factor (R) = 0.042

It can be seen that Equation 9 and Equation 10 (the new form of the impact factor's equation) could give the same value that was calculated using Equation 8 (the original equation).

Example 2: Find the predicted impact factor in the case of using C1, P1, T1 strategy to implement learning.

In this example a teacher integrated digital technology with 20% of the content, one pedagogy dimension (P1) is used to implement each learning objective and one kind of content (C1) is used to introduce content, then this teacher according to the CPT model applied the (C1, P1, T1) strategy, which is equivalent to the point (1, 1, 0.2) in the CPT space.

The magnitude of the vector (C1, P1, T1) = $\sqrt{1^2 + 1^2 + 0.2^2}$ = 1.428

The magnitude of the vector without digital technology integration (C1, P1, T0) = $\sqrt{1^2 + 1^2 + 0^2}$ = 1.4142.

The predicted impact factor of educational technology can be measured by subtracting the second value from the first one 1.428 – 1.4142= 0.014, which means that the integration with digital technology can improve students' attainment by 0.014 (1.4%).

The above (detailed) calculations can be done using Equation 8, as shown below:

$$R = \sqrt{(C1)^2 + (P1)^2 + (T1)^2} - \sqrt{(\mathrm{C1})^2 + (\mathrm{P1})^2}$$

$$\mathrm{R} = \sqrt{1^2 + 1^2 + 0.2^2} - \sqrt{1^2 + 1^2}$$

$$\text{The predicted impact factor (R)} = 0.014$$

The same result can be found using Equation 9 and Equation 10, the new form of Equation 8.

The threshold impact factor: $R_o = \sqrt{C1^2 + P1^2 + 0.2^2}$ - $\sqrt{C1^2 + P1^2}$

$$R_o = \sqrt{1^2 + 1^2 + 0.2^2} - \sqrt{1^2 + 1^2}$$

$$R_o = 0.014$$

The predicted impact factor (R) = R_o (N) ^{2}

Regarding the value of N, or the digital technology integration level, as long as 20% of the content (learning objectives) is integrated with digital technology, then N = 1

$$R = R_o (N)^2$$

The predicted impact factor (R) = 0.014 x $(1)^2$

= 0.014.

Which is the same value that was calculated using Equation 8 (the original equation).

Example 3: Find the predicted impact factor in the case of using C1, P1, T3 strategy to implement learning.

$$R = \sqrt{(C1)^2 + (P1)^2 + (T3)^2} - \sqrt{(C1)^2 + (P1)^2}$$

$$R = \sqrt{1^2 + 1^2 + 0.6^2} - \sqrt{1^2 + 1^2}$$

$$R = 0.123$$

Approximately the same result could be calculated using Equation 9 and Equation 10.

$$R = R_o (N)^2$$

The threshold impact factor: $R_o = \sqrt{1^2 + 1^2 + 0.2^2} - \sqrt{1^2 + 1^2}$

$$R_o = 0.014$$

The value of N is 3 (the third level of integration)

$$R = 0.014 \times (3)^2$$

$$= 0.126$$

In this case, both values of the impact factor are slightly different. For the purpose of clarity and accuracy, the percent error was calculated as follows:

$$\text{The Percent Error} = \frac{(0.126 - 0.123)}{0.123}\ x\ 100\% = 0.024$$

Table 35, Table 36 and Table 37 show the predicted impact factors (improvements) for all CPT combinations (calculated using the CPT model):

C	**P**	**T**	**R**
1	1	0.2	0.014
1	1	0.4	0.055
1	1	0.6	0.122
1	1	0.8	0.211
1	1	1.0	0.318
1	2	0.2	0.009
1	2	0.4	0.035
1	2	0.6	0.079
1	2	0.8	0.139
1	2	1.0	0.213
1	3	0.2	0.006
1	3	0.4	0.025
1	3	0.6	0.056
1	3	0.8	0.100
1	3	1.0	0.154
1	4	0.2	0.005
1	4	0.4	0.019
1	4	0.6	0.043
1	4	0.8	0.077
1	4	1.0	0.120

Table 37. Predicted impact factor, C =1 series.

C	**P**	**T**	**R**
2	1	0.2	0.009
2	1	0.4	0.035
2	1	0.6	0.079
2	1	0.8	0.139
2	1	1.0	0.213
2	2	0.2	0.007
2	2	0.4	0.028
2	2	0.6	0.063
2	2	0.8	0.111
2	2	1.0	0.172
2	3	0.2	0.006
2	3	0.4	0.022
2	3	0.6	0.050
2	3	0.8	0.088
2	3	1.0	0.136
2	4	0.2	0.004
2	4	0.4	0.018
2	4	0.6	0.040
2	4	0.8	0.071
2	4	1.0	0.110

Table 36. Predicted impact factor, C =2 series.

C	**P**	**T**	**R**
3	1	0.2	0.006
3	1	0.4	0.025
3	1	0.6	0.056
3	1	0.8	0.100
3	1	1.0	0.154
3	2	0.2	0.006
3	2	0.4	0.022
3	2	0.6	0.050
3	2	0.8	0.088
3	2	1.0	0.136
3	3	0.2	0.005
3	3	0.4	0.019
3	3	0.6	0.042
3	3	0.8	0.075
3	3	1.0	0.116
3	4	0.2	0.004
3	4	0.4	0.016
3	4	0.6	0.036
3	4	0.8	0.064
3	4	1.0	0.099

Table 35. Predicted impact factor, C = 3 series.

5.3 SUMMARY OF THE CHAPTER

In this chapter, the concept of the vector space formed the relationship between the three factors: the content of the curriculum, pedagogy and digital technology. The idea of this vector was applied to the findings of the pilot study. Consequently, the vector space was developed and redefined using three different variables that were considered as the components of the new vector (C, P and T rather than X, Y and Z).

The vector space is considered as the fulcrum of the CPT model. The relationship between digital technology, pedagogy and the content of the curriculum was mapped using the vector space, as shown in Figure 42. The CPT model presents three-dimensional equations that can predict the improvement in students' attainment as an outcome of using educational technology in different learning scenarios (the predicted impact factor).

After building the core idea of the developed tool in this study (the CPT model and its equations) using the findings of the pilot study, there was a crucial need to check the new model in terms of reliability and validity. Therefore, the second and third stages were used to test the developed model and judge the validity of its equations. The second and third stages will be discussed in the next chapter.

CHAPTER SIX –
Data Analysis and Discussion of the In-Depth Investigation

6 DATA ANALYSIS AND DISCUSSION OF THE IN-DEPTH INVESTIGATION

6.1 THE SECOND STAGE OF THE STUDY – IN-DEPTH INVESTIGATION

INTRODUCTION

The second stage was used to check the validity of the CPT model and its equations. This stage focused on students in order to measure the impact factor quantitatively (the improvement in students' attainment as an outcome of using educational technology). Students were assessed many times to check the observed improvement in their attainment; the collected data were analysed using several statistical functions; please refer to section 3.17.6 and Appendix 1 – Statistical Functions.

In the second stage of this study, a comparative methodology was used, where the observed improvement (the observed impact factor) was compared to the predicted improvement (predicted impact factor), which was calculated using the CPT Model's equations (Equation 8, Equation 9 and Equation 10).

A specialised learning environment (digital technological tools, such as iPads, laptops, a learning management system, a variety of pedagogical dimensions, a positive and clean environment) was created to facilitate students' use of their mobile devices when asked to complete different mobile technology-based activities, such as assignments and online tests.

Using digital technology, students could learn at any convenient time and place, i.e., lifelong learning. For this purpose, different software tools could be used, such as learning management systems; D2L and Plato (Plato is the former LMS used by IAT until D2L replaced it). Other software applications were included, such as Showbie, Kahoot and Socrative (virtual learning platforms that can be used to do the exams online and to run competitions between learners). These software tools facilitated the students' online tasks and communication with their teachers.

The following procedures were prepared by the researcher and adopted to collect primary data in stage two:

i) Planned learning outcomes to be implemented in the classroom without using digital technology (nondigital technology-based learning).

ii) Paper-based assessment tool to assess students after nondigital technology-based learning.

iii) Planned learning outcomes to be implemented using digital technology-based learning.

iv) Paper-based and technology-based assessment tool to assess students after digital technology-based learning.

v) Exams were marked in both cases and marks recorded to be compared.

vi) To be able to determine the impact of using educational technology, positive or negative, students' marks in both situations (with and without using digital technology) were compared.

vii) To be able to determine if the developed model (CPT model) is valid as a predictive model or not, the actual improvements (the observed impact factors) were compared with the predicted impact factors.

Note: the observed impact factors were calculated using the students' results in the pre and post-tests, please refer to section 3.17.4. The predicted impact factors were calculated using the equations of the developed model (CPT model), please refer to Equation 8, Equation 9 and Equation 10.

6.1.1 Data Analysis and Discussion of the Second Stage

The second stage of this study consisted of three cases that were used to test the validity of the CPT model. During these cases two different learning scenarios: digital technology-based learning (Cnc, Pnp, Tnt) and nondigital technology-based learning (Cnc, Pnp, T0) were applied, where T0 indicates the case of not using digital technology. The content was divided into two parts, with the condition that both parts must have (approximately) the same level of complexity. The two parts of the content were taught to the selected group of students, one of them using digital technology (Cnc, Pnp, Tnt) and the other one was implemented without using digital technology (Cnc, Pnp, T0).

Two different approaches were used to review the content cognitive complexity, Florida's original depth of knowledge (DOK) levels and Webb's four-level DOK. These approaches were used to ensure that both contents delivered, trough digital technology or without, have the same level of complexity. Please, refer to section 3.17.5

Note: for a detailed description of the implementation of both scenarios, digital technology-based learning (Cnc, Pnp, Tnt) and nondigital technology-based learning (Cnc, Pnp, T0), please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

The improvement in students' attainment during the main study, is attributed to digital technology or other factors?

The scope of this research is to compare students' attainment in two teaching-learning scenarios; digital and nondigital technology-based learning, applied to two different contents within the same subject. Based on the fact that both contents should have the same depth of knowledge, which was reviewed using Webb's (Mississippi Department of Education, 2009) and Florida's (Cpalms.org, 2019) depth of knowledge (DOK) levels, please refer to section 3.17.5. Moreover, the same pedagogical dimensions and kinds of the curriculum were applied in both situations. Thus, I would state that the only difference between both situations is related to the existence of educational technology (digital technology) in one of them and the absence of it in the second one. Hence, I would argue that improvement in students' attainment is attributed to the use of digital technology not to other factors, such as the pedagogical dimensions or the kinds of the curriculum, as these other factors are common in both learning scenarios. For a detailed description of the implementation of this argument, the implementation of the digital and nondigital technology-based learning, please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

Note: the above argument applies to all CPT strategies in this study.

6.1.1.1 The First Case: C3, P3, T3 and C3, P3, T0 – Physics

The researcher applied C3, P3, T3 strategy (digital technology-based learning), which means that the curriculum had been introduced using all three parts: i) theoretical, using lecture notes, PowerPoint presentations and soft copies of textbooks; ii) practical, where a related experiment was conducted and analysed using Vernier software (this software is offered by IAT to analyse the collected data from the experiments, and can be found at the following website https://www.vernier.com); iii) interactive, which is mainly represented by iBooks and simulations, such as PhET simulations designed by the University of Colorado (University of Colorado, 2018). Phet simulation sites offer free online access for learners and teachers, and it can be found at the following address (https://phet.colorado.edu/en/simulations/category/new). Physical interactive tools such as posters, models and machines were used as well with the learning objectives that were not integrated with digital technology.

During this case, 60% of the content (of the learning objectives) was integrated with digital technology; students used different digital technology tools (software and hardware) to implement learning as follows:

The content was uploaded to the LMS where students could download it to their iPads or laptops so that they could work on it. Extra resources and links were shared with students to enable them to do online research and build new knowledge; students could share the gained knowledge between themselves using the airdrop in their iPads and laptops or using the email that is provided for each student by the school. Students could compete with each other using software applications (Apps), such as LMS and Kahoot. The researcher would claim that digital technology can improve students' attitudes towards learning physics, this claim agrees with Mottmann (1999, p. 75), who stated two essential reasons for using digital technology to teach physics "i) to improve students' physics ability and ii) to improve students' adverse reactions toward physics".

Three pedagogical dimensions were used to deliver the content: direct teaching, which is implemented mainly by the teacher (the researcher); social collaborative learning, where students were divided into groups with several assigned tasks distributed to the groups and constructive learning where students were asked in some of the distributed tasks to build their knowledge and draw some conclusions. Subsequently, the researcher trialled a test to evaluate the students' gained knowledge. Results were collected and analysed using Microsoft® Excel.

In the second scenario, C3, P3, T0 strategy was applied (nondigital technology-based learning). The content of the curriculum was introduced in three modes: i) theoretical, using lecture notes explained and written by the teacher on the board and copied by students; ii) practical, where a related experiment was conducted, and the collected data was analysed manually using simple tools such as ruler, pen and notebook (the researcher kept the tools traditional and simple as much as possible); iii) interactive, which was represented by paper images displayed in the classroom (hard copies) and physical models or objects so that students could interact with it physically.

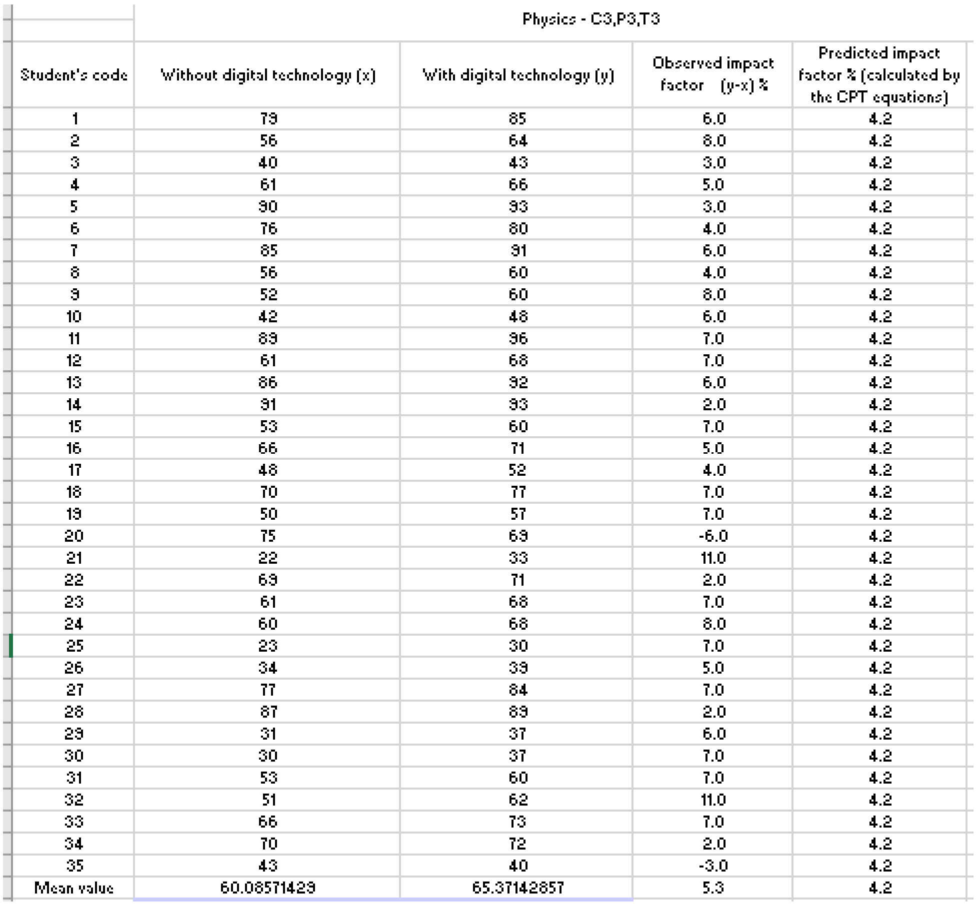
Three pedagogical dimensions were used to deliver the content: direct teaching, social (collaborative) learning and constructive learning. No digital technology was used to deliver the content. Students were examined traditionally (paper-based exam), exams were marked, and the results were compared with those achieved using digital technology (T3). For a detailed description, please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons and Appendix 8 – Samples of the Exams Conducted During this Study.

The Observed and Predicted Impact Factors

Regarding the C3, P3, T3 strategy, as can be seen in Table 35, the mean predicted impact factor (predicted improvement), which was calculated using the equations of the CPT model is equal to 0.042, while the mean observed impact factor (observed improvement), at the level of the group, was found to be 0.0529 (≈ 5.3 %), as shown in Figure 44. It can be seen that the two values are close to each other, which might be considered as an indicator of the validity of the CPT model and its equations.

Note: the value of the predicted impact factor is based on the calculations of the CPT model's equations while the value of the observed impact factor is based on the difference between the post and pre-tests, please refer to section 3.17.4.

Figure 44 and Figure 45 show students' marks without digital technology (pre-test) and with digital technology (post-test) as well as the mean values of the observed and predicted impact factors (improvements).



	Physics - C3,P3,T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	79	85	6.0	4.2
2	56	64	8.0	4.2
3	40	43	3.0	4.2
4	61	66	5.0	4.2
5	90	93	3.0	4.2
6	76	80	4.0	4.2
7	85	91	6.0	4.2
8	56	60	4.0	4.2
9	52	60	8.0	4.2
10	42	48	6.0	4.2
11	89	96	7.0	4.2
12	61	68	7.0	4.2
13	86	92	6.0	4.2
14	91	93	2.0	4.2
15	53	60	7.0	4.2
16	66	71	5.0	4.2
17	48	52	4.0	4.2
18	70	77	7.0	4.2
19	50	57	7.0	4.2
20	75	69	-6.0	4.2
21	22	33	11.0	4.2
22	69	71	2.0	4.2
23	61	68	7.0	4.2
24	60	68	8.0	4.2
25	23	30	7.0	4.2
26	34	39	5.0	4.2
27	77	84	7.0	4.2
28	87	89	2.0	4.2
29	31	37	6.0	4.2
30	30	37	7.0	4.2
31	53	60	7.0	4.2
32	51	62	11.0	4.2
33	66	73	7.0	4.2
34	70	72	2.0	4.2
35	43	40	-3.0	4.2
Mean value	60.08571429	65.37142857	5.3	4.2

Figure 44. Grade 9 students' marks with regard to digital and nondigital technology-based learning: case #1 (C3, P3, T3) and (C3, P3, T0).

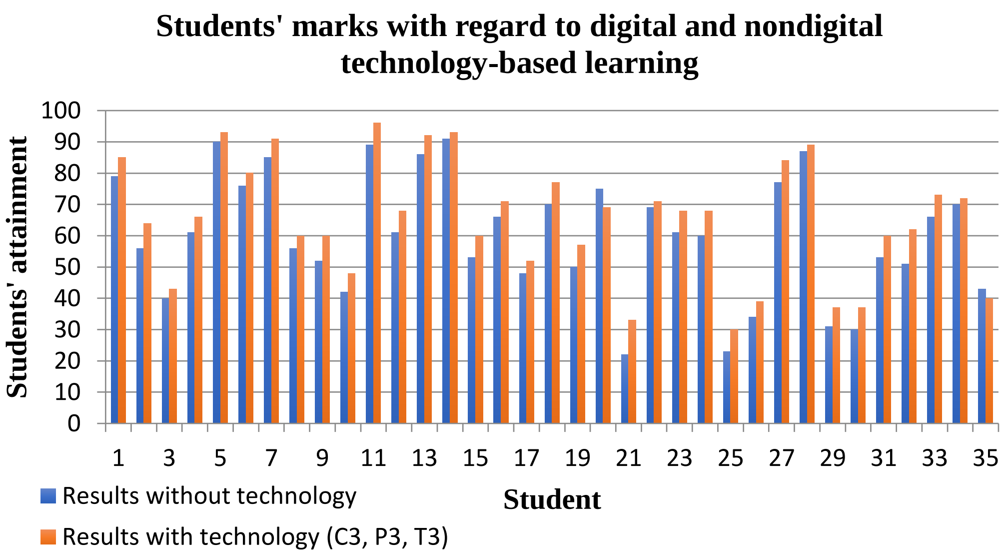


Figure 45. Students' marks with regard to digital and nondigital technology-based learning: case # 1 (C3, P3, T3) and (C3, P3 T0).

The null hypothesis (H_0) of this study states that there is no significant difference between the means of the predicted and observed improvements (impact factors); which implies that the CPT model is a valid and reliable tool as a predictive model for the improvement in students' attainment as an outcome of using educational technology.

Statistical Description

As shown in Table 38, Chi-Square (X^2) value was calculated and found to be $2.32*10^{-8}$, which is less than the critical value in X^2 distribution table (Degrees of freedom (df), in this case, are (n – 1) = (35 – 1) = 34. At 5 per cent level of significance, the table value = 48.60 and at 1 per cent level of significance, it is 56.06 for 34 df. Both values are greater than the calculated value of (X^2**),** which is $2.32*10^{-8}$). This means that the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of expected and observed improvements.

> If the calculated value of X^2 is less than the table value at a certain level of significance, the fit is considered to be a good one, which means that the divergence between the observed and expected frequencies is attributable to fluctuations of sampling. But if the calculated value of X^2 is greater than its table value, the fit is not considered to be a good one. (Kothari, 2004, p. 237)

The P-value was calculated as well and found to be 0.06, which is greater than 0.05. Therefore, the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of the expected and observed improvements.

The t-test: Paired Two Sample for Means was also used to check the null hypothesis by assessing whether the difference between the means of the predicted and observed impact factors (improvements) is significant or not. The statistical value of the t-test was found to be 1.93, which is less than the critical t-test value (2.03). Hence, the null hypothesis cannot be rejected (Minitab Inc, 2017).

Based on the outcomes of these statistical functions, the researcher can claim that the CPT model, in this case (the C3, P3, T3 strategy), is a valid and reliable predictive model for the improvement in students' attainment due to the use of educational technology.

Note: these calculations and the stated critical values were completed and stated by Microsoft® Excel 2016.

The correlation between students' marks with regard to digital and nondigital technology-based learning, has been checked through the Pearson correlation factor (r) and the coefficient of determination (r^2) as shown in Figure 46 and Table 38.

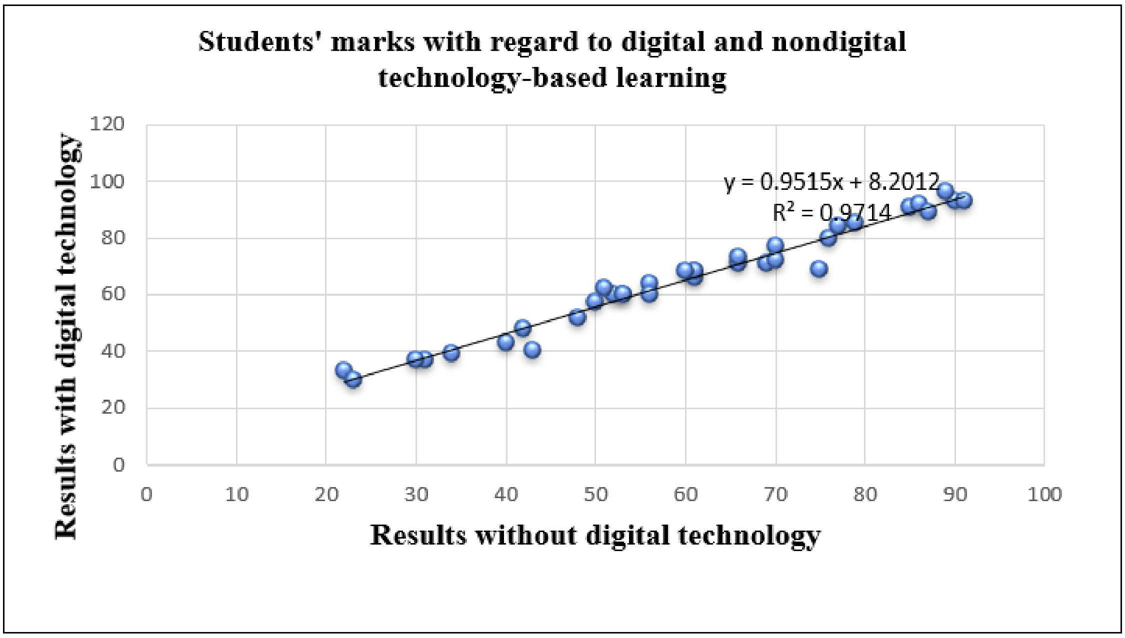


Figure 46. Students' marks with regard to digital and nondigital technology-based learning: case # 1 (C3, P3, T3) and (C3, P3, T0).

In order to check the impact of educational technology on students' attainment, the value of the Pearson correlation factor (r) was calculated and found to be 0.9856; which indicates a strong positive correlation between the use of educational technology and students' attainment (dependent variables). The value of r^2, or the coefficient of determination, is 0.9714, which means that 0.97 of the data points fall on the regression line, as shown in Figure 46.

The coefficient of determination (r^2) "is well defined in linear regression models" (Zhang, 2016, p. 1). However, the coefficient of determination is usually measured between 0 (0%) and 1 (100%), where the higher the value, the better the fit, in other words, more data points fall on the regression line (BusinessDictionary.com).

As shown in Table 38, the value of the effect size, in this case, was found to be

0.27, which indicates a medium effect of educational technology on students' attainment and implies that educational technology and students' attainment can be considered as dependent variables. The values of the Pearson correlation factor and the effect size indicated that educational technology impacted students' attainment in physics positively.

6.1.1.2 The Second Case: C3, P3, T4 and C3, P3, T0 – Physics

In this case, the researcher applied the C3, P3, T4 strategy. Three kinds of content (curriculum) were used: theoretical, practical and interactive. Eighty per cent of the content was integrated with digital technology, and three pedagogical dimensions were used to deliver the content (direct teaching, social (collaborative) learning and cognitive learning). The researcher trialled a test to evaluate the students and results were collected and analysed using MS® Excel.

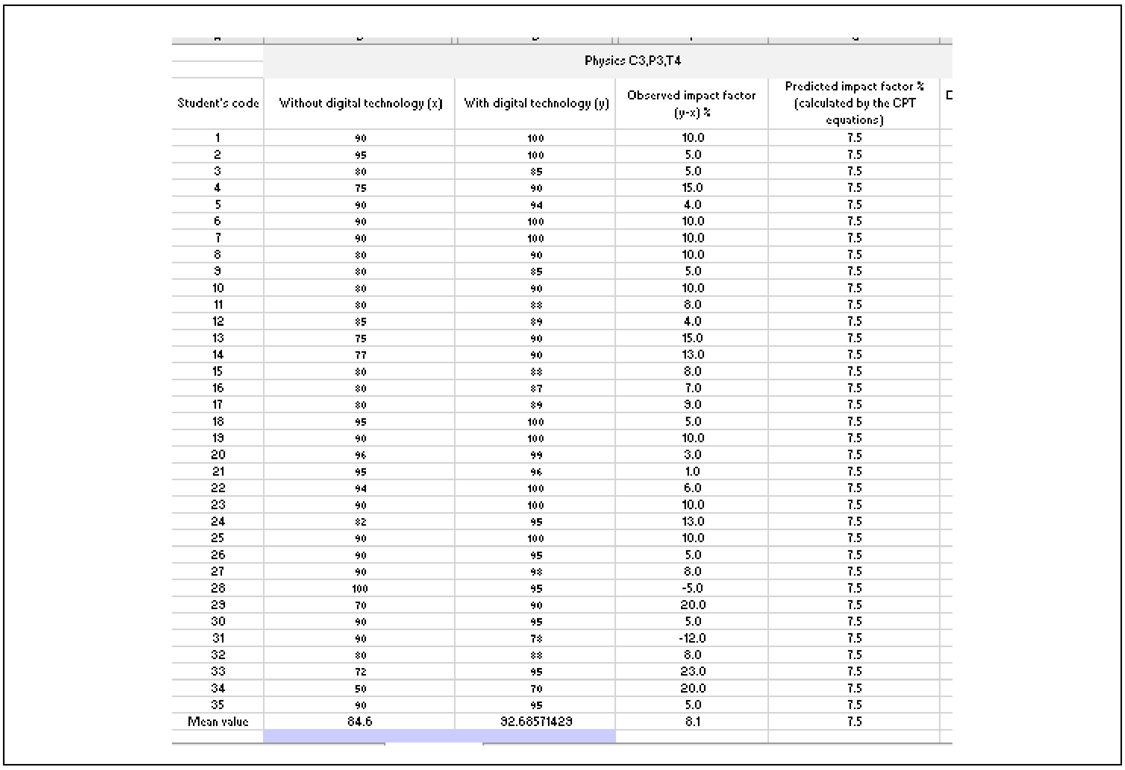
The C3, P3, T0 method (nondigital technology-based learning) was used to teach the second part of the content. The curriculum was introduced by all three components: theoretical, practical and interactive. Three pedagogical dimensions were used to deliver the content; direct teaching, social (collaborative) learning and cognitive learning. Students were examined traditionally (paper-based exam), exams were marked. The students' attainment were compared with their attainment when using digital technology.

Note: for a detailed description of the implementation of both scenarios, digital technology-based learning (Cnc, Pnp, Tnt) and nondigital technology-based learning (Cnc, Pnp, T0), please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons and Appendix 8 – Samples of the Exams Conducted During this Study.

Observed and Predicted Impact Factors

As shown in Figure 47 and Figure 48, in the case of C3, P3, T4 the mean expected improvement, which was calculated using the CPT model is equal to 0.075, and the mean observed improvement was equal to 0.0808 (≈ 8.1 %). It is clear that the two values are very close to each other.

Figure 47 and Figure 48 show the students' marks without digital technology (pre-test) and with digital technology (post-test).



	Physics C3,P3,T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	90	100	10.0	7.5
2	95	100	5.0	7.5
3	80	85	5.0	7.5
4	75	90	15.0	7.5
5	90	94	4.0	7.5
6	90	100	10.0	7.5
7	90	100	10.0	7.5
8	80	90	10.0	7.5
9	80	85	5.0	7.5
10	80	90	10.0	7.5
11	80	88	8.0	7.5
12	85	89	4.0	7.5
13	75	90	15.0	7.5
14	77	90	13.0	7.5
15	80	88	8.0	7.5
16	80	87	7.0	7.5
17	80	89	9.0	7.5
18	95	100	5.0	7.5
19	90	100	10.0	7.5
20	96	99	3.0	7.5
21	95	96	1.0	7.5
22	94	100	6.0	7.5
23	90	100	10.0	7.5
24	82	95	13.0	7.5
25	90	100	10.0	7.5
26	90	95	5.0	7.5
27	90	98	8.0	7.5
28	100	95	-5.0	7.5
29	70	90	20.0	7.5
30	90	95	5.0	7.5
31	90	78	-12.0	7.5
32	80	88	8.0	7.5
33	72	95	23.0	7.5
34	50	70	20.0	7.5
35	90	95	5.0	7.5
Mean value	84.6	92.68571429	8.1	7.5

Figure 47. Grade 11 students' marks with regard to digital and nondigital technology-based learning: case # 2 (C3, P3, T4) and (C3, P3, T0).

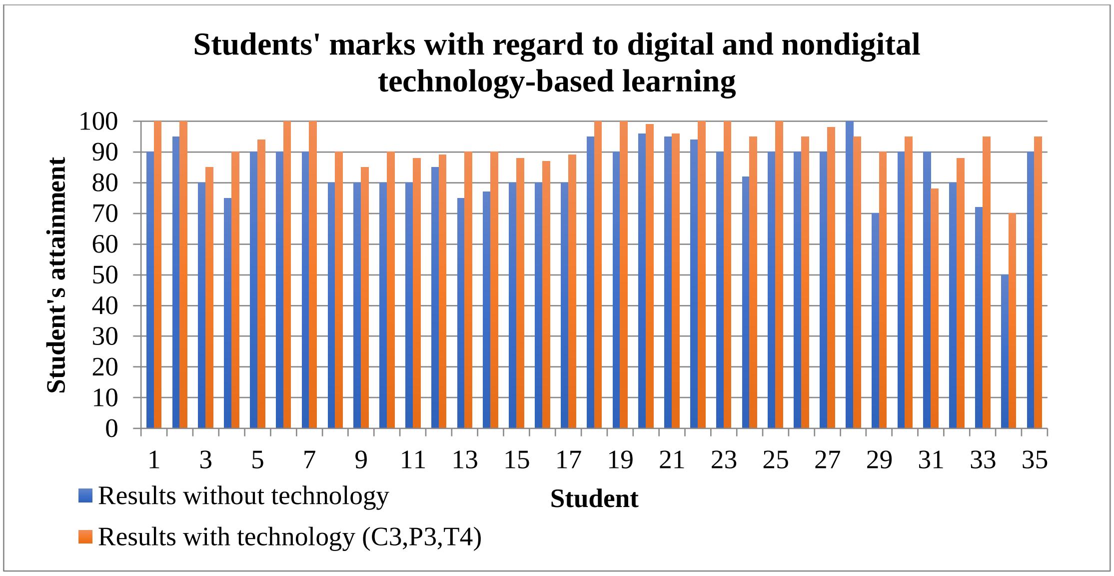


Figure 48. Students' marks with regard to digital and nondigital technology-based learning: case # 2 (C3, P3, T4) and (C3, P3, T0).

The CPT calculations related to the C3, P3, T4 strategy

Using Equation 8, the point C3, P3, T4 meets the point (3, 3, 0.8) in the CPT space:

$$R = \sqrt{C3^2 + P3^2 + T4^2} - \sqrt{C3^2 + P3^2}$$

$$R = \sqrt{3^2 + 0.8^2 + 3^2} - \sqrt{3^2 + 3^2}$$

$$\text{The impact factor } R = 0.075$$

Alternatively, using Equation 9 and Equation 10

$$\text{The predicted impact factor } R = R_o (N)^2$$

The threshold impact factor: $R_o = \sqrt{3^2 + 3^2 + 0.2^2} - \sqrt{3^2 + 3^2}$

$$R_o = 0.0047$$

The value of (N) or the digital technology integration level is equal to 4 since 80% of the content was integrated with digital technology.

$$R = 0.0047 \text{ x } (4)^2$$

$$= 0.075$$

Statistical Description

As shown in Table 38, the Chi-Square value was calculated and found to be $3.7*10^{-24}$, which is less than the critical value in the X^2 distribution table. The P-value was calculated as well and found to be 0.6, which is greater than 0.05. The t-test: Paired Two Sample for Means was also used to check the null hypothesis; the statistical value of the t-test was found to be 0.53, which is less than the critical t-test value of 2.03. Hence, the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of the expected and observed improvements. Therefore, the researcher would claim that the CPT model, in this case (C3, P3, T4), is a valid and reliable tool as a predictive model for the improvement in students' attainment due to the use of educational technology (the impact factor).

Note: these calculations and the stated critical values were completed using Microsoft® Excel 2016.

The correlation between students' marks with regard to digital and nondigital technology-based learning, has been checked through the Pearson correlation factor (r) and the coefficient of determination (r^2), as shown in Figure 49 and Table 38.

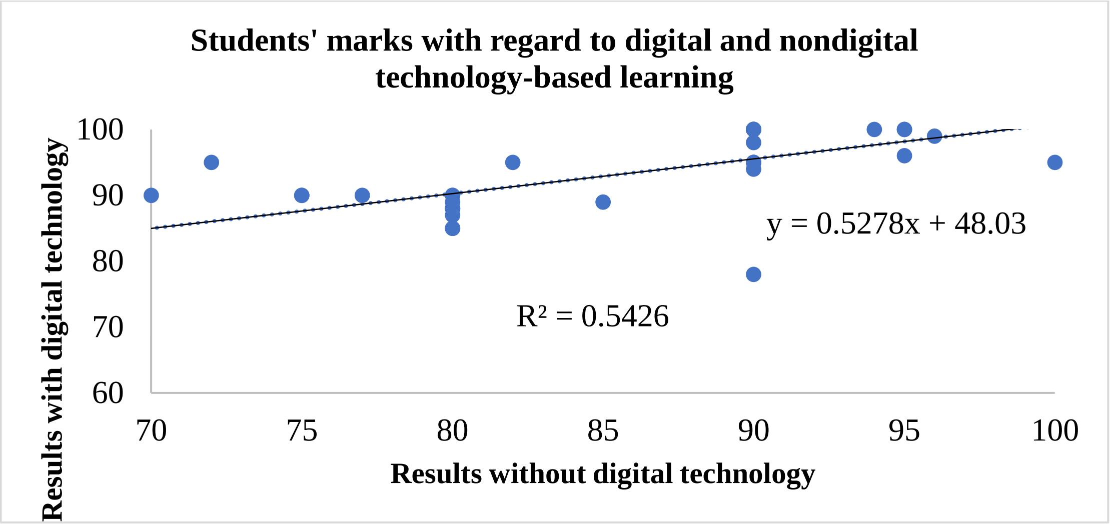


Figure 49. Students' marks with regard to digital and nondigital technology-based learning; case # 2 (C3, P3, T4) and (C3, P3, T0).

The value of Pearson correlation factor r is 0.7366, which is a moderate positive correlation. In other words, the value of (r) indicates a positive correlation between the use of educational technology and students' attainment. The value of r^2, the coefficient of determination, is 0.5426, which means that approximately 54 % of the points fall on the regression line, as shown in Figure 49. As shown in Table 38, the value of the effect size, in this case, was found to be 0.85, which indicates a large effect of educational technology on students' attainment and imply that educational technology and students' attainment are dependent variables.

6.1.1.3 The Third Case: C2, P2, T4 and C2, P2, T0 – Physics

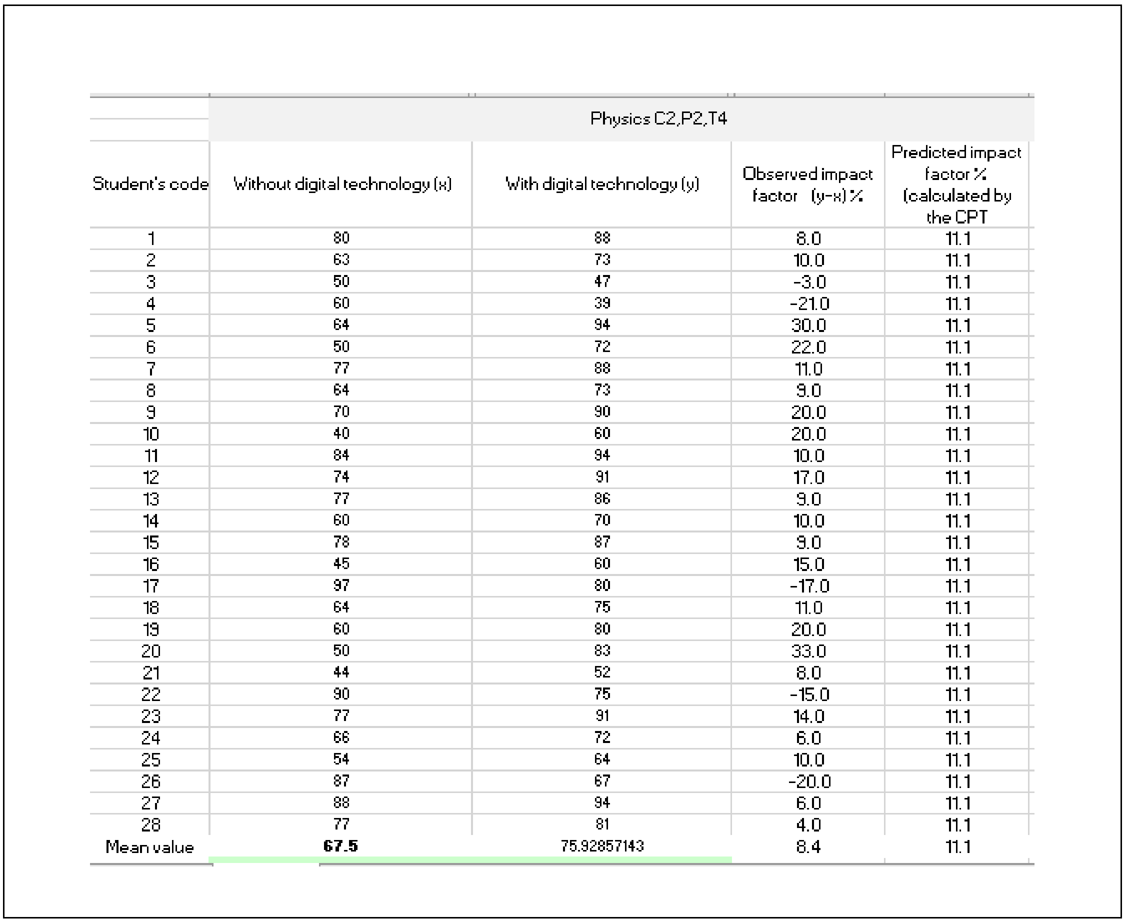
The C2, P2, T4 strategy was applied in this case to teach physics where two kinds of content (curriculum) were used: theoretical, which uses lecture notes, PowerPoint presentations, soft copies of the textbooks. And practical, where a related experiment was conducted and analysed using vernier software (digital technology-based experiments). 80% of the content was integrated with digital technology. The contents were delivered using two pedagogical dimensions: direct teaching and social (collaborative) learning. Exams were conducted and marked, and results were recorded in order to be compared later with students' results with regard to nondigital technology-based learning.

C2, P2, T0 method was used to teach the second part of the content to the students (nondigital technology-based learning). Two kinds of the curriculum were used: theoretical and practical, a related experiment was conducted and analysed manually. Two pedagogical dimensions were used to implement learning, direct teaching, where the teacher explained the content on the board, students copied from the board, and collaborative social learning, where students were divided into groups, each of which five students, so they could perform some activities and tasks collaboratively. Students were examined traditionally (paper-based exam), exams were marked, and the results were compared with the results in the case of using digital technology. Please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons and Appendix 8 – Samples of the Exams Conducted During this Study.

Observed and Predicted Impact Factors

Based on the equations of the CPT model, in the case of using the C2, P2, T4 strategy, the mean predicted impact factor (predicted improvement) is equal to 0.111 (11.1%) (see Table 36). The study showed that the mean observed impact factor (observed improvement in students' attainment) was equal to 0.084 (8.4%), refer to Figure 50 and Figure 51. It can be seen that the two values are relatively close to each other.

Figure 50 and Figure 51 show the students' marks without digital technology (pre-test) and with digital technology (post-test), as well as the mean values of the observed and predicted impact factors (improvements).



	Physics C2,P2,T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT
1	80	88	8.0	11.1
2	63	73	10.0	11.1
3	50	47	-3.0	11.1
4	60	39	-21.0	11.1
5	64	94	30.0	11.1
6	50	72	22.0	11.1
7	77	88	11.0	11.1
8	64	73	9.0	11.1
9	70	90	20.0	11.1
10	40	60	20.0	11.1
11	84	94	10.0	11.1
12	74	91	17.0	11.1
13	77	86	9.0	11.1
14	60	70	10.0	11.1
15	78	87	9.0	11.1
16	45	60	15.0	11.1
17	97	80	-17.0	11.1
18	64	75	11.0	11.1
19	60	80	20.0	11.1
20	50	83	33.0	11.1
21	44	52	8.0	11.1
22	90	75	-15.0	11.1
23	77	91	14.0	11.1
24	66	72	6.0	11.1
25	54	64	10.0	11.1
26	87	67	-20.0	11.1
27	88	94	6.0	11.1
28	77	81	4.0	11.1
Mean value	**67.5**	75.92857143	8.4	11.1

Figure 50. Grade 10 students' marks with regard to digital and nondigital technology-based learning: case # 3 (C2, P2, T4) and (C2, P2, T0).

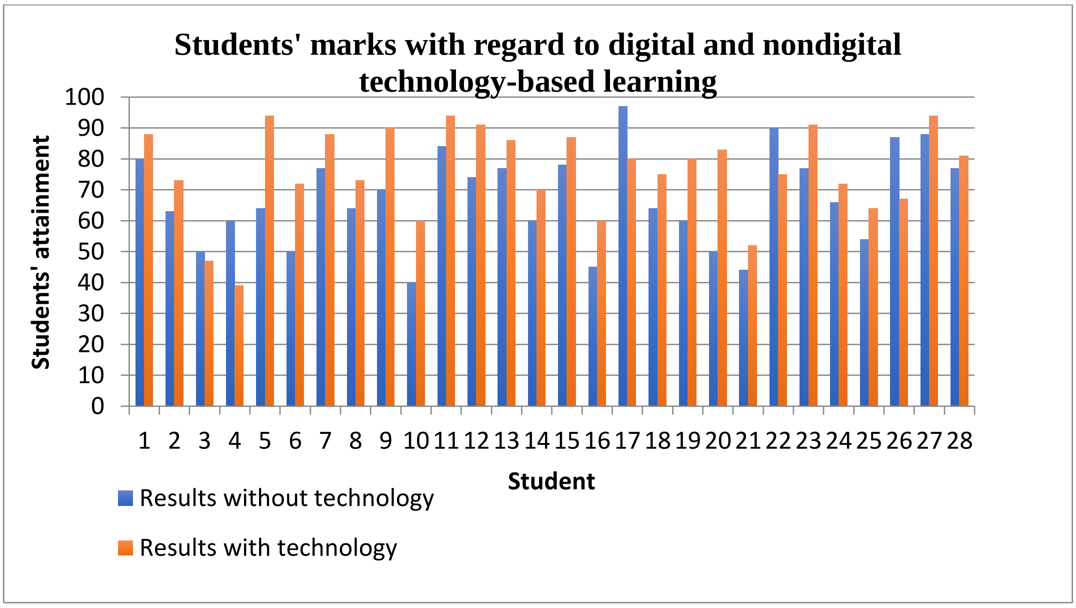


Figure 51. Students' marks with regard to digital and nondigital technology-based learning: case # 3 (C2, P2, T4) and (C2, P2, T0).

Statistical Description

The Chi-Square value was calculated and found to be $1.99*10^{-79}$, which is less than the critical value in the X^2 distribution table. The P-value was calculated as well and found to be 0.30, which is greater than 0.05. The t-test: Paired Two Sample for Means was also used to check the null hypothesis. The statistical value of the t-test was found to be 1.05, which is less than the critical t-test value of 2.05. Hence, the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of expected and observed improvements, which implies that the CPT model, in this case, is a valid and reliable tool as a predictive model for the improvement in students' attainment due to the use of educational technology. Refer to Table 38, Figure 50, Figure 51 and Figure 52

Note: The statistical calculations and the critical values were completed and stated by Microsoft® Excel 2016.

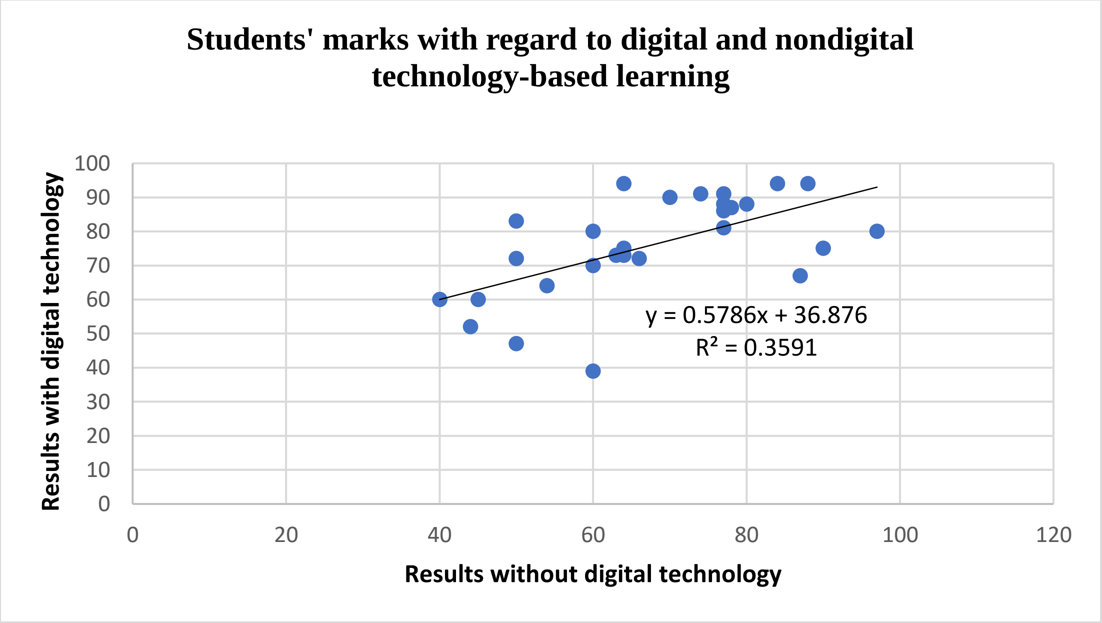


Figure 52. Students' marks with regard to digital and nondigital technology-based learning: case # 3 (C2, P2, T4) and (C2, P2, T0).

The value of Pearson correlation factor r is 0.59. This is a moderate positive correlation that indicates a positive correlation between the use of educational technology and students’ attainment to be considered as dependent variables. The value of r^2, the coefficient of determination, is 0.36, which means that 36 % of the points fall on the regression line, as shown in Figure 52. As shown in Table 38, the value of the effect size, in this case, was found to be 0.56, which indicates a large effect of educational technology on students’ attainment and implies that educational technology and students’ attainment are dependent variables.

No. of students	**Grade / Gender**	**Cnc Pnp Tnt**	**The mean observed impact factor (the observed improvement) out of 100**	**The mean predicted impact factor (expected improvement) out of 100**	**Pearson correlation factor**	**Tstat**	**T-critical**	**Effect size**	**P value**	**Σ X^2**	**The final result based on T-test, Σ X^2 and the p_{value}**
35	9 / M	**C3, P3, T3**	5.30	4.20	0.980	1.93	2.03	0.270	0.06	$2.32*10^{-8}$	The null hypothesis cannot be rejected. There is no significant difference between the means of the expected and observed improvement.
35	11/ M	**C3, P3, T4**	8.10	7.50	0.730	0.53	2.03	0.850	0.60	$3.71*10^{-24}$	
28	10 / M	**C2, P2, T4**	8.40	11.1	0.590	1.05	2.05	0.560	0.30	$1.99*10^{-79}$	

Table 38. Summary of the conducted cases in the second stage.

6.1.2 Statistical Description for All Conducted Cases in the Second Stage

Table 39, Table 40 and Figure 53 below show the mean values of the statistical functions (chi-square value, P-value, T-test, Pearson correlation factor (R) and the Effect size (Cohen's D) for all conducted cases in stage two that are shown in Table 38.

The statistical function	**Statistical description based on the mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size.**
Chi-Square	The Chi-Square mean value was calculated and found to be less than the critical value in the X^2 distribution table, which implies that the fit between the observed and expected frequencies (improvements) is considered to be a good one. Which implies that the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the predicted and observed impact factors (improvements).
P-value	As shown in Table 40 and Figure 53, the P-value (the mean value) was calculated and found to be greater than 0.05, which confirms that the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the predicted and observed impact factors (improvements).
T-test	The statistical mean value of t-test was found to be 1.17, which is less than the critical value of 2.04 as shown in Table 40 which implies that the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the predicted and observed impact factors (improvements).
Pearson correlation factor	As shown in Table 40 and Figure 53, the mean value of the Pearson correlation factor is 0.77. This indicates a moderate positive correlation between the use of educational technology and students' attainment. Therefore these two variables can be considered as dependent variables.
Effect size	As shown in Table 40 and Figure 53, the mean value of the effect size is equal to 0.56; this value is located between medium effect and large effect, which implies that the use of educational technology and students' attainment are dependent variables.

Table 39. Statistical description based on the mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size that were applied to the findings of the second stage.

Table 40 shows the mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size. The mean values represent all cases in Table 38.

The statistical function	The mean value
T-test	1.17
T-critical	2.04
Effect size (Cohen’s D)	0.560
Correlation factor (R)	0.770
P-value	0.320
ΣX^2	$1.16x10^{-8}$

Table 40. Mean values of the statistical functions that were applied to the findings of the second stage.

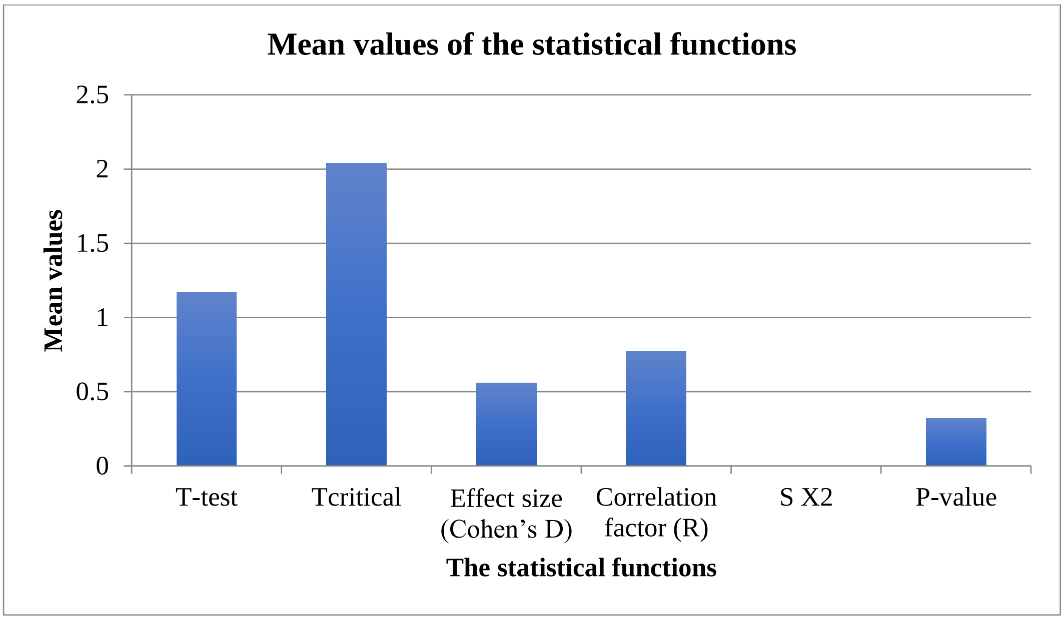


Figure 53. Mean values of the statistic functions (T-test, T-critical, Effect size (Cohen’s D), Correlation factor (r), chi-square value and P-value).

Table 41, Figure 54 and Figure 55 show the mean observed impact factor against the mean predicted impact factor for all cases conducted in stage two.

Cnc, Pnp, Tnt	**Mean observed impact factor (based on the pre and post-tests**	**Mean predicted impact factor (predicted improvement calculated from the CPT model' equations)**
C2, P2, T4	0.084	0.111
C3, P3, T3	0.053	0.042
C3, P3, T4	0.081	0.075
Mean value	0.073	0.076

Table 41. The means of observed and predicted impact factors in the second stage.

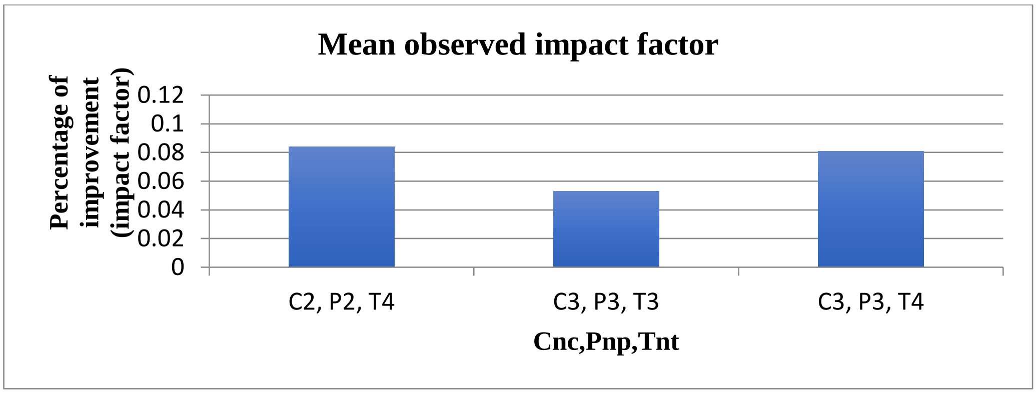


Figure 54. The mean observed impact factor in different CPT strategies: C3, P3, T3; C3, P3, T4 and C2, P2, T4.

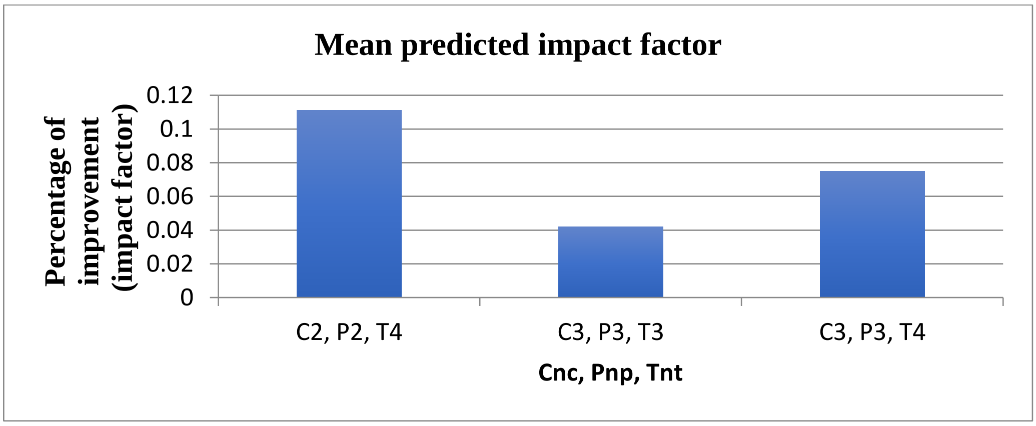


Figure 55. The mean predicted impact factor in different CPT strategies: C3, P3, T3; C3, P3, T4 and C2, P2, T4.

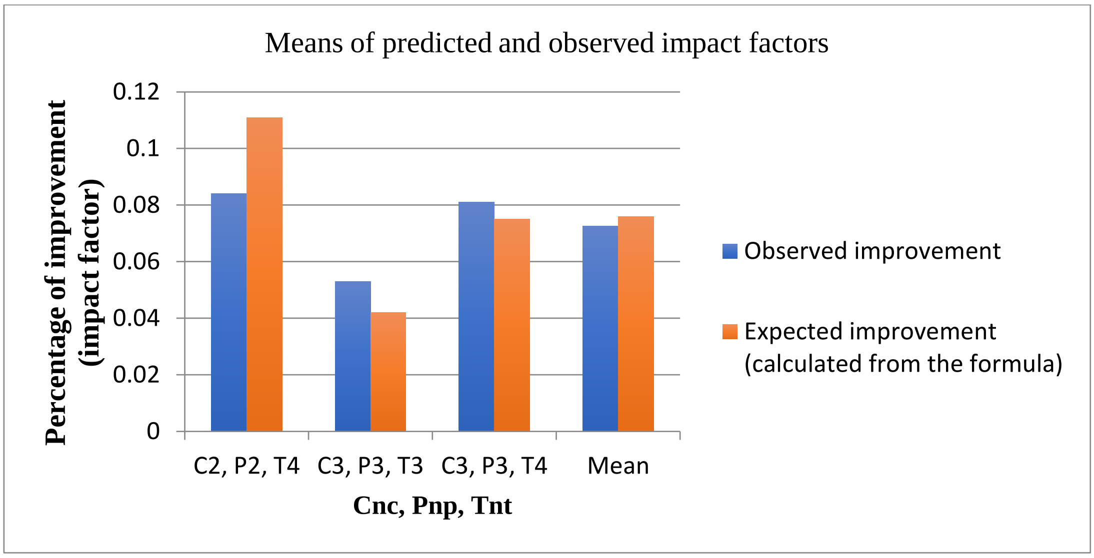


Figure 56. Comparison between the means of observed and predicted impact factors.

The "So What?" Aspect

Overall, three different CPT strategies were conducted in the second stage. In each case, the mean observed impact factor was compared with the mean predicted impact factor. As can be seen from Figure 56 and Table 42, the means of predicted and observed impact factors were the closest in the case of, C3, P3, T4 strategy, where three kinds of curriculum were used (theoretical, practical and interactive), three pedagogical dimensions and 80% of the material was integrated with digital technology.

Additionally, the effect size was the highest, in this case, C3, P3, T4 as it was 0.85, which is described as a significant effect of using educational technology on students' attainment.

In the case of C3, P3, T4, students' attainment was improved by approximately 8.1% (or 0.081), which is the observed impact factor, while the predicted impact factor is equal to 7.5 % (or 0.075). This makes a minor difference between both values of the impact factor (observed and predicted) of 0.006, as shown below in Table 42.

Cnc Pnp Tnt	The mean observed impact factor, out of 100	The mean predicted impact factor, out of 100	Pearson correlation factor	Tstat	T-critical	Effect size	P-value	Σ X^2
C3, P3, T4	8.10	7.50	0.730	0.530	2.03	0.850	0.60	$3.71*10^{-24}$

Table 42. The means of observed and predicted impact factors, and statistical description in the case of using C3, P3, T4 strategy.

As shown in Table 38, in all cases, there was an improvement in students' attainment as an outcome of using educational technology. Therefore, I would claim that the use of various pedagogies and intensive use of digital technology to deliver the content, maximises the learning outcomes and raises students' level of understanding, which is reflected positively in their attainments.

Table 43 and Figure 57 show the overall mean predicted impact factor for the cases 1, 2 and 3 and the overall mean observed impact factor for the cases 1 to 3.

	Mean observed impact factor	Mean predicted impact factor
Mean value	0.073	0.076

Table 43. The mean predicted impact factor (calculated from the CPT model) and the mean observed impact factor, based on the difference between pre and post-tests.

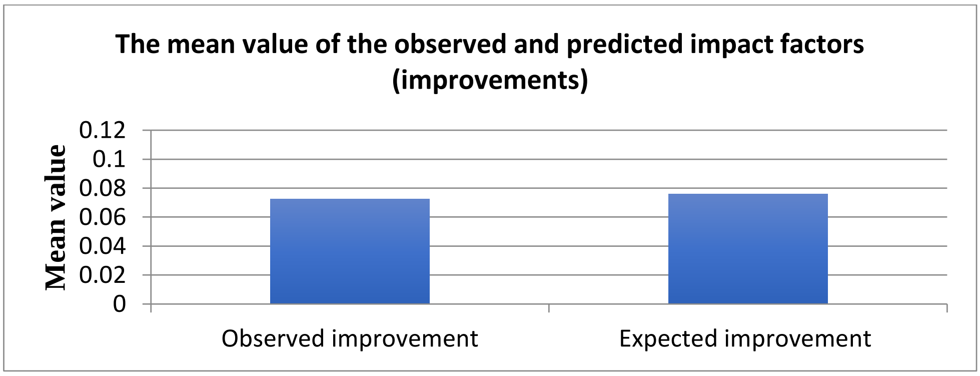


Figure 57. The overall mean values of expected and observed improvements (impact factors), as shown in Table 43.

As can be seen in Table 43 and Figure 57, the mean observed value was extremely close to the predicted one, which gives credibility to the developed model and its equations to be considered as a valid and reliable tool that can predict the improvement in students' attainment in different learning scenarios (CPT strategies) for teaching physics.

6.1.3 Summary of the Second Stage

The second stage was used to test the CPT model and check the validity of the CPT model's equations. The data analysis of this stage showed that the CPT model is reliable and it can be considered as a valid tool to be used as a predictive model for the improvement in students' attainment as an outcome of using educational technology.

Various statistical functions were used to check the validity of the CPT model. These include the Chi-Square test, P-value, T-test: Paired Two Sample for Means was also used. The results of using these functions indicate that the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of predicted and observed impact factors, which implies that the CPT model is a valid and reliable tool as a predictive model for the improvement in students' attainment due to the use of educational technology. As shown in Table 39, Table 40 and Figure 53, the effect size and the Pearson correlation coefficient indicate a positive relationship between the use of educational technology and students' attainment so that these two variables can be considered as dependent variables.

The means of observed and predicted impact factors (improvements) in students' attainment were the closest in the case of, C3, P3, T4 strategy. It could be concluded from this stage that the use of several pedagogy dimensions to deliver the content combined with the effective use of digital technology raises students' understanding, which leads to an improvement in their attainment.

For more in-depth investigation of the CPT model, there was a need to apply this model to other fields and larger samples to check its validity, which took place in the third stage. Similarly, to the second stage, the third stage focused on students as well, observing the improvement in their attainments as an outcome of using educational technology to be compared with the expected improvements that were predicted by the equations of the CPT model. Thus, the validity of the CPT model could be checked.

6.2 THE THIRD STAGE OF THE STUDY (IN-DEPTH INVESTIGATION)

In the third stage of this study, a comparative methodology was used; the participating students' marks were compared in relation to the use or not of digital technology in the teaching-learning process. The following procedures were considered to collect the primary data in stage three:

i) Planned learning outcomes to be implemented in the classroom without the use of digital technology (the teacher prepared it).

ii) Paper-based assessment tool to assess students after nondigital technology-based learning.

iii) Planned learning outcomes to be implemented using digital technology-based learning.

iv) Paper and technology-based assessment tool to assess students after digital technology-based learning.

v) Exams were marked in both situations and results were compared with each other.

vi) To be able to determine the impact of using educational technology on students' attainment, students' marks in both situations (with and without digital technology) were compared and analysed using two statistical functions: Pearson correlation coefficient and the effect size.

vii) To be able to determine if the developed model (the CPT model) is valid as a predictive model or not, the means of the observed and predicted impact factors were compared and analysed using three different statistical functions: Chi-Square test, P-value and t-test.

This stage focused on the effect of using educational technology on students' attainment. Different subjects were included in this stage: physics, mathematics, biology, social studies and English language. Teachers who were involved in this stage of the study were requested to create a positive learning environment which would include several factors, such as technological tools: iPads, laptops, learning management system, various pedagogical dimensions, a positive and clean environment, friendly relationship with students. This kind of environment facilitates students' learning and achieving their learning outcomes. Using digital technology, students could communicate with their teachers easily and post their own responses to topic tasks that were published by the instructor on a discussion board such as a learning management system. Different learning management systems were used in this stage of the study, such as Plato, Showbi platform system and Desire to Learn (D2L) http://aths.ankabut.ac.ae/?target=%2fd2l%2fhome, (D2L is the current learning management system used by IAT).

The assessments conducted in this stage met the following criteria:

i. The assessments must integrate the theoretical and practical sides of the subject/material so that students should use their theoretical knowledge to describe a real-life application or an experiment.

ii. Assessments must cover different categories of questions, such as short response, problem-solving and conceptual questions.

iii. The assessments must include at least three different levels of complexities according to Bloom's Taxonomy (to be suitable for a range of students at different levels, such as comprehensive, application and analysis) (Teaching Learning Center, 2015; bloomstaxonomy.org, 2018). Please refer to section 3.17.5.2 and Appendix 8 – Samples of the Exams Conducted During this Study.

iv. Students must be given enough time to answer the exam questions.

6.2.1 Data Analysis and Discussion of the Third Stage

During the third stage of the study, similarly to the second stage, two different scenarios: digital technology-based learning (Cnc, Pnp, Tnt) and nondigital technology-based learning (Cnc, Pnp, T0) were applied in the selected cases, where T0 indicates to the case of not using educational technology. Two parts of content, with the same level of complexities, were taught to students. For the purpose of checking the validity and reliability of the CPT model, several CPT strategies were applied on more extensive samples and different subjects: Physics, Mathematics and Biology from the Science department, and English language, Social Studies from the Humanities department.

6.2.2 The First Part of Stage Three – Science Subjects

6.2.2.1 The First Subject: Physics

The researcher applied two different CPT strategies to teach physics in this stage; the applied strategies were (**C3, P3, T3)**; (**C3, P3, T0) and (C2, P2, T4);** (**C2, P2, T0)**.

Note: for a detailed description of the implementation of both scenarios, digital technology-based learning (Cnc, Pnp, Tnt) and nondigital technology-based learning (Cnc, Pnp, T0), please refer to examples 1, 2 and 3 Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

The First Strategy / C3, P3, T3 and C3, P3, T0

The curriculum was introduced using all three forms: theoretical, practical, and interactive content. The theoretical part made use of lecture notes, PowerPoint presentations, soft copies of the textbooks. The practical involved conducting a relevant experiment and analysing it using vernier software, which is offered by IAT, while the interactive content was delivered using iBooks, simulations such as PhET simulation (University of Colorado, 2018) and physical interactive tools. Graham and Rowlands in their study stated that interactive Physics “is an environment in which almost any physical situation can be recreated and monitored” as it can “provide excellent visual images in conjunction with numerical, graphical or vector representations of different quantities” (Graham & Rowlands, 2000, p. 489).

In this strategy (C3, P3, T3), 60% of the content (of the learning objectives) were integrated with digital technology. Students used various technology tools (software and hardware) to implement learning as the pattern described below:

A learning management system (LMS) was used as a virtual publication platform to which the content was uploaded. Learners could then download the uploaded content using their iPads or laptops (these devices are offered freely for all students by IAT). Extra resources and links were shared with students to do online research and to build new knowledge. Students could share the gained knowledge amongst themselves using the airdrop in the iPad and laptop or using the email (school email), which is provided for each student, by the school. Furthermore, students could compete with each other using different applications such as Kahoot.

Three pedagogical dimensions were used to deliver the content: i) direct teaching, implemented mainly by the teacher inside the classroom; ii) collaborative learning, students were divided into small groups of four or five students, with distributed tasks to each group, and iii) constructive learning, students were asked to build and develop their knowledge, by going through extra resources that were shared with them. Then students were examined to evaluate their gained knowledge with regard to digital technology-based learning and results were collected and analysed using Microsoft® Excel.

In the case of using C3, P3, T0 strategy which refers to nondigital technology-based learning: three types of curriculum: i) theoretical content, using lecture notes were copied by students from the board; ii) practical content, a relevant experiment was conducted, and the collected data was analysed manually using simple tools, such as a ruler, pen and copybook; iii) interactive, which was represented by images display (hard copies) and physical models or objects display so that students could interact with it physically.

Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. No digital technology was used (T0) to deliver the content. Students were examined traditionally (paper-based exam), exams were marked, and the results were compared with the results in the case of using digital technology. Refer to Table 44 and Figure 62.

The Second Strategy / C2, P2, T4 and C2, P2, T0

Two kinds of the curriculum were used: theoretical and practical content where a related experiment to the content was conducted in the laboratory; the conducted experiment was analysed using software technology. Eighty per cent of the content was integrated with digital technology; students used different technology tools (software and hardware) to implement learning, such as the learning management system (D2L), iPad or laptop, extra resources and links were shared with students through the email or airdrop on their iPads or the MacBook Pro laptops. Two pedagogical dimensions were used in this strategy: direct teaching and collaborative learning.

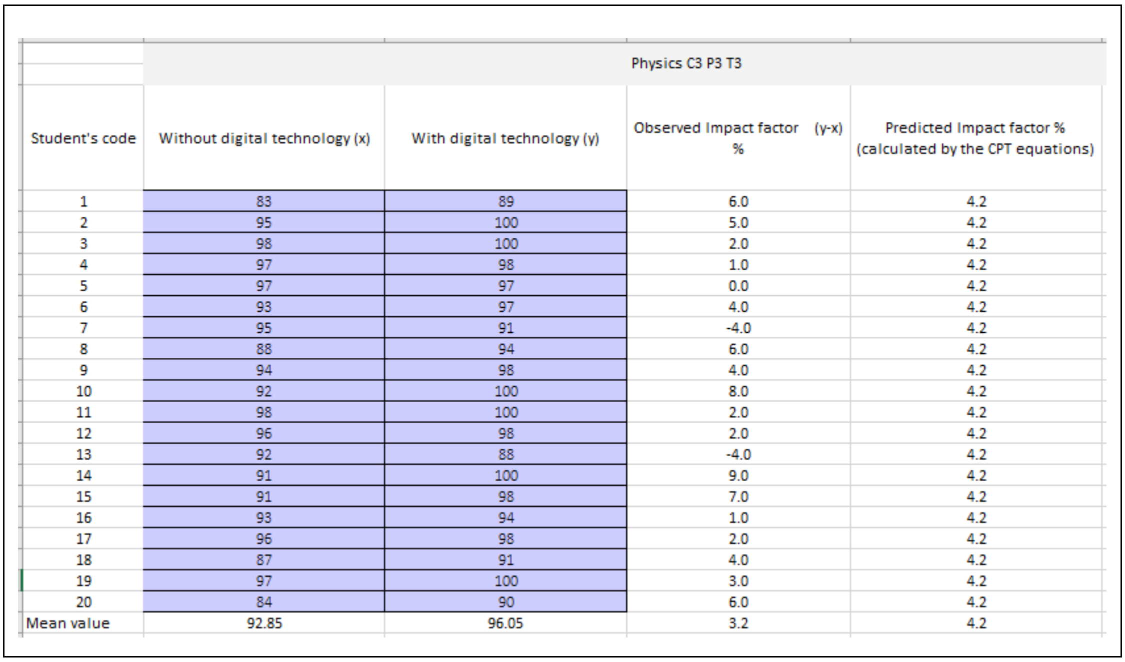
In the case of using C2, P2, T0 strategy (nondigital technology-based learning), two pedagogical dimensions were applied to deliver the content: direct teaching, and collaborative learning. Two kinds of the curriculum were used: theoretical and practical, the conducted experiment and the collected data was constructed and analysed manually using simple manual tools, then the researcher trialled a test to evaluate the students; results were collected, analysed using MS® Excel.

The Predicted and Observed Impact Factors

The mean value of the observed impact factor while using C3, P3, T3 was 0.032, and the mean predicted impact factor as calculated using the equations of the CPT model was found to be 0.042, refer to Figure 58 and Figure 62. While in the case of using C2, P2, T4 the mean value of the observed impact factor, in all cases conducted to investigate the C2, P2, T4 strategy (this strategy was trialled three times, see Figure 59, Figure 60 and Figure 61) was 0.073 (i.e., 7.3%), and the mean value of the predicted impact factor based on the CPT model's equations is 0.111.

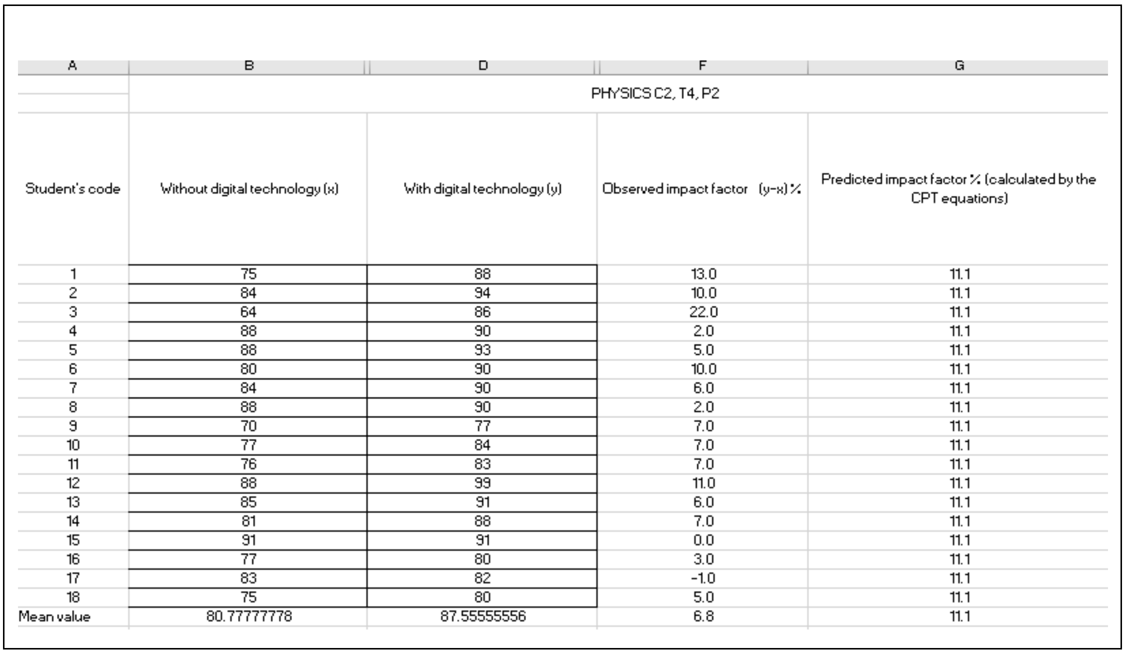
Note: the C2, P2, T4 strategy was trialled three times with different classes (please refer to Table 63), the observed improvements were as follows: 6.8%, 7.4% and 7.8%. The mean value is 7.3 %.

Figure 58, Figure 59, Figure 60 and Figure 61 show students' marks without digital technology (pre-test) and with digital technology (post-test) as well as the mean values of the observed and predicted impact factors (improvements).



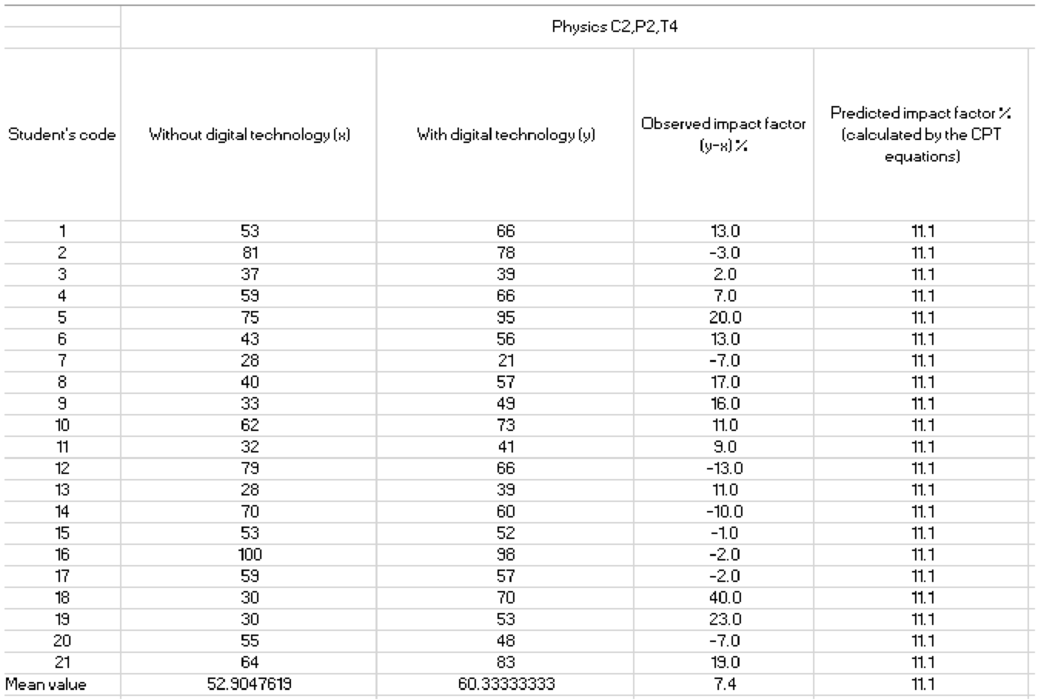
	Physics C3 P3 T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed Impact factor (y-x) %	Predicted Impact factor % (calculated by the CPT equations)
1	83	89	6.0	4.2
2	95	100	5.0	4.2
3	98	100	2.0	4.2
4	97	98	1.0	4.2
5	97	97	0.0	4.2
6	93	97	4.0	4.2
7	95	91	-4.0	4.2
8	88	94	6.0	4.2
9	94	98	4.0	4.2
10	92	100	8.0	4.2
11	98	100	2.0	4.2
12	96	98	2.0	4.2
13	92	88	-4.0	4.2
14	91	100	9.0	4.2
15	91	98	7.0	4.2
16	93	94	1.0	4.2
17	96	98	2.0	4.2
18	87	91	4.0	4.2
19	97	100	3.0	4.2
20	84	90	6.0	4.2
Mean value	92.85	96.05	3.2	4.2

Figure 58. Grade 9 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T3.



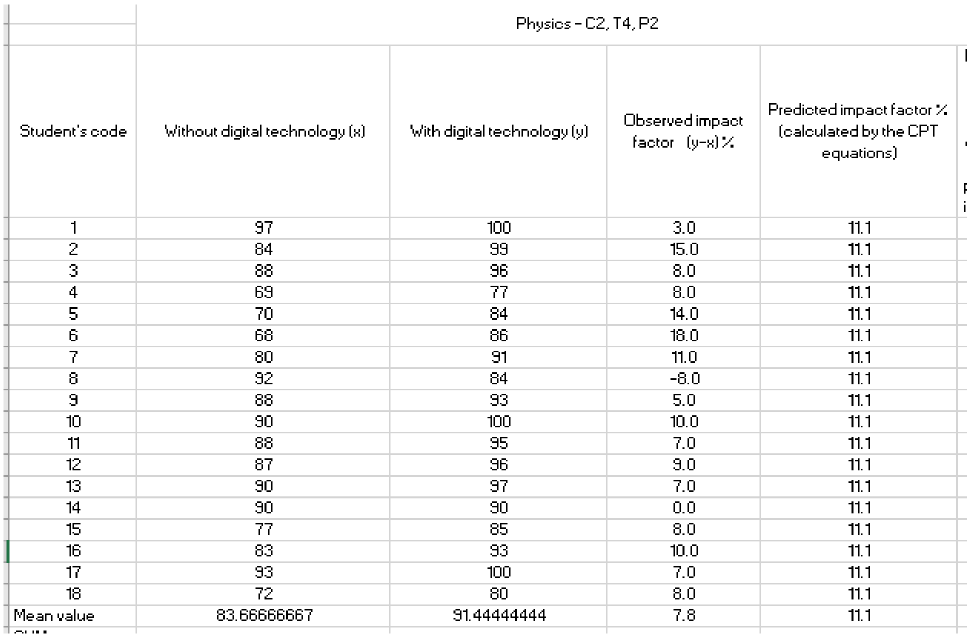
A	B	D	F	G
	PHYSICS C2, T4, P2			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	75	88	13.0	11.1
2	84	94	10.0	11.1
3	64	86	22.0	11.1
4	88	90	2.0	11.1
5	88	93	5.0	11.1
6	80	90	10.0	11.1
7	84	90	6.0	11.1
8	88	90	2.0	11.1
9	70	77	7.0	11.1
10	77	84	7.0	11.1
11	76	83	7.0	11.1
12	88	99	11.0	11.1
13	85	91	6.0	11.1
14	81	88	7.0	11.1
15	91	91	0.0	11.1
16	77	80	3.0	11.1
17	83	82	-1.0	11.1
18	75	80	5.0	11.1
Mean value	80.77777778	87.55555556	6.8	11.1

Figure 59. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C2, P2, T4



	Physics C2,P2,T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	53	66	13.0	11.1
2	81	78	-3.0	11.1
3	37	39	2.0	11.1
4	59	66	7.0	11.1
5	75	95	20.0	11.1
6	43	56	13.0	11.1
7	28	21	-7.0	11.1
8	40	57	17.0	11.1
9	33	49	16.0	11.1
10	62	73	11.0	11.1
11	32	41	9.0	11.1
12	79	66	-13.0	11.1
13	28	39	11.0	11.1
14	70	60	-10.0	11.1
15	53	52	-1.0	11.1
16	100	98	-2.0	11.1
17	59	57	-2.0	11.1
18	30	70	40.0	11.1
19	30	53	23.0	11.1
20	55	48	-7.0	11.1
21	64	83	19.0	11.1
Mean value	52.9047619	60.33333333	7.4	11.1

Figure 60. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C2, P2, T4



	Physics - C2, T4, P2			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	97	100	3.0	11.1
2	84	99	15.0	11.1
3	88	96	8.0	11.1
4	69	77	8.0	11.1
5	70	84	14.0	11.1
6	68	86	18.0	11.1
7	80	91	11.0	11.1
8	92	84	-8.0	11.1
9	88	93	5.0	11.1
10	90	100	10.0	11.1
11	88	95	7.0	11.1
12	87	96	9.0	11.1
13	90	97	7.0	11.1
14	90	90	0.0	11.1
15	77	85	8.0	11.1
16	83	93	10.0	11.1
17	93	100	7.0	11.1
18	72	80	8.0	11.1
Mean value	83.66666667	91.44444444	7.8	11.1

Figure 61. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C2, P2, T4

The difference between the two values of improvements (observed and predicted impact factors) in the case of using C3, P3, T3 is around 0.01 and in the case of using C2, P2, T4 is around 0.04. This gives significant credibility to the CPT model as the predicted, and observed impact factors are very close to each other, as shown in Table 44 and Figure 62.

Subject: Physics / **Strategy**	**Number of trials**	**Mean observed impact factor.**	**Mean predicted impact factor**	**The difference between the means of observed and predicted impact factors**
C3, P3, T3	1	0.032	0.042	0.010
C2, P2, T4	3	0.073	0.110	0.040

Table 44. The difference between the means of predicted and observed impact factors.

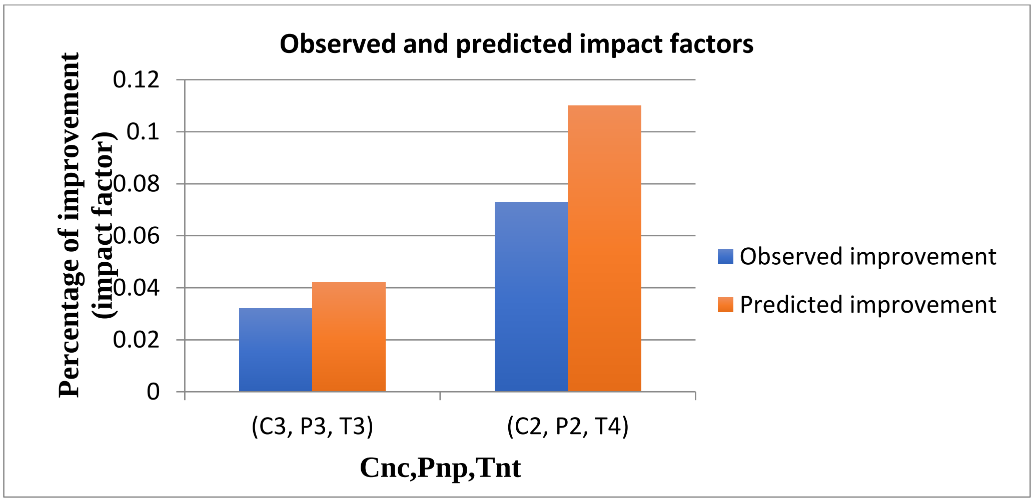


Figure 62. The means of observed and predicted impact factors.

The observed improvement in students' attainment in the case of using C2, P2, T4, was higher than the achieved improvement using C3, P3, T3, even though three pedagogies (direct teaching, collaborative learning and constructive learning) and three kinds of curriculum were applied in C3, P3, T3, while in the case of C2, P2, T4 two pedagogies were applied (direct teaching and collaborative learning). However, the percentage of digital technology integrated with the content in the case of C2, P2, T4 was higher than the digital technology integration in the case of C3, P3, T3, which might be the reason for achieving a greater improvement in the students' attainment in the case of C2, P2, T4 than the case of C3, P3, T3. This idea might lead one to conclude that the use of digital technology can have a stronger impact than pedagogy and the kind of curriculum. However, other reasons might also be considered, such as the content's level of difficulty between both cases.

Overall, it can be seen that the means of predicted and observed impact factors were close to each other, which implies that the CPT model is a valid and reliable tool as a predictive model for the improvement in students' attainment due to the use of educational technology.

Statistical Description

To enhance the validity of the data collected, each CPT strategy was trialled more than once, as demonstrated in Figure 58, Figure 59, Figure 60, Figure 61. Table 45 shows the means of observed and predicted impact factors and a statistical description for each CPT strategy used to teach physics in the third stage of this study.

Case #	Subject Cnc Pnp Tnt	The mean observed impact factor %	The mean predicted impact factor %	Tstat	T critical	(Cohen' s D) Effect size	Correlation factor (R)	P-value	ΣX^2
1	Physics using C2, P2, T4	6.80	11.1	3.63	2.10	0.930	0.670	0.001	$4.70*10^{-9}$
2	Physics using C2, P2, T4	7.80	11.1	2.45	2.10	0.869	0.769	0.025	$4.27X10^{-08}$
3	Physics using C3, P3 T3	3.20	4.20	1.28	2.09	0.700	0.670	0.210	$4.93*10^{-6}$
4	Physics using C2, P2, T4	7.40	11.1	1.29	2.08	0.364	0.785	0.210	$7.10X10^{-58}$

Table 45. The means of the observed and predicted impact factors and a statistical description of the CPT strategies that were used to teach physics.

The Chi-Square value was calculated in all cases and found to be less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies (improvements) is considered to be a good one (Kothari, 2004), as shown in Table 45, Figure 63, Figure 64, Figure 65 and Figure 66.

As shown in Table 45, the P-value was also calculated for all cases and found to be less than 0.05 in cases 1 and 2 and greater than 0.05 in cases 3 and 4, which implies that the null hypothesis can be rejected in the first two cases but cannot be rejected in the other two cases. The t-test: Paired Two Sample for means was also used to check the null hypothesis by checking the difference between the means of expected and observed improvement and gauging its significance. The statistical value of t-test was found greater than the critical value of t-test in cases 1 and 2 and less than the critical value in cases 3 and 4, which implies that the null hypothesis can be rejected in the first two cases but cannot be rejected in the other two cases.

Based on the outcomes of the statistical functions, and the fact that the means of expected and observed improvements are close to each other in all cases; the null hypothesis cannot be rejected. As such, there was no significant difference between the means of expected and observed impact factor (improvement).

Note: these calculations and the stated critical values were conducted using Microsoft® Excel 2016.

The correlation between students’ marks with regard to digital and nondigital technology-based learning has been checked through the Pearson correlation factor (r), as shown in Table 45, and the coefficient of determination (r^2) as shown in Figure 63, Figure 64, Figure 65 and Figure 66.

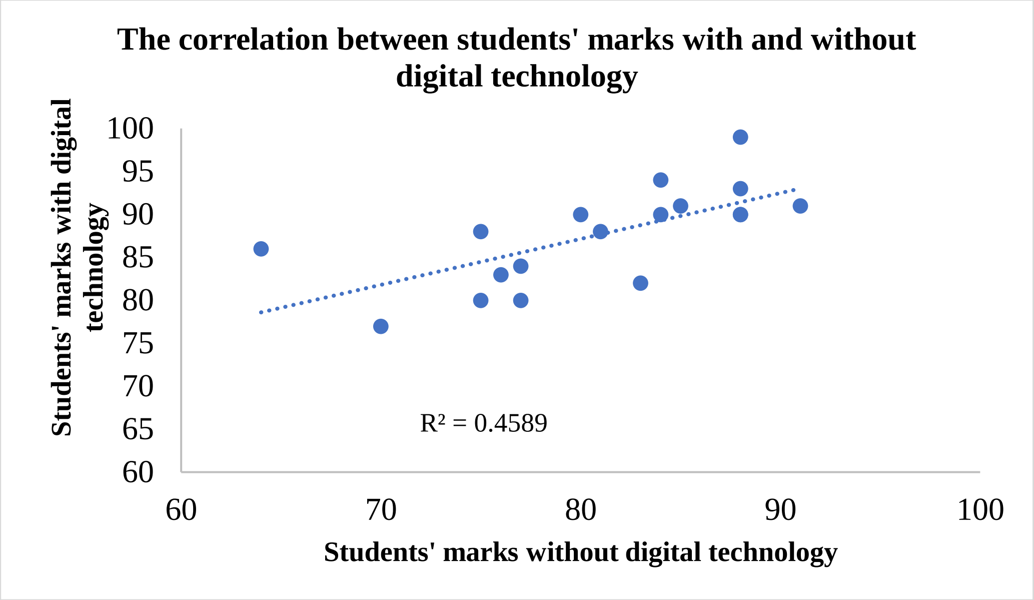


Figure 63. Students’ marks with regard to digital and nondigital technology-based learning: case # 1 (refer to Table 45).

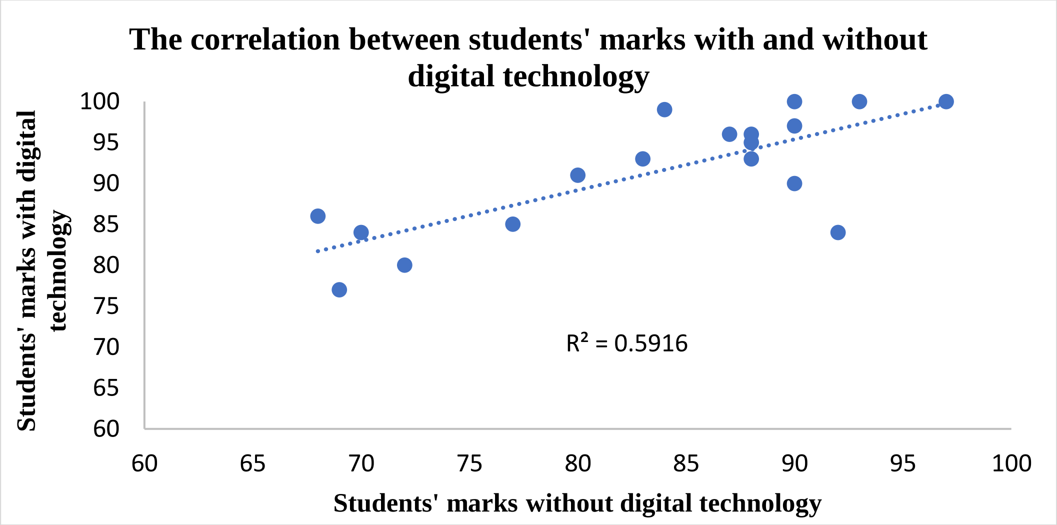


Figure 64. Students’ marks with regard to digital and nondigital technology-based learning: case # 2 (refer to Table 45).

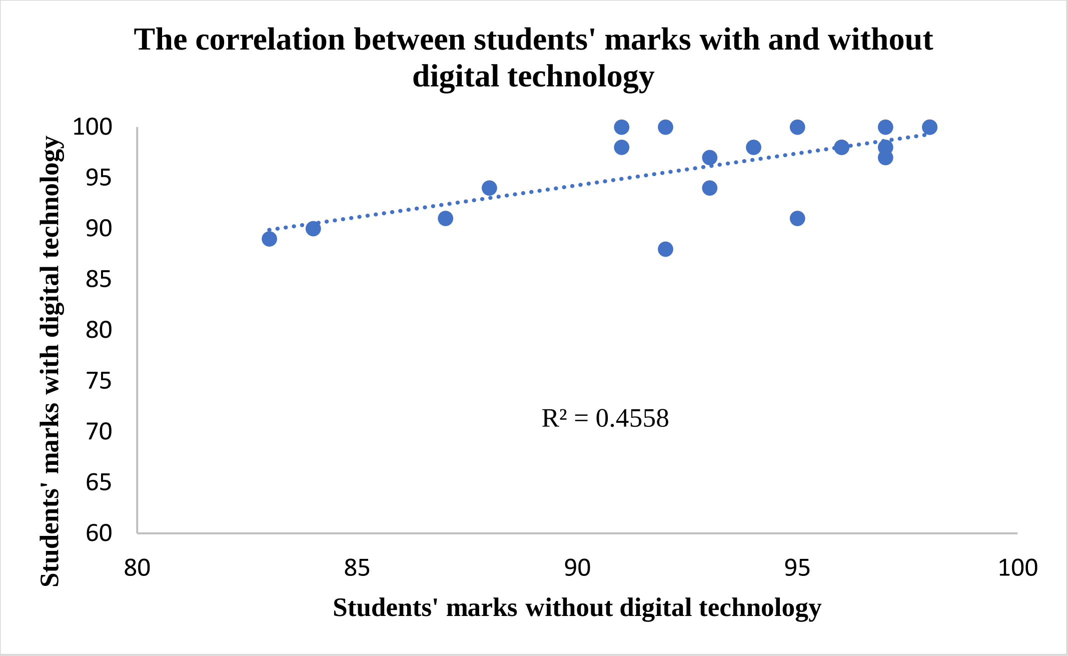


Figure 65. Students’ marks with regard to digital and nondigital technology-based learning: case # 3 (refer to Table 45).

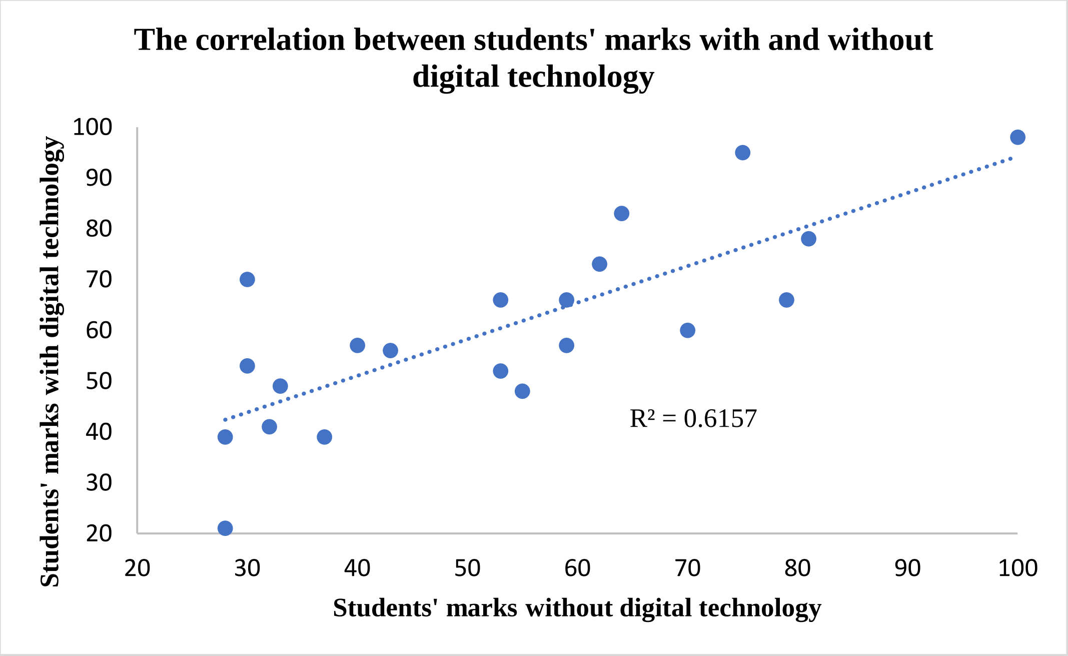


Figure 66. Students’ marks with regard to digital and nondigital technology-based learning: case # 4 (refer to Table 45).

As shown in Table 45, Figure 63, Figure 64, Figure 65 and Figure 66, the Pearson correlation factor (r) and the coefficient of determination (r^2) were calculated in all cases. The values of (r) were 0.67, 0.76, 0.67 and 0.78 for the cases 1 to 4, respectively, which indicate a moderate positive correlation between the use of educational technology and students' attainment. The values of the coefficient of determination (r^2) showed that in most of the cases that are shown in Table 45, approximately half of the data points fall on the regression line. Furthermore, the values of the effect size in the first three cases in Table 45 indicate a large effect, and a medium effect in the last case, of educational technology on students' attainment, which implies that educational technology and students' attainment are dependent variables. Based on the values of the Pearson correlation factor (r) and the effect size, it can be concluded that educational technology has a positive impact on students' attainment.

The CPT Calculations

C3, P3, T3 strategy meets the point (3, 3, 0.6) in the CPT space.

Hence, the predicted impact factor:

$$R = \sqrt{3^2 + 3^2 + 0.6^2} - \sqrt{3^2 + 3^2}$$

$$= 0.0422$$

The second form of Equation 8 (Equation 9 and Equation 10) can also be used to calculate the impact factor:

$$R = R_o (N)^2$$

$$\text{The threshold impact factor: } R_o = \sqrt{3^2 + 3^2 + 0.2^2} - \sqrt{3^2 + 3^2}$$

$$R_o = 0.0047$$

Sixty per cent of the content integrated with digital technology, the third level of integration. Hence, N= 3

Then

$$R= 0.0047 \times (3)^2$$

$$R = 0.042$$

Regarding the C2, P2, T4 strategy, it meets the point (2, 2, 0.8) in the CPT space.

$$\text{The impact factor (R)} = \sqrt{C2^2 + P2^2 + T4^2} - \sqrt{C2^2 + P2^2}$$

$$R = \sqrt{2^2 + 2^2 + 0.8^2} - \sqrt{2^2 + 2^2}$$

$$= 0.111$$

Alternatively, using the second form of Equation 8 (Equation 9 and Equation 10):

$$R = R_o (N)^2$$

$$R_o = \sqrt{2^2 + 2^2 + 0.2^2} - \sqrt{2^2 + 2^2}$$

$$R_o = 0.007$$

The level of digital technology integration (N) = 4

Then,

$$R = 0.007 \times (4)^2$$

$$R = 0.111$$

6.2.2.2 The Second Subject: Biology

Three different CPT strategies were applied to teach biology at this stage. The applied strategies were (**C3, P3, T3**)**,** (**C3, P3, T0**)**;** (**C3, P3, T4**)**,** (**C3, P3, T0**)**; and** (**C2, P2, T4**)**,** (**C2, P2, T0**).

The First and Second Strategies / C3, P3, T3; C3, P3, T4 (digital technology-based learning) and C3 P3 T0 (nondigital technology-based learning)

The content of the curriculum was delivered using the three approaches: theoretical, practical and interactive which is represented by the iBooks, simulation and physical interactive tools. Sixty per cent of the content was integrated with digital technology; students used a range of technology tools (software and hardware) to implement learning, such as a learning management system (D2L), iPad and laptop, resources and links were shared with students, and different applications were used such as Showbie and Kahoot.

Three Pedagogical dimensions were used to deliver the content: direct teaching, collaborative social learning and constructive learning. Students were asked to employ their current knowledge as well as the shared links and resources to build new knowledge they did not possess before, to develop models and draw conclusions. The same circumstances were applied to C3, P3, T4; the only difference was the percentage (amount) of the content integrated with digital technology, since in the case of C3, P3, T4, 80 % of the content was integrated with digital technology, i.e., 4 out of 5 learning objectives incorporated digital technology.

In the case of using C3, P3, T0 strategy (nondigital technology-based learning): curriculum was introduced by all three parts: i) theoretical content, was introduced using traditional tools such as board, hard copy of the textbook, ii) practical content, a related experiment was conducted, the collected data and notes were analysed manually using traditional tools such as a pen, notebook and hard copies of the textbook. No external resources were used by students, and iii) interactive content, which was represented by displaying images in hard copies (posters) and physical models or objects display, such as artificial physical models of the photosynthesis process so that students could interact with it physically. Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. Students were examined traditionally (paper-based exam), exams were marked, and the results were compared with the results that were gathered in the case of using digital technology.

The exact implementation of the C3, P3, T4 and C3, P3, T0 strategies is shown in Appendix 6 – Examples of Lesson Plans/ Implementation of the CPT Lessons, the 2nd example of lesson plans.

The Third Strategy / C2, P2, T4 and C2, P2, T0

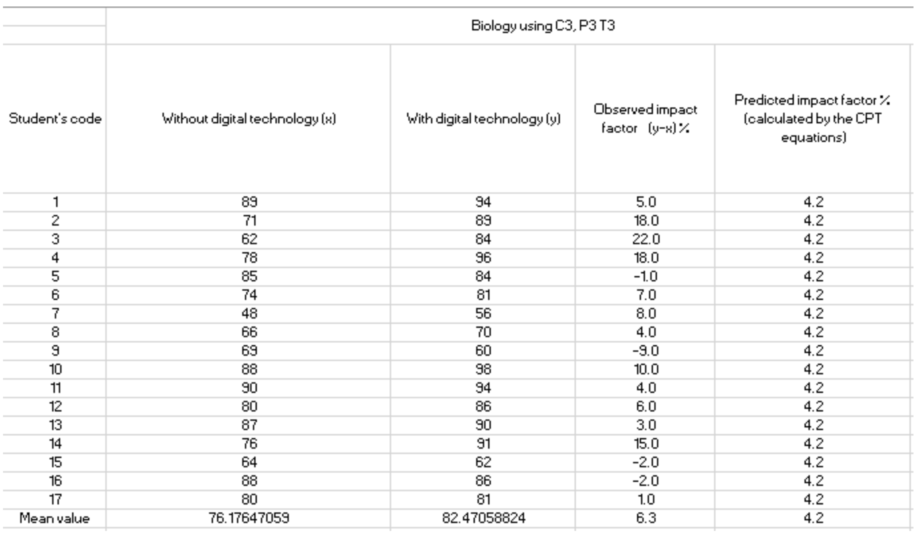
In the case of using the C2, P2, T4 strategy: two kinds of the curriculum were used: theoretical and interactive. Eighty per cent of the content was integrated with digital technology; two pedagogical dimensions were used to deliver the content: direct teaching and collaborative learning.

In the case of using C2, P2, T0 strategy (nondigital technology-based learning), two kinds of the curriculum were used: theoretical and interactive. Two pedagogical dimensions were applied to implement learning: direct teaching and collaborative learning were used to deliver the content. Students were examined, results were collected, compared with the digital technology-based learning results and analysed using MS® Excel.

The Predicted and Observed Impact Factors

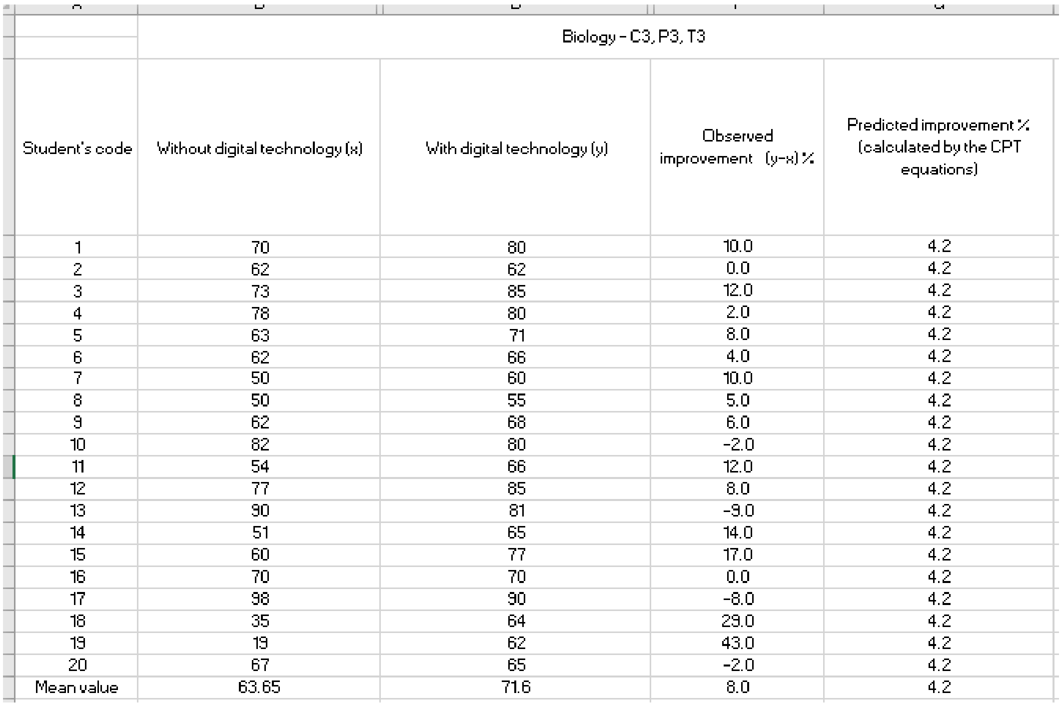
As shown in Figure 67 and Figure 68, the mean value of the observed impact factor in the case of using C3, P3, T3 was 0.072, and the mean predicted impact factor as calculated using the equations of the CPT model is equal to 0.042. However, as shown in Figure 69 and Figure 70 the mean observed impact factor using C3, P3, T4 was 0.071, and the mean predicted impact factor, based on the equations of the CPT model, was found to be 0.075. Finally, in the case of using C2, P2, T4 the mean value of the observed impact factor was 0.061, knowing that the mean value of the predicted impact factor based on the CPT model is 0.111, please refer to Figure 71. Based on these results, I concluded that the use of digital technology could improve students' learning and attainment in the biology subject. These findings agree with those of Haunsel and Hill (1989), Kubiatko and Halakova (2009), who assert that the use of digital technology to teach biology could improve students' level of knowledge and their attitudes towards learning biology.

Figure 67, Figure 68, Figure 69, Figure 70 and Figure 71 show students' marks without digital technology (pre-test) and with digital technology (post-test) as well as the mean values of the observed and predicted impact factors (improvements).



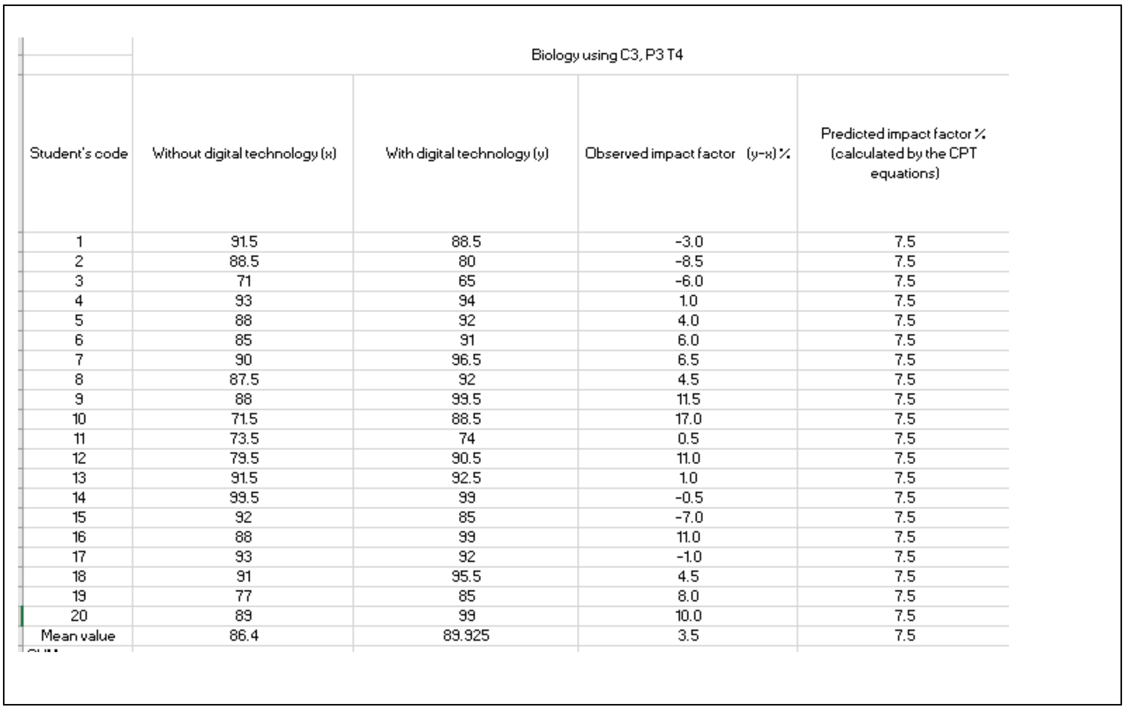
	Biology using C3, P3 T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	89	94	5.0	4.2
2	71	89	18.0	4.2
3	62	84	22.0	4.2
4	78	96	18.0	4.2
5	85	84	-1.0	4.2
6	74	81	7.0	4.2
7	48	56	8.0	4.2
8	66	70	4.0	4.2
9	69	60	-9.0	4.2
10	88	98	10.0	4.2
11	90	94	4.0	4.2
12	80	86	6.0	4.2
13	87	90	3.0	4.2
14	76	91	15.0	4.2
15	64	62	-2.0	4.2
16	88	86	-2.0	4.2
17	80	81	1.0	4.2
Mean value	76.17647059	82.47058824	6.3	4.2

Figure 67. Grade 10 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T3 to teach biology



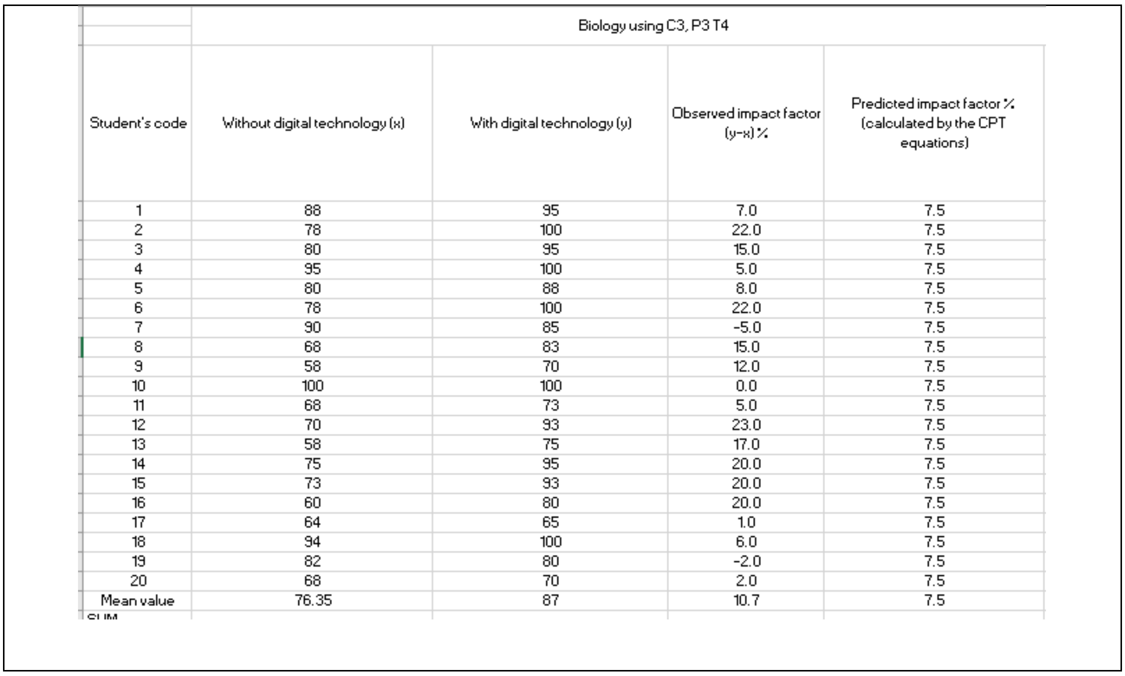
	Biology - C3, P3, T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed improvement (y-x) %	Predicted improvement % (calculated by the CPT equations)
1	70	80	10.0	4.2
2	62	62	0.0	4.2
3	73	85	12.0	4.2
4	78	80	2.0	4.2
5	63	71	8.0	4.2
6	62	66	4.0	4.2
7	50	60	10.0	4.2
8	50	55	5.0	4.2
9	62	68	6.0	4.2
10	82	80	-2.0	4.2
11	54	66	12.0	4.2
12	77	85	8.0	4.2
13	90	81	-9.0	4.2
14	51	65	14.0	4.2
15	60	77	17.0	4.2
16	70	70	0.0	4.2
17	98	90	-8.0	4.2
18	35	64	29.0	4.2
19	19	62	43.0	4.2
20	67	65	-2.0	4.2
Mean value	63.65	71.6	8.0	4.2

Figure 68. Grade 10 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T3 to teach biology



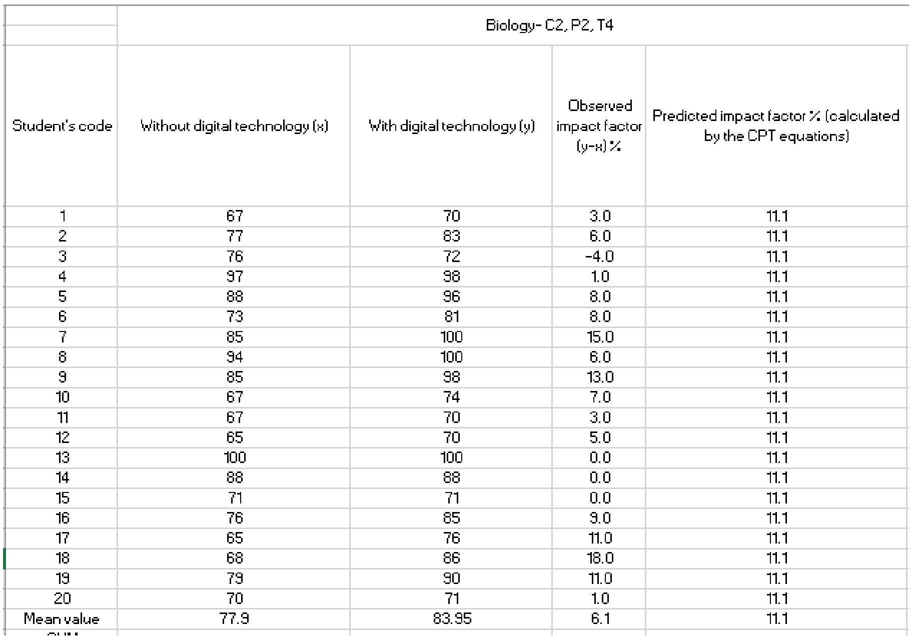
	Biology using C3, P3 T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	91.5	88.5	-3.0	7.5
2	88.5	80	-8.5	7.5
3	71	65	-6.0	7.5
4	93	94	1.0	7.5
5	88	92	4.0	7.5
6	85	91	6.0	7.5
7	90	96.5	6.5	7.5
8	87.5	92	4.5	7.5
9	88	99.5	11.5	7.5
10	71.5	88.5	17.0	7.5
11	73.5	74	0.5	7.5
12	79.5	90.5	11.0	7.5
13	91.5	92.5	1.0	7.5
14	99.5	99	-0.5	7.5
15	92	85	-7.0	7.5
16	88	99	11.0	7.5
17	93	92	-1.0	7.5
18	91	95.5	4.5	7.5
19	77	85	8.0	7.5
20	89	99	10.0	7.5
Mean value	86.4	89.925	3.5	7.5

Figure 69. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T4 to teach biology



	Biology using C3, P3 T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	88	95	7.0	7.5
2	78	100	22.0	7.5
3	80	95	15.0	7.5
4	95	100	5.0	7.5
5	80	88	8.0	7.5
6	78	100	22.0	7.5
7	90	85	-5.0	7.5
8	68	83	15.0	7.5
9	58	70	12.0	7.5
10	100	100	0.0	7.5
11	68	73	5.0	7.5
12	70	93	23.0	7.5
13	58	75	17.0	7.5
14	75	95	20.0	7.5
15	73	93	20.0	7.5
16	60	80	20.0	7.5
17	64	65	1.0	7.5
18	94	100	6.0	7.5
19	82	80	-2.0	7.5
20	68	70	2.0	7.5
Mean value	76.35	87	10.7	7.5

Figure 70. Grade 8 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T4 to teach biology



	Biology- C2, P2, T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	67	70	3.0	11.1
2	77	83	6.0	11.1
3	76	72	-4.0	11.1
4	97	98	1.0	11.1
5	88	96	8.0	11.1
6	73	81	8.0	11.1
7	85	100	15.0	11.1
8	94	100	6.0	11.1
9	85	98	13.0	11.1
10	67	74	7.0	11.1
11	67	70	3.0	11.1
12	65	70	5.0	11.1
13	100	100	0.0	11.1
14	88	88	0.0	11.1
15	71	71	0.0	11.1
16	76	85	9.0	11.1
17	65	76	11.0	11.1
18	68	86	18.0	11.1
19	79	90	11.0	11.1
20	70	71	1.0	11.1
Mean value	77.9	83.95	6.1	11.1

Figure 71. Grade 8 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C2, P2, T4 to teach biology

The difference in the compared values, predicted and observed impact factors, ranged from 0.004 in the case of C3, P3, T4 to 0.05 in the case of C2, P2, T4. Since the means of the predicted impact factors stayed within the same boundaries of the mean values of the observed impact factors and did not exceed the limitation of 0,05, that resulted in acknowledging the fact that there is no significant difference between the predicted and observed values. Thus, the null hypothesis can not be rejected, refer to Table 46 and Figure 72.

Subject: Biology **Strategy**	**Number of trials**	**Mean value of the observed impact factor**	**Mean value of the predicted impact factor**	**The difference between the means of observed and predicted impact factors**
C3, P3, T3	2	0.072	0.042	0.030
C3, P3, T4	2	0.071	0.075	0.004
C2, P2, T4	1	0.061	0.110	0.050

Table 46. The difference between the means of the predicted and observed impact factors.

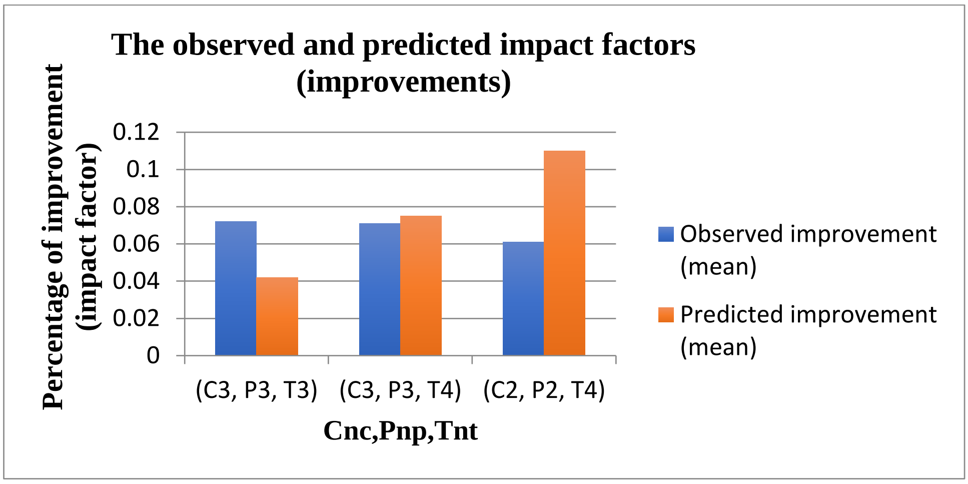


Figure 72. The difference between the observed and the predicted impact factors.

The observed impact factor was the highest in the case of using C3, P3, T3, while the lowest observed impact factor was found to be in the case of C2, P2, T4 even though according to the CPT model it should have been the highest. Furthermore, the difference between the observed and predicted impact factors was the lowest in the case of C3, P3, T4, i.e., the means of expected and observed improvements were the closest in the case of C3, P3, T4, as shown in Table 46. and Figure 72.

Overall, it can be seen that the means of the predicted and observed impact factors were very close to each other in two cases: C3, P3, T4 and C3, P3, T3. However, regarding the case of C2, P2, T4, the means were close to each other, but the difference between the means was slightly bigger than the difference made in the other two cases. Please refer to Table 46.

Statistical Description

To enhance the validity of the data collected, each CPT strategy was trialled more than once as demonstrated in Table 47, which shows the means of the observed and predicted impact factors and a statistical description for each CPT strategy used to teach biology.

Case #	Subject Cnc Pnp Tnt	The mean observed impact factor, %	The mean predicted impact factor, %	Tstat	T-critical	Effect size (Cohen' s D)	Correlation factor (R)	P-value	Σ X^2
1	Biology using C2, P2, T4	6.10	11.1	3.95	2.09	0.520	0.870	$8.00*10^{-4}$	$2.60*10^{-13}$
2	Biology using C3, P3 T4	10.7	7.50	1.56	2.09	0.810	0.720	0.130	$1.10*10^{-38}$
3	Biology using C3, P3 T4	3.50	7.50	2.60	2.09	0.421	0.670	0.017	$3.07*10^{-24}$
4	Biology using C3, P3, T3	6.30	4.20	1.05	2.11	0.500	0.780	0.310	$1.33*10^{-49}$
5	Biology using C3, P3, T3	8.00	4.20	1.39	2.09	0.530	0.780	0.180	$2.49*10^{-141}$

Table 47. The means of the predicted and observed impact factors and a statistical description of the CPT strategies that were used to teach biology.

The Chi-Square value was calculated in all cases and found to be less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies (the expected and observed improvements) is considered to be a good one (Kothari, 2004). This can be seen in Table 47, Figure 73, Figure 74, Figure 75, Figure 76 and Figure 77.

As shown in Table 47, the P-value was also calculated for all cases. In cases 1 and 3 it was found to be less than 0.05 and in cases 2, 4 and 5 greater than 0.05, which implies that the null hypothesis can be rejected in cases 1 and 3 but cannot be rejected in cases 2, 4 and 5. The t-test: Paired Two Sample for means was also used to check the null hypothesis. The statistical value of the t-test was found to be higher than the critical value of the t-test in cases 1 and 3, and less than the critical value of t-test in cases 2, 4 and 5, hence, the null hypothesis can be rejected in cases 1 and 3 and cannot be rejected in cases 2, 4 and 5.

As shown in Table 47, the Pearson correlation factor (r) was calculated in all cases; the values of (r) were 0.87, 0.72, 0.67, 0.78 and 0.78 for the cases 1 to 5 respectively. These results indicate a moderate positive correlation between the use of educational technology and students' attainment (dependent variables). Furthermore, the values of the effect size in all of the cases, which are shown in Table 47, indicate a medium and large effect of educational technology on students' attainment (dependent variables). The values of the Pearson correlation factor and effect size suggest the positive impact of educational technology on students' attainment.

Note: these calculations and the stated critical values were determined using Microsoft® Excel 2016.

The correlation between students' marks with regard to digital and nondigital technology-based learning has been checked through the Pearson correlation factor (r), and the coefficient of determination (r^2), as shown in Table 47, Figure 73, Figure 74, Figure 75, Figure 76 and Figure 77.

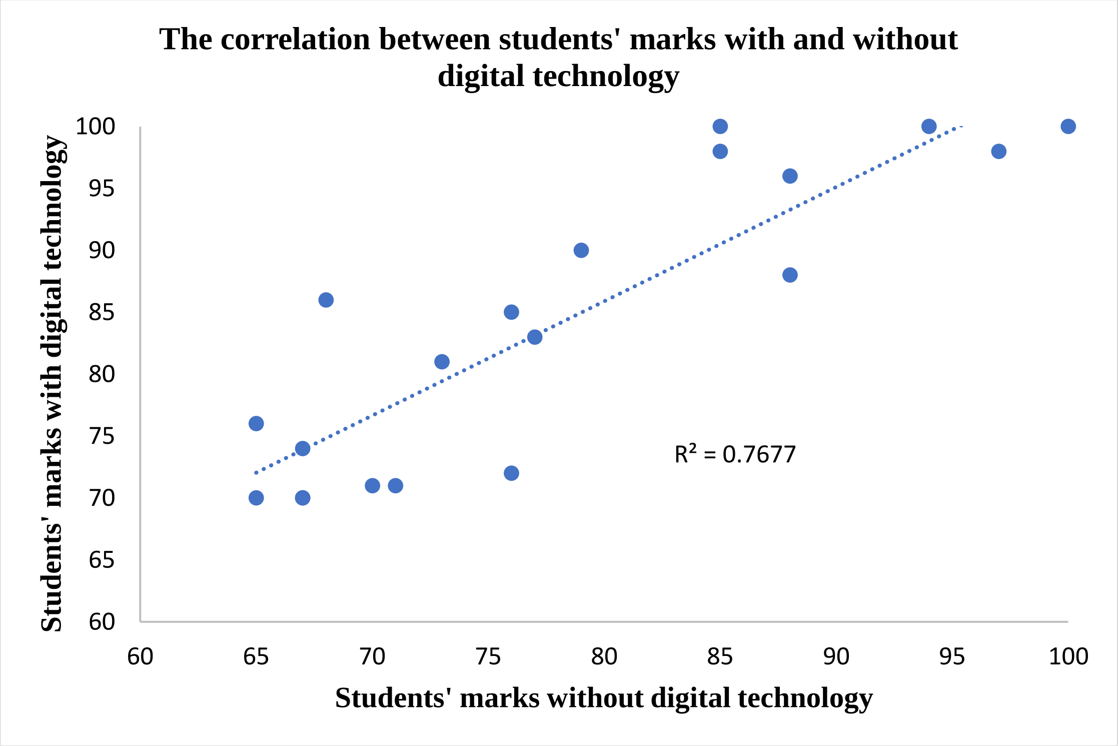


Figure 73. Students' marks with regard to digital and nondigital technology-based learning: case # 1 in Table 47.

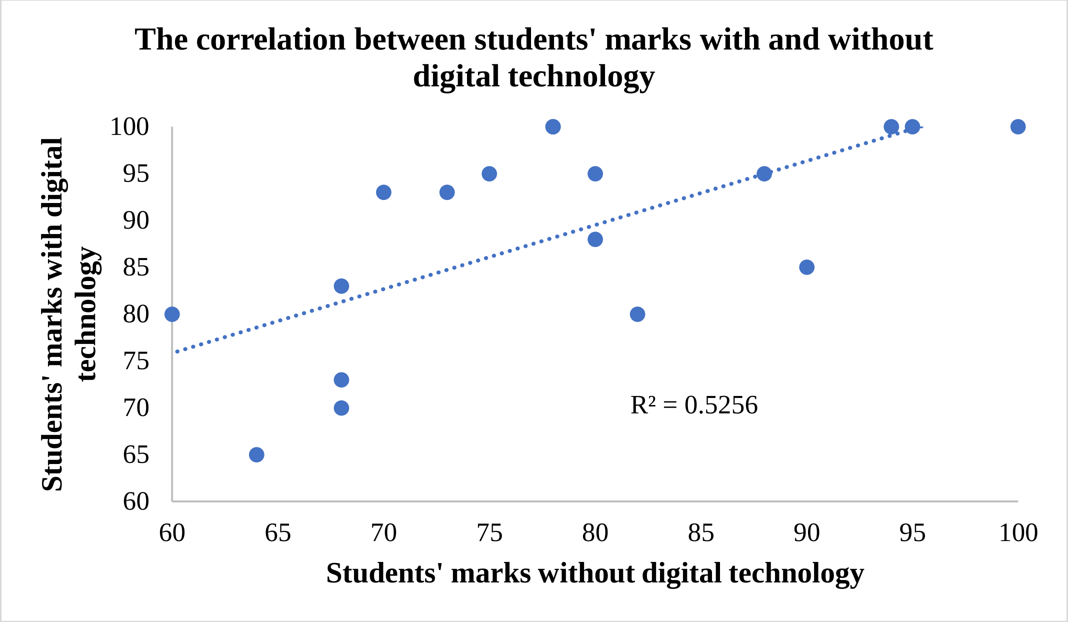


Figure 74. Students’ marks with regard to digital and nondigital technology-based learning: case # 2 in Table 47.

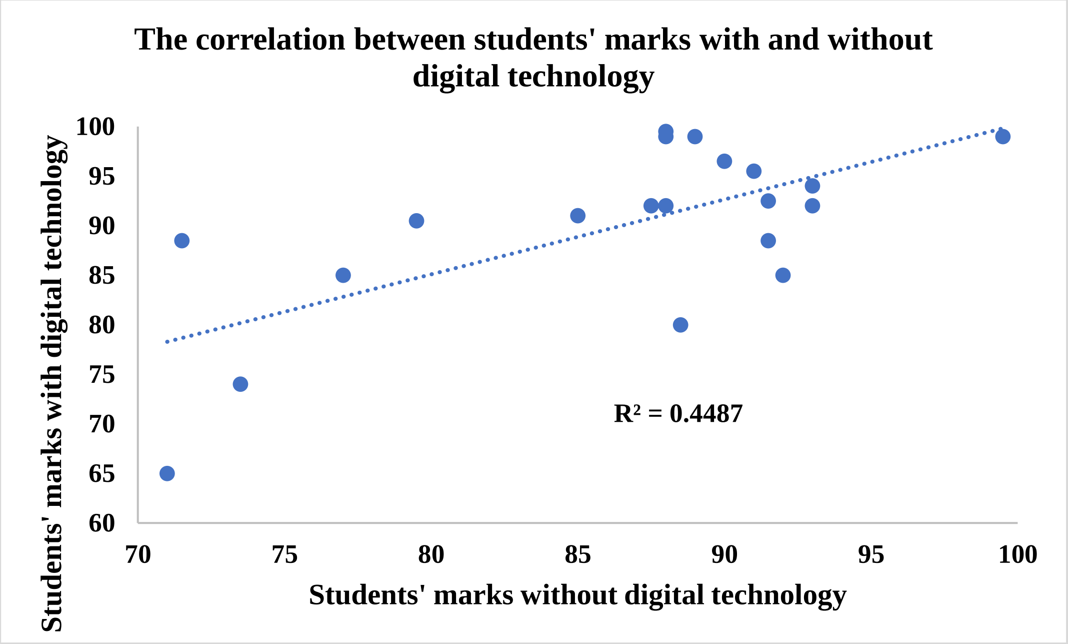


Figure 75. Students’ marks with regard to digital and nondigital technology-based learning: case # 3 in Table 47.

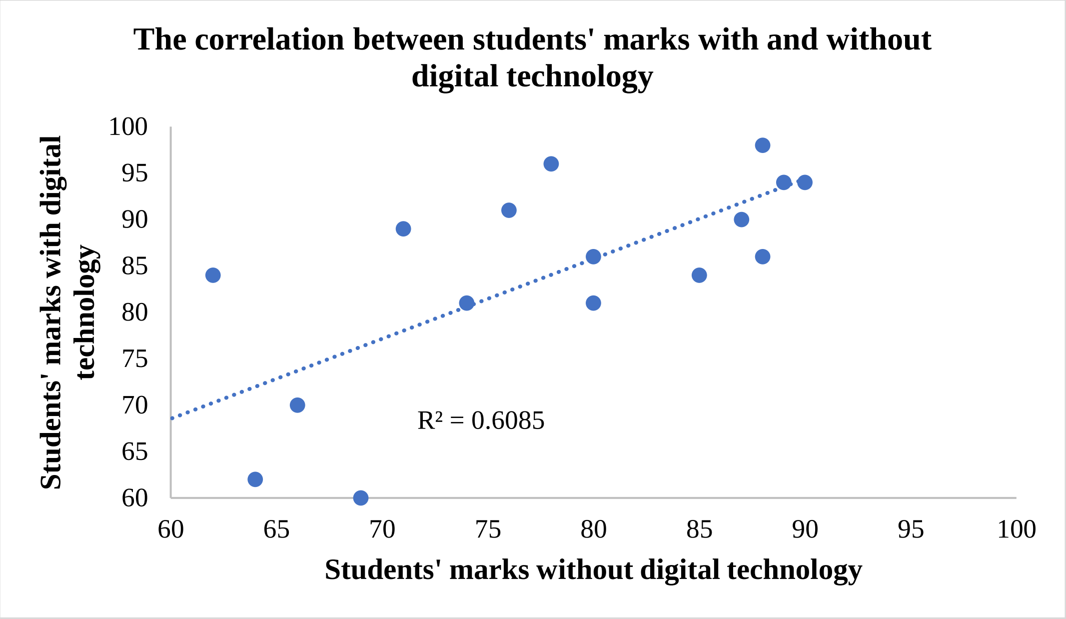


Figure 76. Students' marks with regard to digital and nondigital technology-based learning: case # 4 in Table 47.

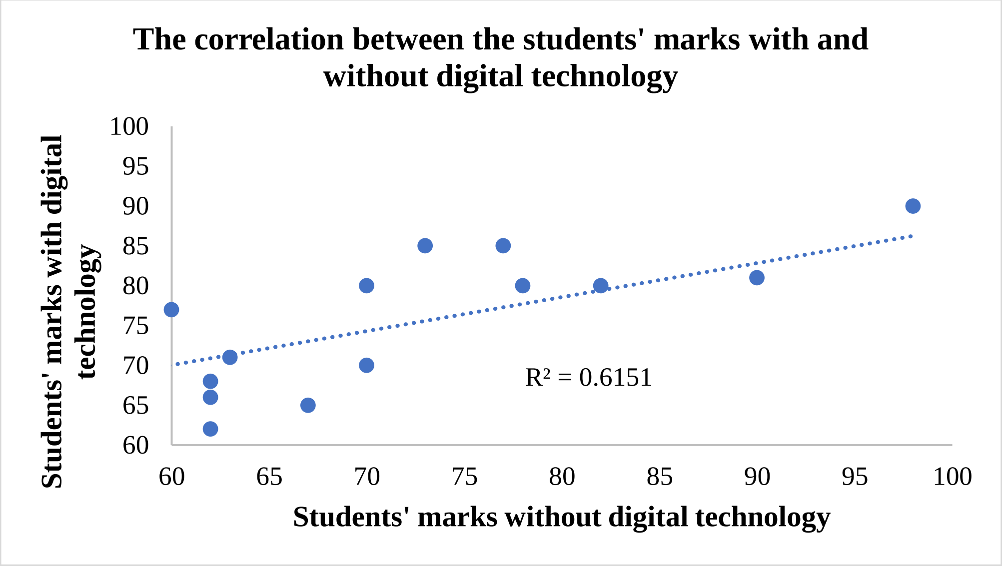


Figure 77. Students' marks with regard to digital and nondigital technology-based learning: case # 5 in Table 47.

As shown in Figure 73, Figure 74, Figure 75, Figure 76 and Figure 77, the values of the coefficient of determination (r^2) were calculated in all cases and found to be 0.76, 0.52, 0.45, 0.60 and 0.61 respectively for the cases 1 to 5 that were conducted to teach biology. This means that in most of the cases, more than half of the data points fall on the regression line, which suggests that educational technology and students' attainment are dependent variables.

Based on the outcomes of the applied statistical functions and the means of predicted and observed impact factors in all cases, the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of expected and observed improvements.

6.2.2.3 The Third Subject: Mathematics

Three different CPT strategies were applied to teach mathematics in this stage: **C3, P3, T3; C3, P3, T0; C3, P3, T4; C3, P3, T0; and C2, P2, T4; C2, P2, T0**.

The First and Second Strategies / C3, P3, T3; C3, P3, T4 (digital technology-based learning) and C3 P3 T0 (nondigital technology-based learning)

During the C3, P3, T3 strategy, digital technology-based learning, three kinds of the curriculum were used: theoretical, practical and interactive represented by simulations, videos and physical interactive tools. Bransford et al. (2000) and Grayson and McDermott (1996) claimed that interactive tools, such as simulations could be considered as a powerful resource for the application of mathematics and science as they contributed to improving students' understanding in several areas of physics and branches of mathematics, including kinematics, geometry and optics.

Sixty per cent of the content was integrated with digital technology, and three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. Students were examined, and results recorded. The same circumstances were applied to C3, P3, T4; the only difference being in the percentage of digital technology integration with the content.

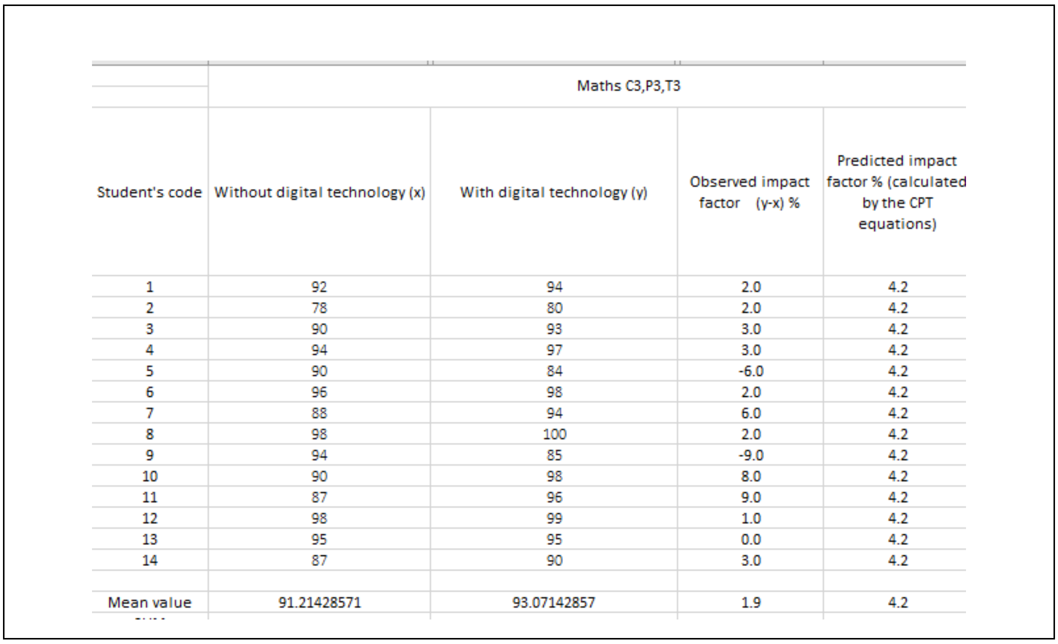
Regarding the nondigital technology-based learning scenario, C3, P3, T0 strategy, the curriculum was presented using all three methods: theoretical, practical and interactive. Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. Students were examined traditionally (paper-based exam), exams were marked, and the results were compared with the results that were collected by applying digital technology-based learning.

The Third Strategy / C2, P2, T4 and C2, P2, T0

During the C2, P2, T4 strategy, digital technology-based learning, two kinds of the curriculum were used theoretical and practical. Eighty per cent of the content was integrated with digital technology, and two pedagogical dimensions were used to deliver the content: direct teaching and collaborative learning. The same pedagogical dimensions were used in the C2, P2, T0 strategy (nondigital technology-based learning), the content was introduced using two kinds of curriculum: theoretical and practical.

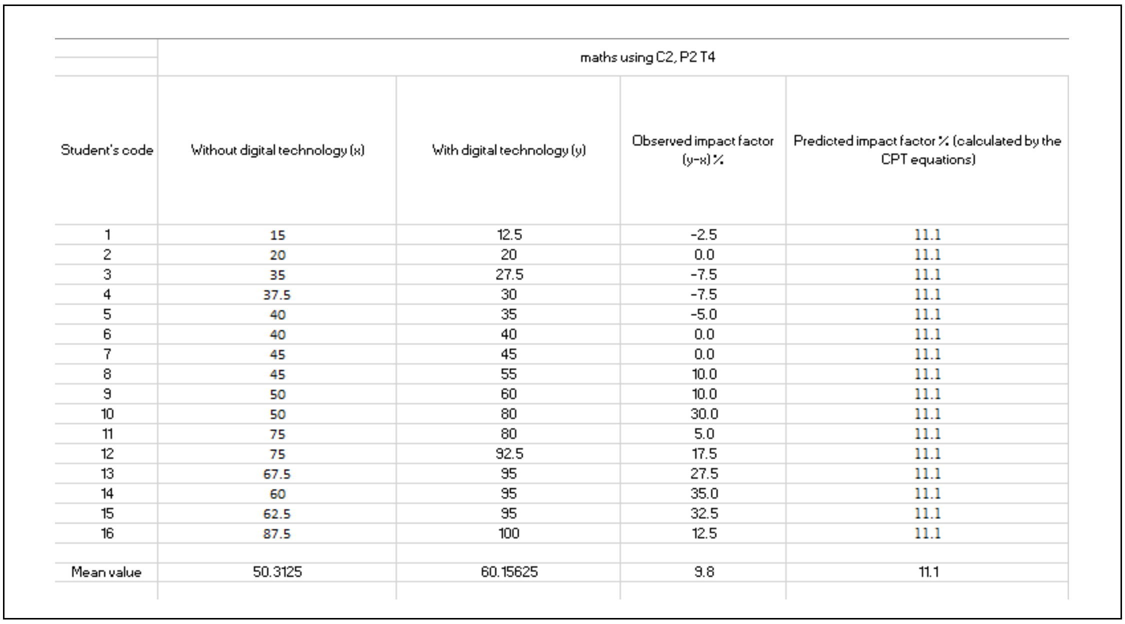
The Predicted and Observed Impact Factors

As shown in Figure 78, the mean observed impact factor while using C3, P3, T3 was 0.019, and the mean predicted impact factor, as calculated using the equations of the CPT model, is equal to 0.0422. The difference between the two values of impact factors is equal to 0.023. On the other hand, in the case of using C2, P2, T4 the mean value of the observed impact factor was 0.098, and the mean predicted impact factor based on the CPT model is 0.111, making a difference between the two values of improvements of 0.012, refer to Figure 79. Finally, as shown in Figure 80, the mean observed impact factor while using C3, P3, T4 was 0.047, and the mean predicted impact factor, as calculated from the equations of the CPT model, was 0.075, which results in a difference of 0,028 between the predicted and the observed impact factors.



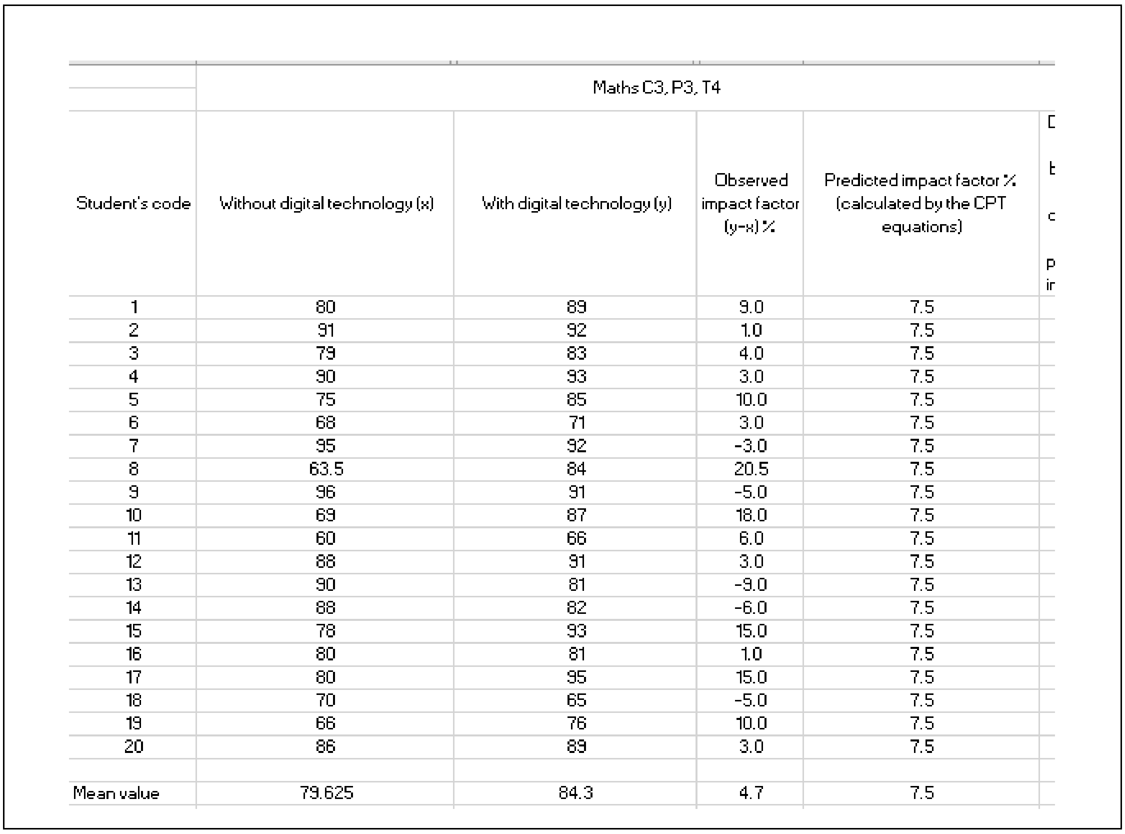
	Maths C3,P3,T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	92	94	2.0	4.2
2	78	80	2.0	4.2
3	90	93	3.0	4.2
4	94	97	3.0	4.2
5	90	84	-6.0	4.2
6	96	98	2.0	4.2
7	88	94	6.0	4.2
8	98	100	2.0	4.2
9	94	85	-9.0	4.2
10	90	98	8.0	4.2
11	87	96	9.0	4.2
12	98	99	1.0	4.2
13	95	95	0.0	4.2
14	87	90	3.0	4.2
Mean value	91.21428571	93.07142857	1.9	4.2

Figure 78. Grade 10 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T3 to teach mathematics



	maths using C2, P2 T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	15	12.5	-2.5	11.1
2	20	20	0.0	11.1
3	35	27.5	-7.5	11.1
4	37.5	30	-7.5	11.1
5	40	35	-5.0	11.1
6	40	40	0.0	11.1
7	45	45	0.0	11.1
8	45	55	10.0	11.1
9	50	60	10.0	11.1
10	50	80	30.0	11.1
11	75	80	5.0	11.1
12	75	92.5	17.5	11.1
13	67.5	95	27.5	11.1
14	60	95	35.0	11.1
15	62.5	95	32.5	11.1
16	87.5	100	12.5	11.1
Mean value	50.3125	60.15625	9.8	11.1

Figure 79. Grade 9 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C2, P2, T4 to teach mathematics



	Maths C3, P3, T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	80	89	9.0	7.5
2	91	92	1.0	7.5
3	79	83	4.0	7.5
4	90	93	3.0	7.5
5	75	85	10.0	7.5
6	68	71	3.0	7.5
7	95	92	-3.0	7.5
8	63.5	84	20.5	7.5
9	96	91	-5.0	7.5
10	69	87	18.0	7.5
11	60	66	6.0	7.5
12	88	91	3.0	7.5
13	90	81	-9.0	7.5
14	88	82	-6.0	7.5
15	78	93	15.0	7.5
16	80	81	1.0	7.5
17	80	95	15.0	7.5
18	70	65	-5.0	7.5
19	66	76	10.0	7.5
20	86	89	3.0	7.5
Mean value	79.625	84.3	4.7	7.5

Figure 80. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T4 to teach mathematics

The means of the predicted and observed impact factors stayed within the same boundaries as the differences between the two values (observed and predicted) in the three cases ranged from 0.012 and did not exceed 0.028. This gives credibility to the CPT model as a predictive model for the improvement in students' attainment. Please refer to Table 48 and Figure 81.

Based on the collected data shown in Table 48, the researcher would claim that the use of digital technology could improve students' learning and attainments in mathematics. This claim can be supported by the findings of Kaput et al. (2008), who demonstrated in their study that educational technology improves students' abilities to learn mathematics by offering them extra resources of knowledge that improve their critical thinking.

Mathematics / **Strategy**	**Number of trials**	**Mean observed impact factor.**	**Mean predicted impact factor**	**The difference between the means of observed and predicted impact factors**
C3, P3, T3	1	0.019	0.042	0.023
C3, P3, T4	1	0.047	0.075	0.028
C2, P2, T4	1	0.098	0.110	0.012

Table 48. The difference between the means of predicted and observed impact factors.

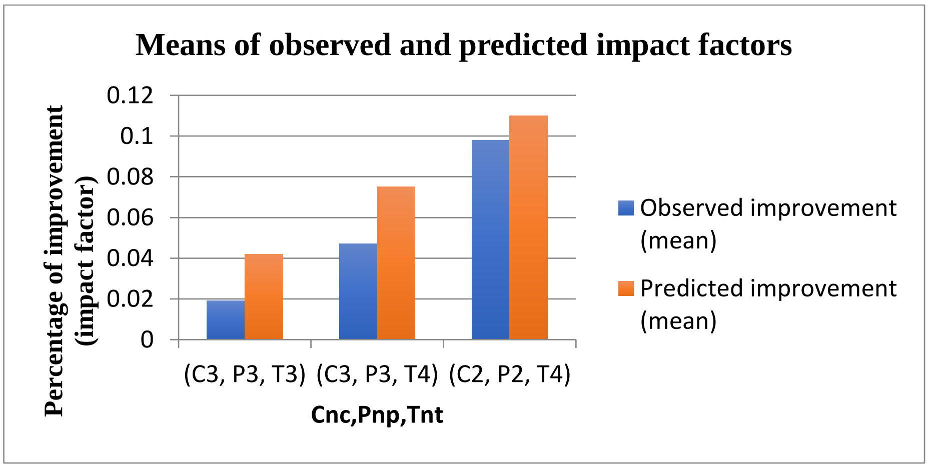


Figure 81. The difference between the means of observed and predicted impact factors.

As shown in Table 48 and Figure 81, the mean observed impact factor in the students' attainment was the highest in the case of using C2, P2, T4. Furthermore, the observed and predicted impact factors were the closest when the C2, P2, T4 strategy was applied.

Based on the collected data, the C2, P2, T4 strategy appears to be an effective technique in the case of teaching mathematics and physics as it achieved the best learning outcomes and greatest observed improvement in students' attainment. This contrasts with the case of teaching biology using the same strategy (C2, P2, T4), as it gave the lowest observed improvement. Please refer to Table 44, Table 46 and Table 48.

With regard to the C3, P3, T3 and C3, P3, T4 strategies, the observed and expected improvements were close to each other as well. However, it can be seen in Table 48 that using C3, P3, T3 to teach mathematics did not reach expectation. The observed improvement was 0.019 or 1.9%, which is a small improvement when it is compared with the improvements made by other strategies, refer to Table 48. Hence, the researcher claims that this strategy did not work well with mathematics.

In general, the expected and observed improvement values were close to each other in all tested strategies that were employed to teach mathematics, especially in the case of C2, P2, T4. This means that the CPT model could predict the improvement in students' attainment, which gives credibility to the CPT model and its equations.

Statistical Description

Table 49 shows the observed and predicted impact factors and provides a statistical description for each CPT strategy used to teach mathematics.

Case #	Subject Cnc Pnp Tnt	The mean observed impact factor, %	The mean predicted impact factor, %	Tstat	T-critical	Effect size (Cohen’ s D)	Correlation factor (R)	P-value	ΣX^2
1	Maths using C2, P2, T4	9.80	11.1	0.340	1.75	0.380	0.920	0.730	$2.31 * 10^{-53}$
2	Maths using C3, P3 T4	4.70	7.50	1.520	2.09	0.464	0.663	0.140	$3.10*10^{-31}$
3	Maths using C3, P3, T3	1.90	4.20	1.84	2.16	0.320	0.665	0.090	$3.04*10^{-13}$

Table 49. The means of the expected and observed improvements and a statistical description of the CPT strategies that were conducted to teach mathematics.

The Chi-Square value was calculated in all cases and found to be less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies (improvements) is considered to be a good one (Kothari, 2004). This can be seen clearly in Table 49, Figure 82, Figure 83 and Figure 84. Thus, the null hypothesis cannot be rejected, i.e., there was no significant difference between the means of the expected and observed improvements.

The P-value was also calculated for all cases and found to be in every instance greater than 0.05. The t-test: Paired Two Sample for Means was also used to check the null hypothesis; the statistical value of t-test was found to be in all cases less than the critical value of the t-test. Based on the P-value and the t-test, the researcher claims that the null hypothesis cannot be rejected.

As shown in Table 49, the Pearson correlation factor (r) was calculated in all cases; the values of (r) were 0.92, 0.66 and 0.67 for cases 1 to 3, respectively. These values indicate a strong (case 1) and moderate (cases 2 and 3) positive correlation between the use of educational technology and students’ attainment, so these two variables can be considered as dependent variables. Furthermore, the values of the effect size in all cases shown in Table 49 indicate a medium effect of educational technology on students’ attainment.

Note: these calculations and the stated critical values were determined using

Microsoft® Excel 2016.

Figure 82, Figure 83, and Figure 84 show the correlation between the students' marks with and without using digital technology, i.e., how these marks fit with each other. The values of the coefficient of determination (r^2) were calculated in all cases and found to be 0.84, 0.43 and 0.44 for the cases 1 to 3, respectively, which were conducted to teach mathematics. This indicates that 84 % of the points in the first case, and approximately 50% of the points in cases 2 and 3, fall on the regression line, which represents the relationship between students' marks with and without using digital technology.

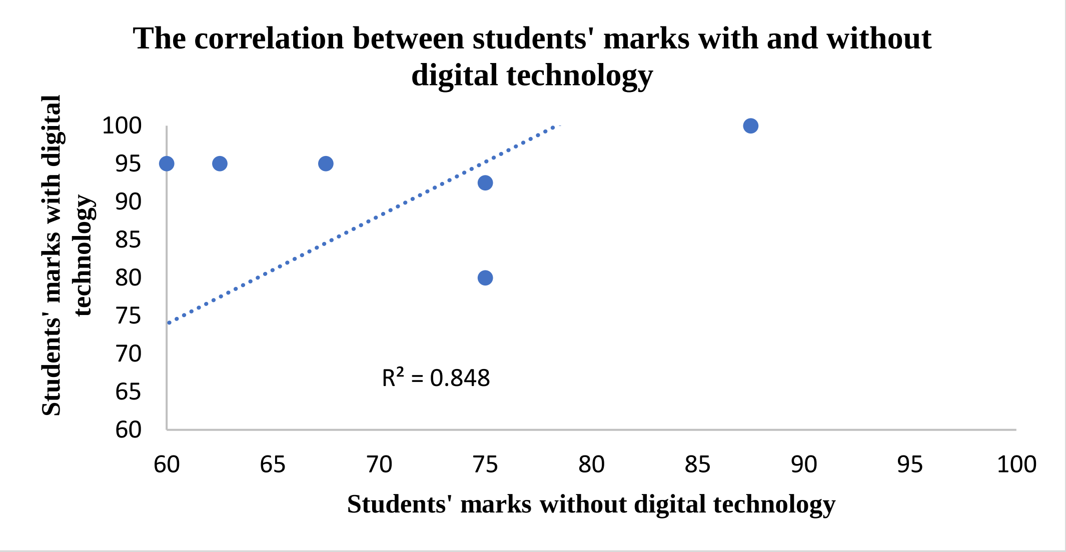


Figure 82. Students' marks with regard to digital and nondigital technology-based learning: case # 1 in Table 49.

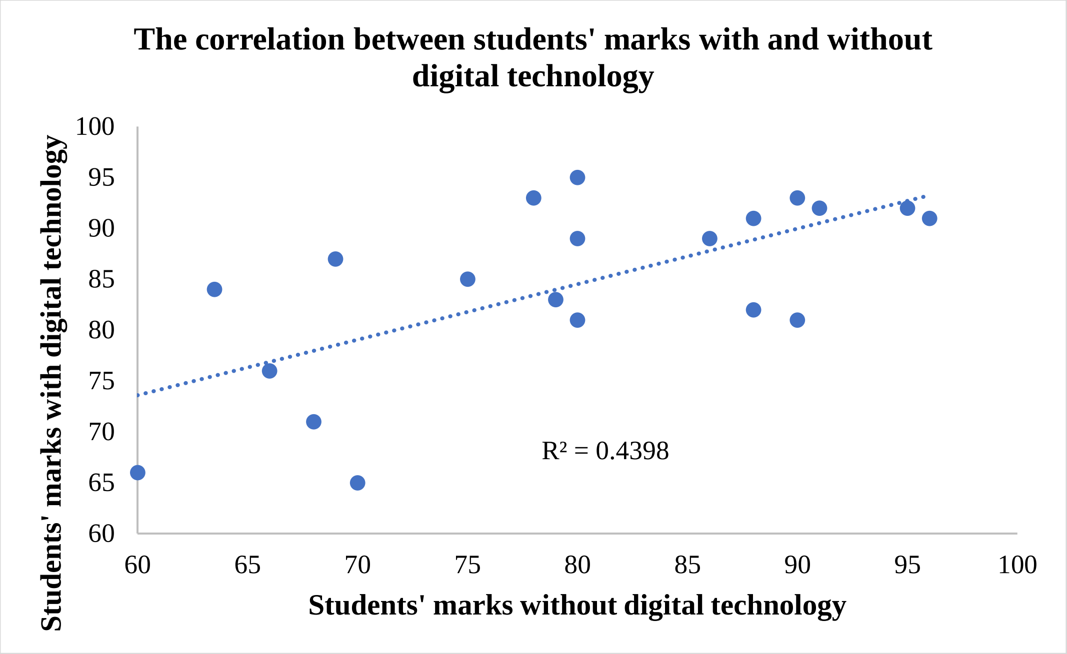


Figure 83. Students' marks with regard to digital and nondigital technology-based learning: case # 2 in Table 49.

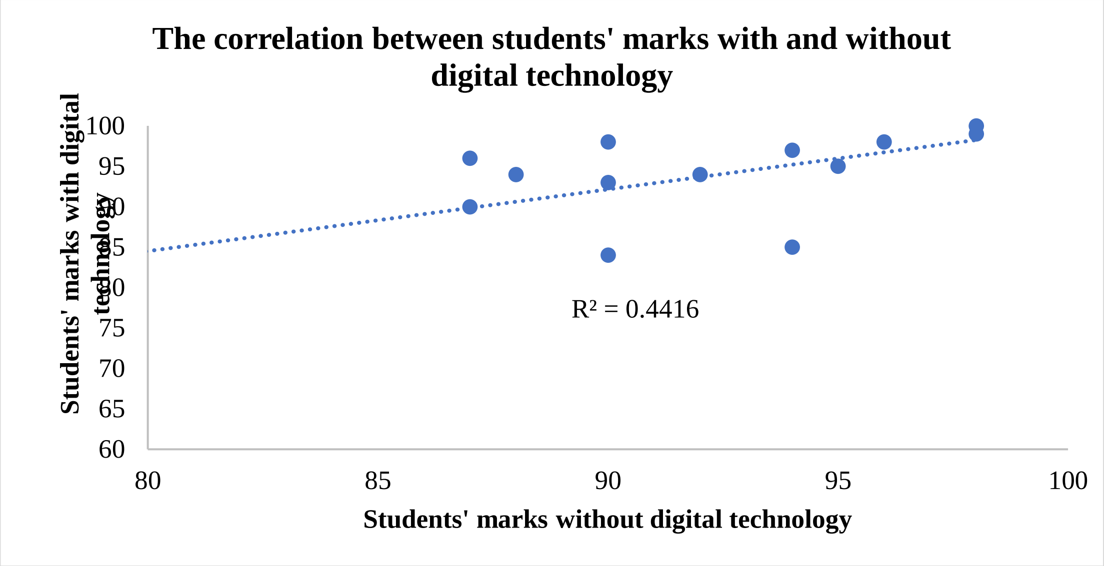


Figure 84. Students' marks with regard to digital and nondigital technology-based learning: case # 3 in Table 49.

Based on the outcomes of the applied statistical functions, the researcher would suggest that the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of predicted and observed impact factors.

Thus, the CPT model is to be considered as a valid tool to predict the improvement in students’ attainment as an outcome of using educational technology.

6.2.3 Comparison of the Tested Science Subjects: Physics, Mathematics and Biology

The C3, P3, T3 strategy was used in physics, mathematics and biology. As shown in Table 50 and Figure 85, the mean value of the observed impact factor was the highest when the C3, P3, T3 strategy was applied to teach biology, then physics and finally the mathematics.

Biology and physics rely substantially on real-life applications, unlike mathematics. Thus, students’ level of understanding can be improved by connecting the theoretical knowledge in topics such as biology and physics with real-life applications (Musasia, 2016). The practical work in the laboratories and simulations as part of the interactive curriculum can help students to grasp and visualise the taught concepts more (Adegoke & Chukwunenye, 2013). "Experimental work in the sciences especially in Physics, Chemistry and Biology is very important and a basic requirement in secondary school learning of sciences" (Adegoke & Chukwunenye, 2013, p. 19) in contrast to the mathematics which is based mainly on abstract, blur and blind variables that which might be more challenging to link to real-life applications.

Table 50 and Figure 85 show the mean values of the predicted and observed impact factors when using C3, P3, T3 to teach physics, mathematics and biology.

Strategy / C3, P3, T3 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Physics	0.042	0.032
Mathematics	0.042	0.019
Biology	0.042	0.072

Table 50. The mean values of the predicted and observed impact factors (improvement in students’ attainment) in the case of using C3, P3, T3.

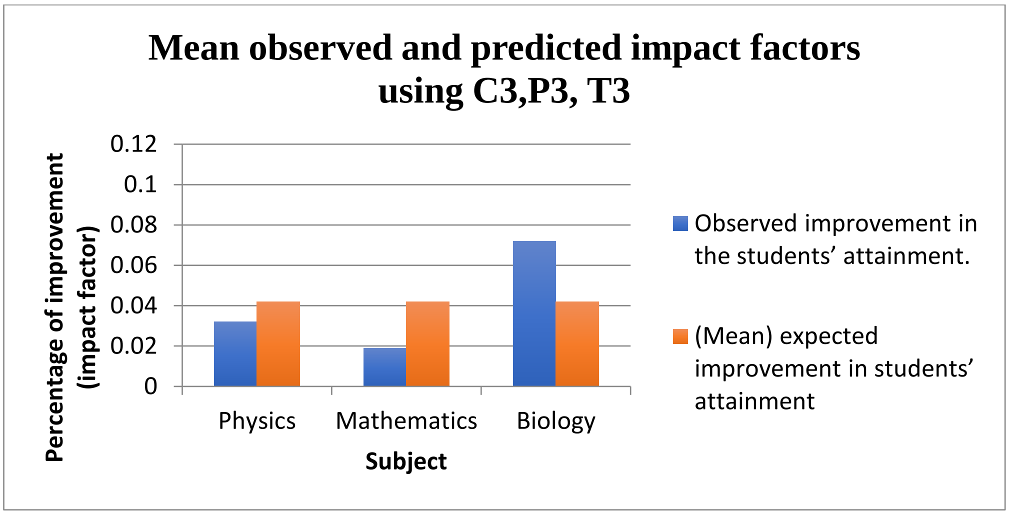


Figure 85. The mean values of the predicted and observed impact factors (improvement in students' attainment) in the case of using C3, P3, T3.

As shown in Table 50 and Figure 85, the observed improvement in students' attainment was the highest when using the C3, P3, T3 strategy to teach biology, while the lowest observed improvement was found to be in the case of mathematics using the same strategy. However, the difference between the observed and predicted improvements was the lowest in the case of physics, i.e. the means of predicted and observed impact factors were the closest in the case of physics.

The C2, P2, T4 strategy was used to teach physics, mathematics and biology. As shown in Table 51 and Figure 86, the mean value of the observed improvement was the highest when C2, P2, T4 was applied to teach mathematics, followed by physics and then biology. This result seems to contradict the previous one as the observed improvement was the highest in the case of mathematics in contrast to the situation when C3, P3, T3 was applied to teach the same subjects. However, the range of observed improvements for physics and biology stayed within the same boundaries (refer to Table 51).

As shown in Table 51, there was a dramatic increase in students' improvement when using C2, P2, T4 to teach mathematics, as it was the highest value of improvement, which would suggest that digital technology-based learning using the C2, P2, T4 strategy, works well with mathematics since 80 % of the content was integrated with digital technology in this strategy.

The significant increase in students' attainment when using C2, P2, T4 to teach mathematics might be influenced by other factors, such as the content's level of complexity or the students' cognitive development and attitudes towards learning. However, these additional factors are not the subject of this study, as the researcher's main focus remains on the role of the three main factors: content, pedagogy and digital technology in improving students' attainment.

Table 51 and Figure 86, show that the means of the observed and predicted impact factors, in the case of C2, P2, T4 strategy.

Strategy/ C2, P2, T4 **Subject**	**Mean value of the predicted impact factor**	**Mean value of the observed impact factor**
Physics	0.110	0.073
Mathematics	0.110	0.098
Biology	0.110	0.061

Table 51. The mean values of the predicted and observed impact factors in the case of using C2, P2, T4.

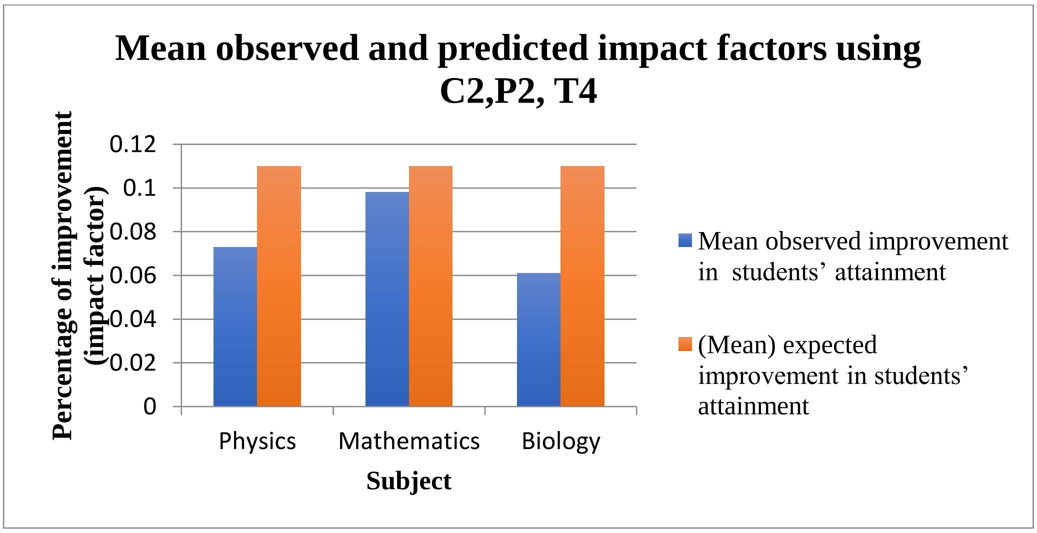


Figure 86. The mean values of the predicted and observed impact factors in the case of using C2, P2, T4.

With regard to the third strategy C3, P3, T4, it was used in mathematics and biology. As shown in Table 52 and Figure 87, the mean value of the observed improvement was higher when C3, P3, T4 was applied to biology than the case of mathematics. The observed improvement was very close to the expected one in the case of biology as the difference between the two values of improvement was 0.004, which can be negligible. Unlike the case of mathematics, where the gap between the observed and the expected improvement was 0.028, which, though not extensive, can still be considered significant, i.e., it cannot be neglected.

Strategy/ C3, P3, T4 / **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Mathematics	0.075	0.047
Biology	0.075	0.071

Table 52. The mean values of the predicted and observed impact factors in the case of using C3, P3, T4.

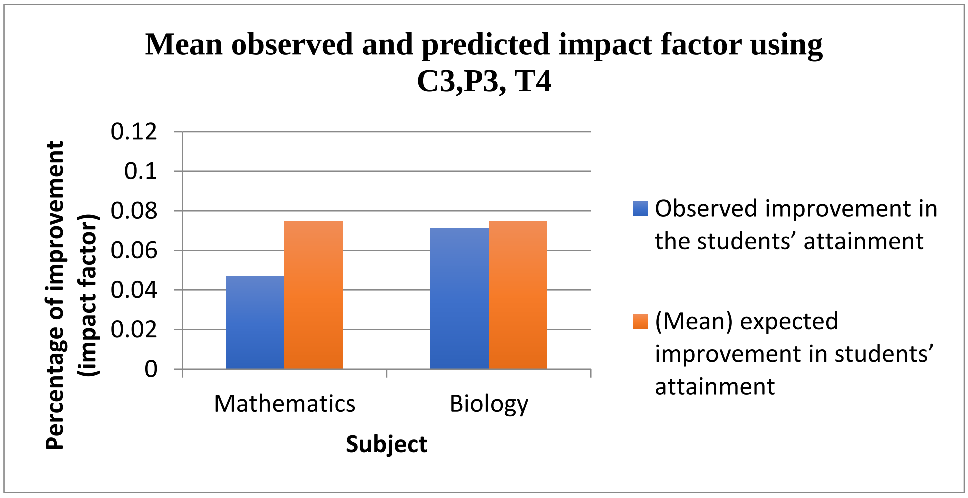


Figure 87. The mean values of the predicted and observed impact factors in the case of using C3, P3, T4.

Summary / "So What?"

It can be seen from the previous figures and tables that the values of predicted and observed impact factors were close to each other, which implies that the CPT model could predict the improvement in students' attainment as an outcome of using educational technology (the impact factor). In general, the strategies C2, P2, T4; C3, P3, T3 and C3, P3, T4 worked well with all tested subjects: physics, biology and mathematics. However, based on the analysed data, the C2, P2, T4 strategy gave the best mean observed improvement when used with mathematics. The C3, P3, T4 strategy provided the best mean observed improvement when it was used with biology and C3, P3, T3 was the best when applied to biology and physics (please refer to Table 50, Table 51 and Table 52). For more information, please refer to section 6.4

6.2.4 The Second Part of Stage Three: The Humanities Subjects

During this part of the study, similarly to stage two and the first part of stage three, two techniques Cnc, Pnp, Tnt (digital technology-based learning) and Cnc, Pnp, T0 (nondigital technology-based learning) were applied to the selected cases. The content was divided into two parts, with the same level of complexities, one part was taught to students using digital technology (Tnt), while the other one was taught without (T0). To check the validity and reliability of the CPT model, several CPT strategies were applied to more extensive samples and two different subjects: English language and social studies from the humanities department.

6.2.4.1 The First Subject: English Language

Three different CPT strategies were applied to teach the English language at this stage. The applied strategies were: i) **(C3, P3, T3), (C3, P3, T0); ii) (C3, P3, T4), (C3, P3, T0) and iii) (C2, P2, T4), (C2, P2, T0)**.

The First and Second Strategies / C3, P3, T3; C3, P3, T4 (digital technology-based learning) and C3 P3 T0 (nondigital technology-based learning)

With regard to C3, P3, T4 strategy (digital technology-based learning), three kinds of curriculum were used. Firstly, theoretical curriculum used lecture notes, PowerPoint presentations. Secondly, practical curriculum, a related activity was conducted, such as a conversation activity or using the lesson’s vocabulary to describe a specific event. Finally, interactive curriculum, which was represented mainly by the iBooks and videos related to the topic in addition to physical interactive tools, such as posters.

Eighty per cent of the content (of the learning objectives) was integrated with digital technology; students used different technology tools (software and hardware) to implement learning, such as laptops, iPads, LMS, iBooks, as well as a range of applications (apps) on the iPad were used, including Good reader application, type on pdf free. Extra resources were shared with students so that they could develop their skills. Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. Warschauer (2000) presents two different perspectives on how to integrate digital technology with language teaching. First, the cognitive approach: this is where students have the chance to maximise their learning outcomes, activities and tools, such as text-reconstruction and simulation software. Second, the social (collaborative) approach, this is a key element in developing language skills, so students are encouraged to work in teams and interact socially. Eaton (2010) noted that computer-based communication, which includes collaborative social learning, has a positive impact on learning the English language.

Note: The circumstances that were applied to the C3, P3, T4 strategy, were applied to the C3, P3, T3 strategy with the only difference being the percentage of digital technology integration.

In the case of using C3, P3, T0 strategy (nondigital technology-based learning): curriculum was delivered using three parts: theoretical content, lecture notes were explained and written by the teacher on the board and copied by students into their copybooks; practical content, some activities related to the lesson were implemented such as conversation, writing tasks; interactive content, which was represented by images displays (hard copies). Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning.

Students were examined traditionally (paper-based exam), exams were marked, and the results of the nondigital technology-based learning were compared with the results that were collected in the case of using digital technology-based learning.

Notes were provided by the English teacher about the CPT studies in the English language: The speaking task was quite interesting for students. They found the pictures related to their topic, described the process successfully and created good videos. The online reading comprehension site www.readtheory.org was challenging.

Some students were quite engaged because the reading site allowed them to gain new knowledge. Others, who had a lower skill level were still engaged but tended to guess more often than the other students who had higher reading levels. The spelling website www.quizlet.com allowed the students to use a variety of options before they did the quizzes. Several categories of questions were offered by www.quizlet.com, such as multiple choices, true-false and matching, which allowed the assessment to be differentiated based on the student's needs and abilities.

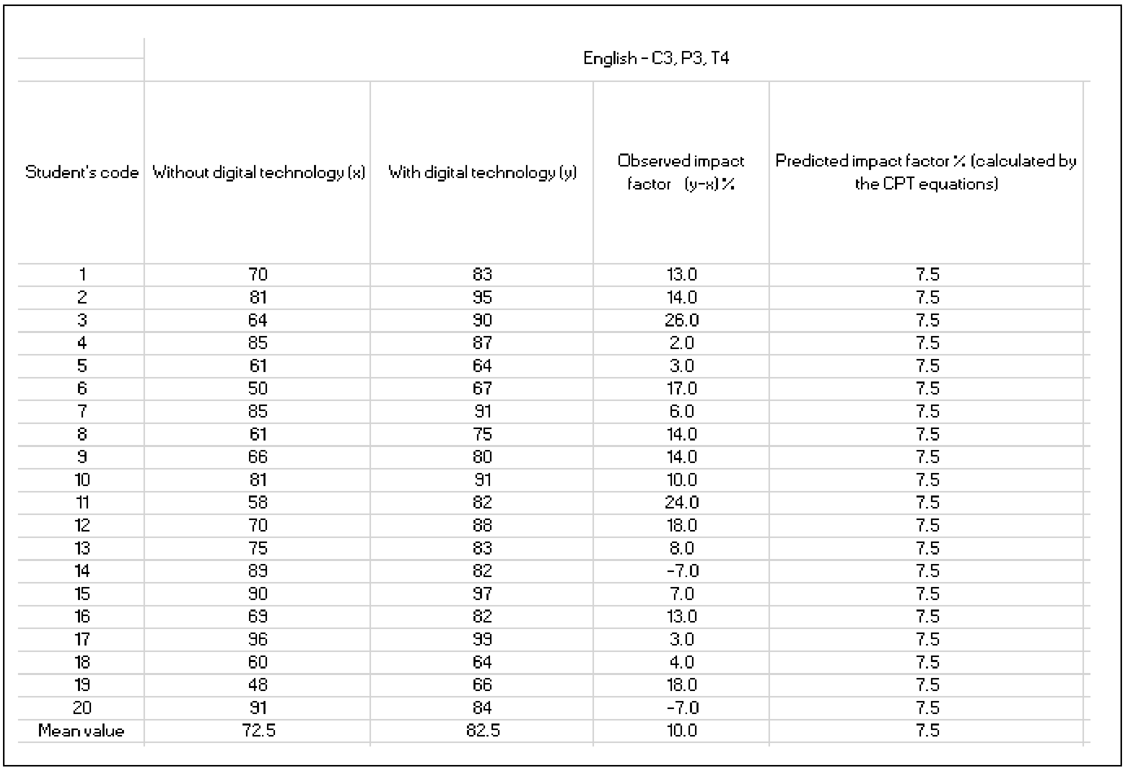
The Third Strategy / C2, P2, T4 and C2, P2, T0

Two kinds of the curriculum were used: theoretical and interactive; 80% of the content was integrated with digital technology. Two pedagogical dimensions were used: direct teaching and collaborative learning.

In the case of using the C2, P2, T0 strategy (nondigital technology-based learning), two pedagogical dimensions, direct teaching and collaborative learning were used to deliver the content. Two kinds of the curriculum were used theoretical and practical; the latter involved some activities related to the content, such as conversation and writing tasks.

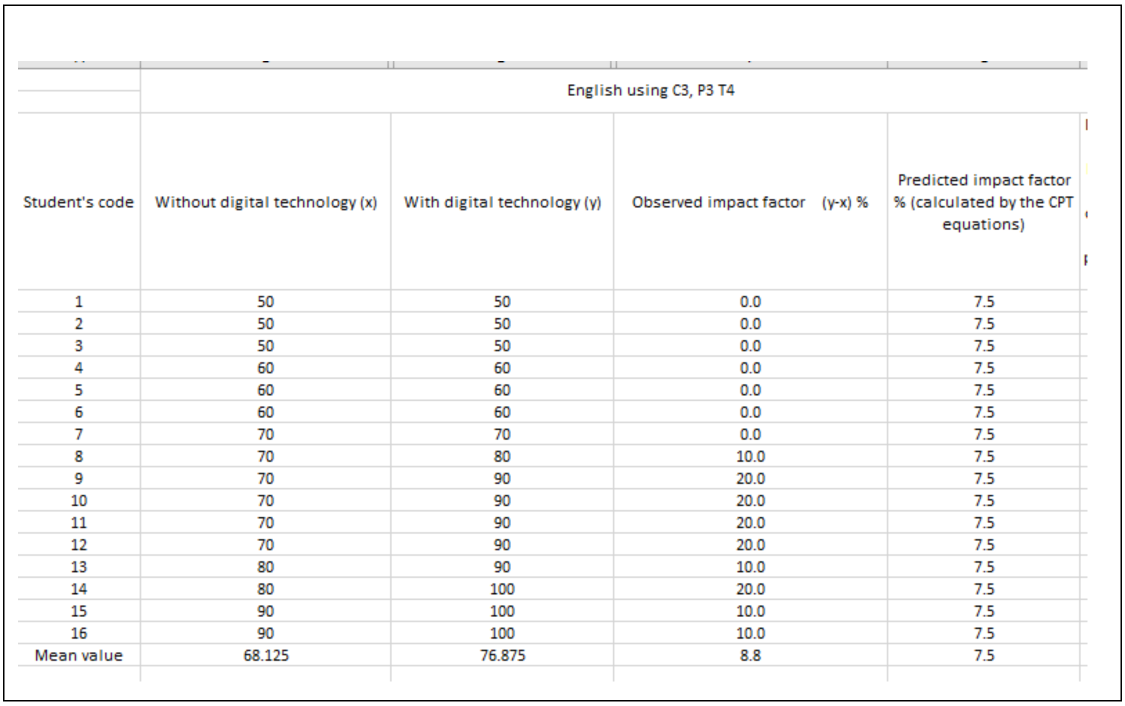
The Predicted and Observed Impact Factors

As shown in Figure 88 and Figure 89, the mean observed impact factor while using C3, P3, T4 was 0.094, and the mean predicted impact factor, as calculated using the equations of the CPT model, was found to be 0.075. On the other hand, in the case of using C2, P2, T4 the mean value of the observed impact factor was 0.044, which is quite far from the expected value, bearing in mind that the mean predicted impact factor based on the CPT model is 0.111, refer to Figure 90. The difference between the two values (observed and predicted) in the case of using C3, P3, T4 is around 0.02 and in the case of using C2, P2, T4 is 0.066. Finally, in the case of C3, P3, T3 the mean observed impact factor was 0.015 while the mean predicted impact factor was 0.042, with a difference between the two values of 0.027, refer to Figure 91.



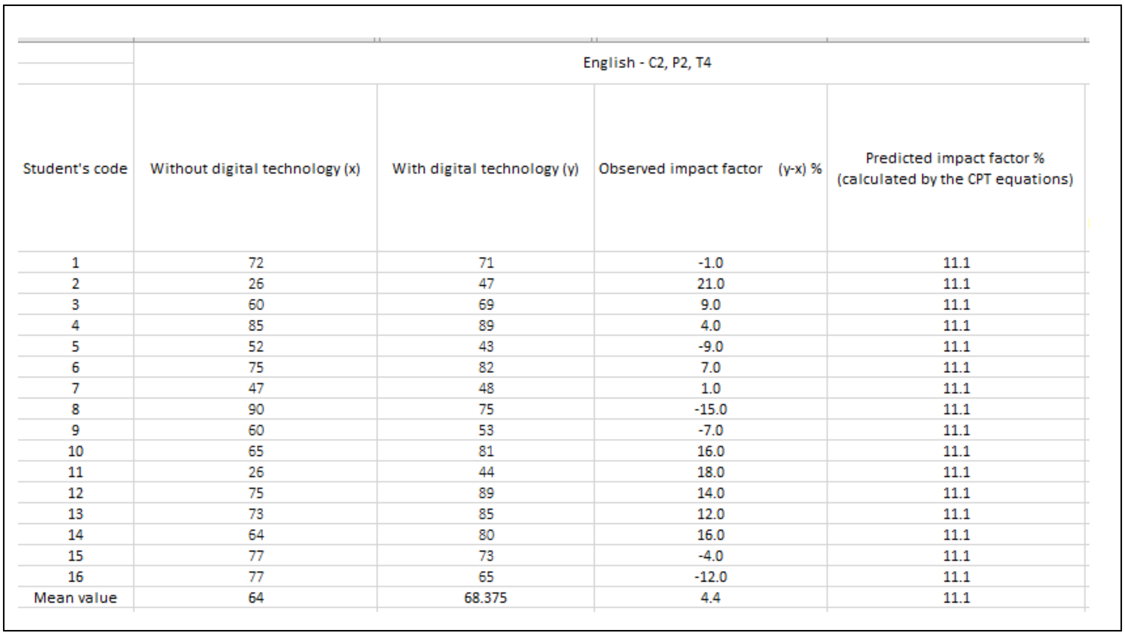
	English - C3, P3, T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	70	83	13.0	7.5
2	81	95	14.0	7.5
3	64	90	26.0	7.5
4	85	87	2.0	7.5
5	61	64	3.0	7.5
6	50	67	17.0	7.5
7	85	91	6.0	7.5
8	61	75	14.0	7.5
9	66	80	14.0	7.5
10	81	91	10.0	7.5
11	58	82	24.0	7.5
12	70	88	18.0	7.5
13	75	83	8.0	7.5
14	89	82	-7.0	7.5
15	90	97	7.0	7.5
16	69	82	13.0	7.5
17	96	99	3.0	7.5
18	60	64	4.0	7.5
19	48	66	18.0	7.5
20	91	84	-7.0	7.5
Mean value	72.5	82.5	10.0	7.5

Figure 88. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T4 to teach the English language



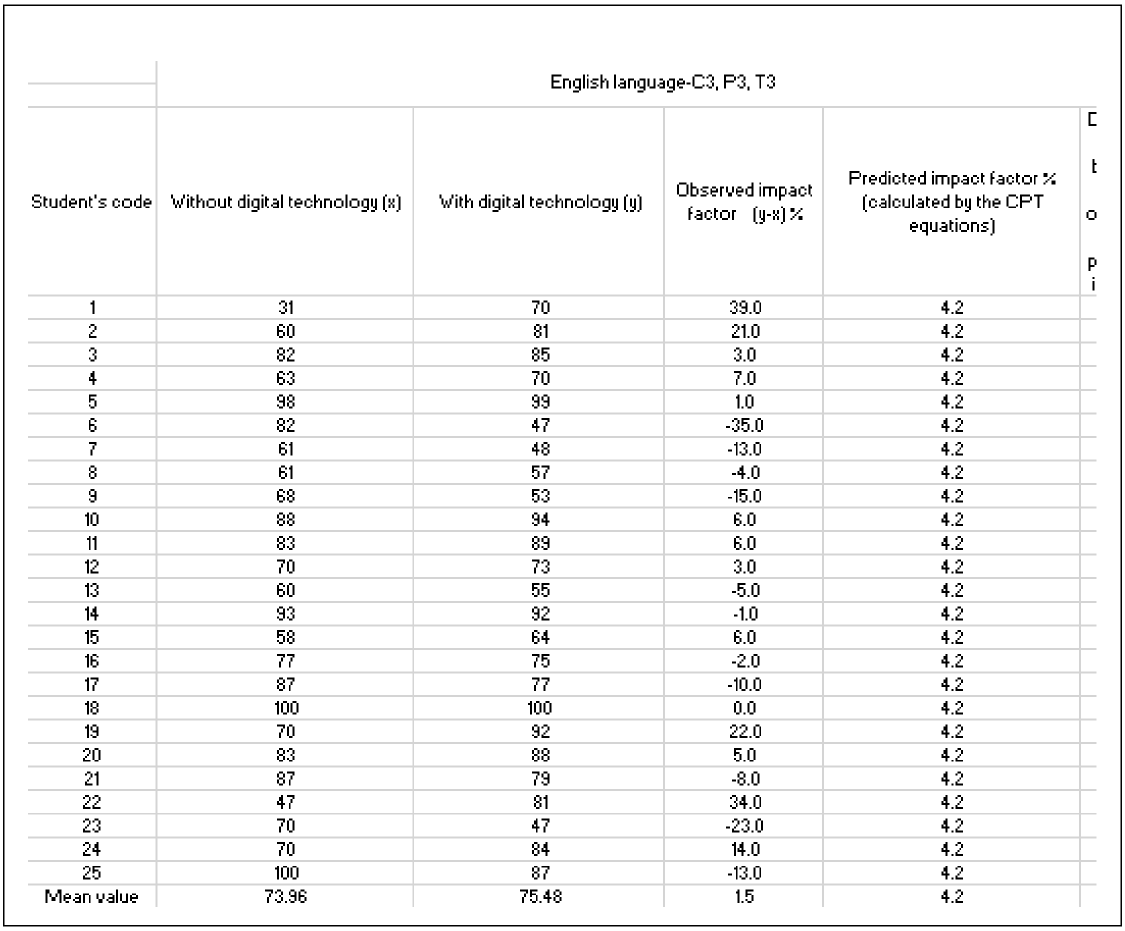
	English using C3, P3 T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	50	50	0.0	7.5
2	50	50	0.0	7.5
3	50	50	0.0	7.5
4	60	60	0.0	7.5
5	60	60	0.0	7.5
6	60	60	0.0	7.5
7	70	70	0.0	7.5
8	70	80	10.0	7.5
9	70	90	20.0	7.5
10	70	90	20.0	7.5
11	70	90	20.0	7.5
12	70	90	20.0	7.5
13	80	90	10.0	7.5
14	80	100	20.0	7.5
15	90	100	10.0	7.5
16	90	100	10.0	7.5
Mean value	68.125	76.875	8.8	7.5

Figure 89. Grade 9 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T4 to teach the English language



	English - C2, P2, T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	72	71	-1.0	11.1
2	26	47	21.0	11.1
3	60	69	9.0	11.1
4	85	89	4.0	11.1
5	52	43	-9.0	11.1
6	75	82	7.0	11.1
7	47	48	1.0	11.1
8	90	75	-15.0	11.1
9	60	53	-7.0	11.1
10	65	81	16.0	11.1
11	26	44	18.0	11.1
12	75	89	14.0	11.1
13	73	85	12.0	11.1
14	64	80	16.0	11.1
15	77	73	-4.0	11.1
16	77	65	-12.0	11.1
Mean value	64	68.375	4.4	11.1

Figure 90. Grade 9 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C2, P2, T4 to teach the English language



	English language-C3, P3, T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	31	70	39.0	4.2
2	60	81	21.0	4.2
3	82	85	3.0	4.2
4	63	70	7.0	4.2
5	98	99	1.0	4.2
6	82	47	-35.0	4.2
7	61	48	-13.0	4.2
8	61	57	-4.0	4.2
9	68	53	-15.0	4.2
10	88	94	6.0	4.2
11	83	89	6.0	4.2
12	70	73	3.0	4.2
13	60	55	-5.0	4.2
14	93	92	-1.0	4.2
15	58	64	6.0	4.2
16	77	75	-2.0	4.2
17	87	77	-10.0	4.2
18	100	100	0.0	4.2
19	70	92	22.0	4.2
20	83	88	5.0	4.2
21	87	79	-8.0	4.2
22	47	81	34.0	4.2
23	70	47	-23.0	4.2
24	70	84	14.0	4.2
25	100	87	-13.0	4.2
Mean value	73.96	75.48	1.5	4.2

Figure 91. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted

impact factors while using C3, P3, T3 to teach the English language

It can be seen in Table 53 and Figure 92, that the use of educational technology improved students' attainment in the English language. This finding agrees with other researchers' findings. For instance, Sharma (2009) stated that educational technology has a substantial impact on teaching and learning languages. Sharma (2009) claimed that the successful implementation of educational technology is an essential element in promoting learning languages. Hoven (1999) claims that the use of educational technology can help students with listening tasks since computers can provide visual and audio input simultaneously, which can facilitate learners' understanding. Furthermore, educational technology can improve students' reading and grammar skills by improving their vocabulary, which leads to enhancing their comprehension of reading tasks (Ybarra & Green, 2003).

English language / Strategy	**Number of trials**	**Mean value of the observed impact factor**	**Mean value of the predicted impact factor**	**The difference between the observed and predicted impact factors**
C3, P3, T4	2	0.094	0.075	0.019
C2, P2, T4	1	0.044	0.110	0.066
C3, P3, T3	1	0.015	0.042	0.027

Table 53. The mean observed and predicted impact factors in the case of using C3, P3, T4; C3, P3, T4 and C2, P2, T4 to teach the English language.

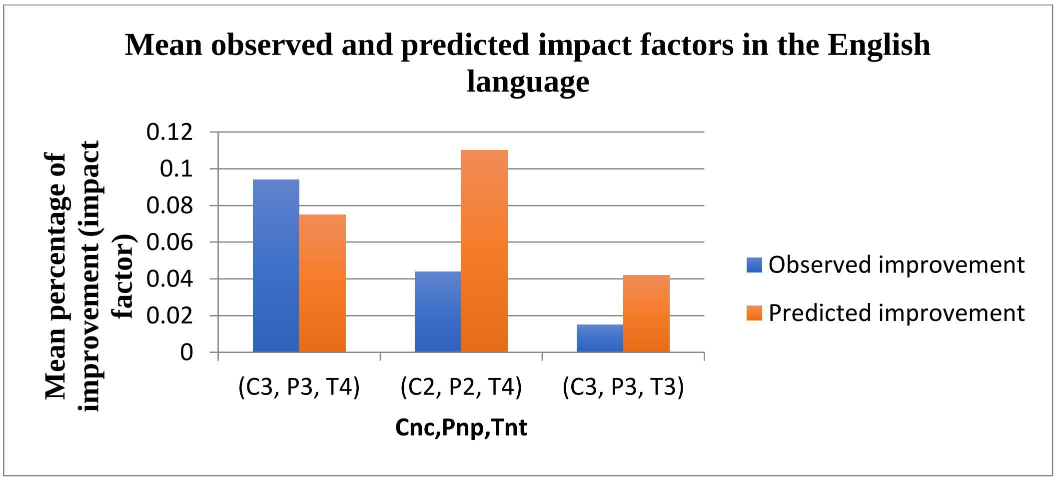


Figure 92. The means of observed and predicted impact factors in the case of using C3, P3, T4; C3, P3, T4 and C2, P2, T4 to teach the English language.

Statistical Description

To enhance the validity of the data collected, some of the CPT strategies were trialled more than once as demonstrated in Table 54, which shows the observed and predicted impact factors, and a statistical description for each CPT strategy used to teach the English language.

Case #	Subject Cnc Pnp Tnt	The mean observed impact factor, %	The mean predicted impact factor, %	Tstat	T-critical	Effect size (Cohen' s D)	Correlation factor (R)	P-value	ΣX^2
1	English using C2, P2 T4	4.40	11.1	2.34	2.14	0.250	0.780	0.030	$3.40*10^{-43}$
2	English using C3, P3 T4	8.80	7.50	0.560	2.14	0.700	0.920	0.580	$2.45*10^{-26}$
3	English using C3, P3 T3	1.50	4.20	0.820	2.06	0.100	0.520	0.420	0.00
4	English using C3, P3 T4	10.0	7.50	1.25	2.09	0.748	0.780	0.223	$1.60*10^{-35}$

Table 54. The statistical description of the CPT strategies that were used to teach the English language.

The Chi-Square value was calculated and found to be in all cases less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies (observed and predicted impact factors) is considered to be a good one (Kothari, 2004), which can be seen in Table 54, Figure 93, Figure 94, Figure 95 and Figure 96. Therefore, the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the expected and observed improvements.

As shown in Table 54, the P-value was calculated as well for all cases and found to be less than 0.05 in case 1 and greater than 0.05 in cases 2, 3 and 4. This implies that the null hypothesis can be rejected only in case 1 and cannot be rejected in cases 2, 3 and 4. The T-test: Paired Two Sample for Means was calculated to check the null hypothesis, and the statistical value of the t-test was found greater than the critical value of the t-test in case 1 and less than the critical value in cases 2, 3 and 4 so that the null hypothesis can be rejected in case 1 and cannot be rejected in cases 2, 3 and 4. i.e. there was no significant difference between the means of the expected and observed improvements.

As can be seen in Table 54, Figure 93, Figure 94, Figure 95 and Figure 96, the value of Pearson correlation factor (r) in all cases indicates a strong and moderately positive correlation between the use of educational technology and students' attainment; therefore, these two variables can be considered as dependent variables. Furthermore, the values of the effect size in all cases shown in Table 54 indicate a large effect (cases 2 and 4), medium effect (case 1) and a small effect of educational technology on students' attainment in case 3.

Note: these calculations and the stated critical values were completed using Microsoft® Excel 2016.

Figure 93, Figure 94, Figure 95 and Figure 96 show the correlation between the students' marks with and without using digital technology, i.e., how these marks fit with each other. The values of the coefficient of determination (r^2) were calculated in all cases and found to be 0.62, 0.85, 0.27 and 0.60 respectively for the cases 1 to 4 that were conducted to teach the English language. This indicates that more than half of the points in cases 1, 2 and 4, and only 27 % of the points in the third case fall on the regression line.

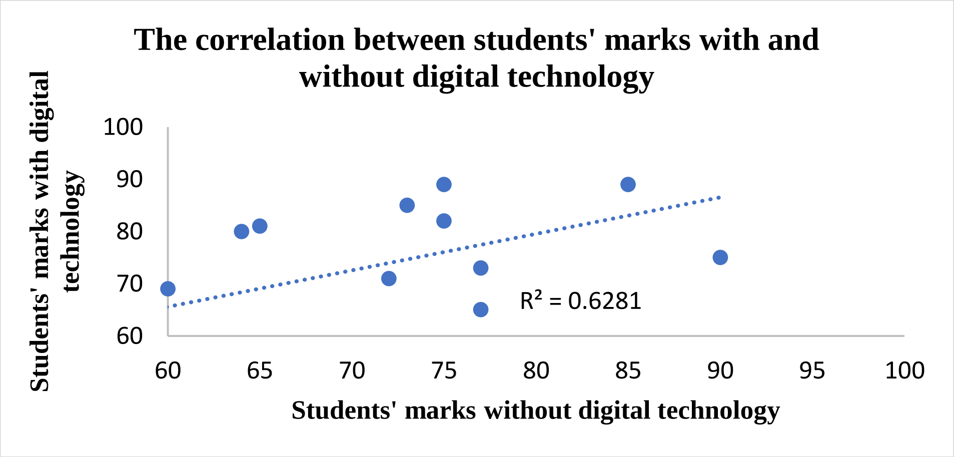


Figure 93. Students' marks with regard to digital and nondigital technology-based learning: case # 1 in Table 54.

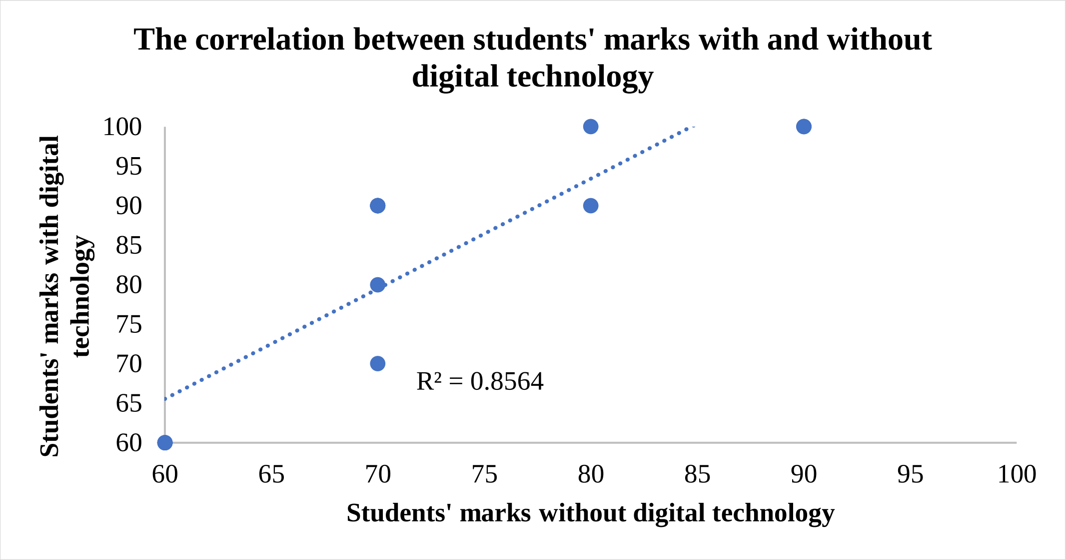


Figure 94. Students' marks with regard to digital and nondigital technology-based learning: case # 2 in Table 54.

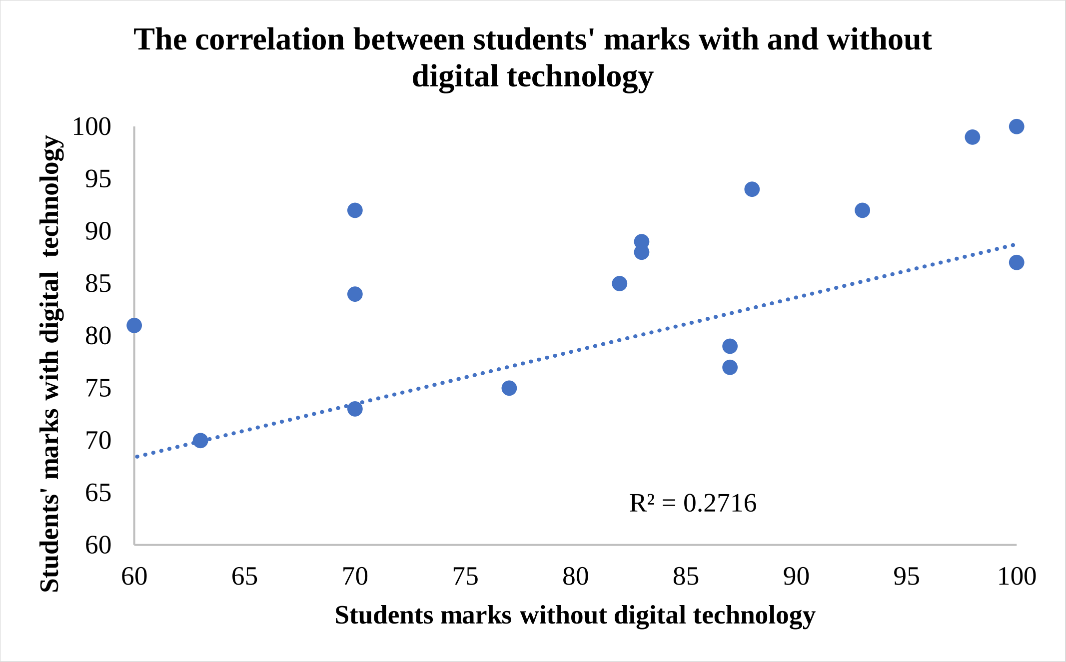


Figure 95. Students' marks with regard to digital and nondigital technology-based learning: case # 3 in Table 54.

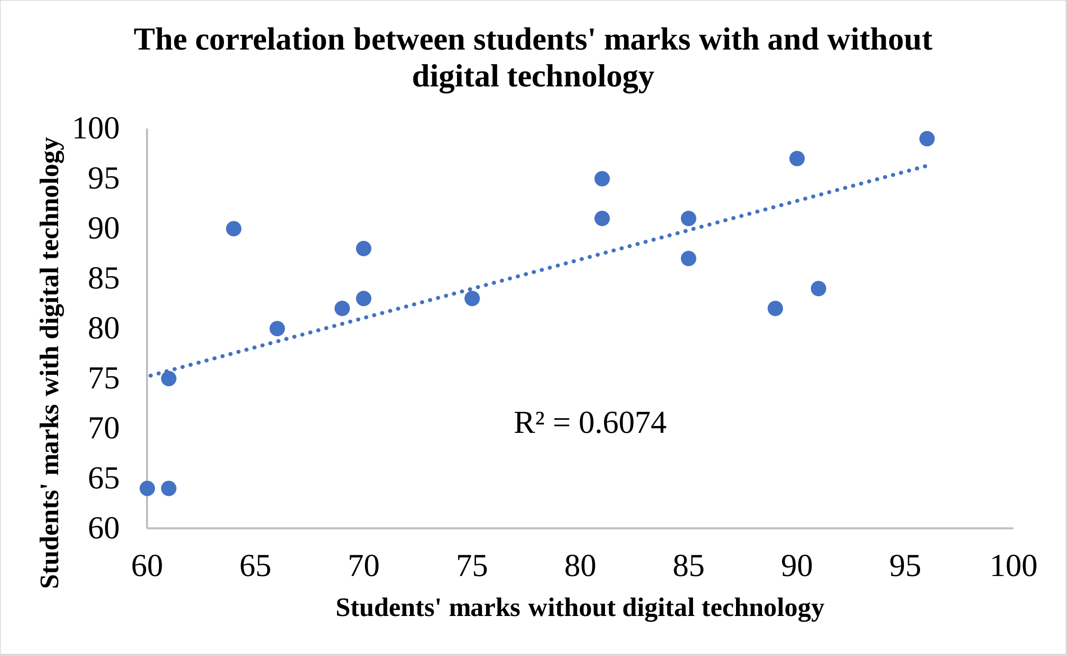


Figure 96. Students’ marks with regard to digital and nondigital technology-based learning: case # 4 in Table 54.

Based on the outcomes of the applied statistical functions, the null hypothesis cannot be rejected as there was no significant difference between the means of the expected and observed improvement. Thus, the researcher would claim that the CPT model is a valid predictive model for the improvement in students’ attainment as an outcome of using educational technology.

6.2.4.2 The Second Humanities Subject: Social Studies

Three different CPT strategies to teach social studies were applied at this stage: **(C3, P3, T3) (C3, P3, T0); (C3, P3, T4) (C3, P3, T0) and (C1, P1, T1) (C1, P1, T0)**.

The First and Second Strategies / C3, P3, T3; C3, P3, T4 (digital technology-based learning) and C3 P3 T0 (nondigital technology-based learning)

Three types of the curriculum were used: theoretical, practical and interactive (videos, iBooks and a range of physical interactive tools); 60% of the content was integrated with digital technology. Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. The same circumstances were applied to C3, P3, T4, with the only difference being the percentage of the content integrated with digital technology.

In the case of using C3, P3, T0 (nondigital technology-based learning): the curriculum was presented using all three parts: theoretical, practical and interactive, the latter involved display of hard copy posters. Three pedagogical dimensions were used to deliver the content: direct teaching, collaborative learning and constructive learning. Students were examined traditionally (paper-based exam), exams were marked, and the results were compared with the results in the case of using digital technology-based learning.

The Third Strategy / C1, P1, T1 and C1, P1, T0

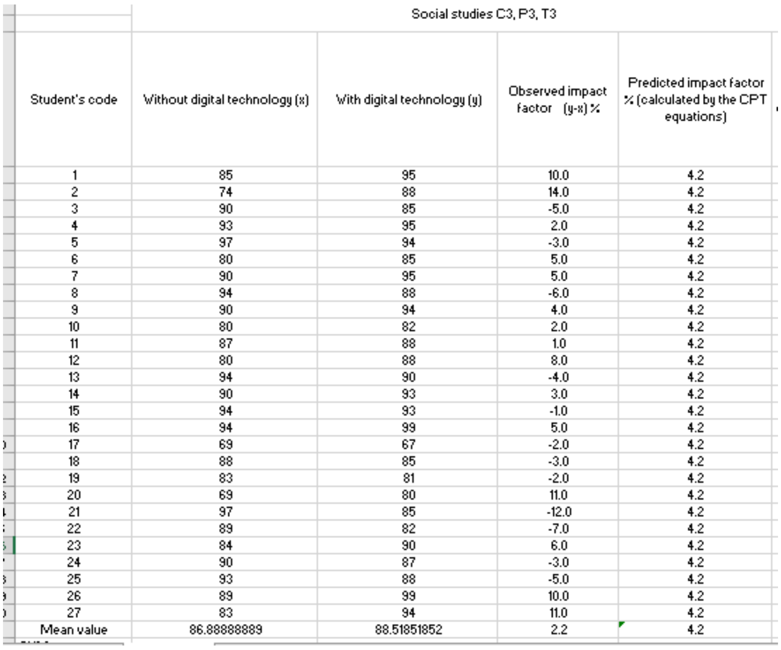
Only the theoretical kind of curriculum was used; 20% of the content was integrated with digital technology and one-pedagogical dimension, direct teaching, was used to deliver the content.

In the case of using the C1, P1, T0 strategy one pedagogical dimension, direct teaching, was used to deliver the content, which was introduced using one kind of curriculum, a theoretical curriculum with no digital technology supporting the learning process in this case.

The exact implementation of this strategy can be found in Appendix 6 – Examples of Lesson Plans/ Implementation of the CPT Lessons, 3rd example of lesson plans.

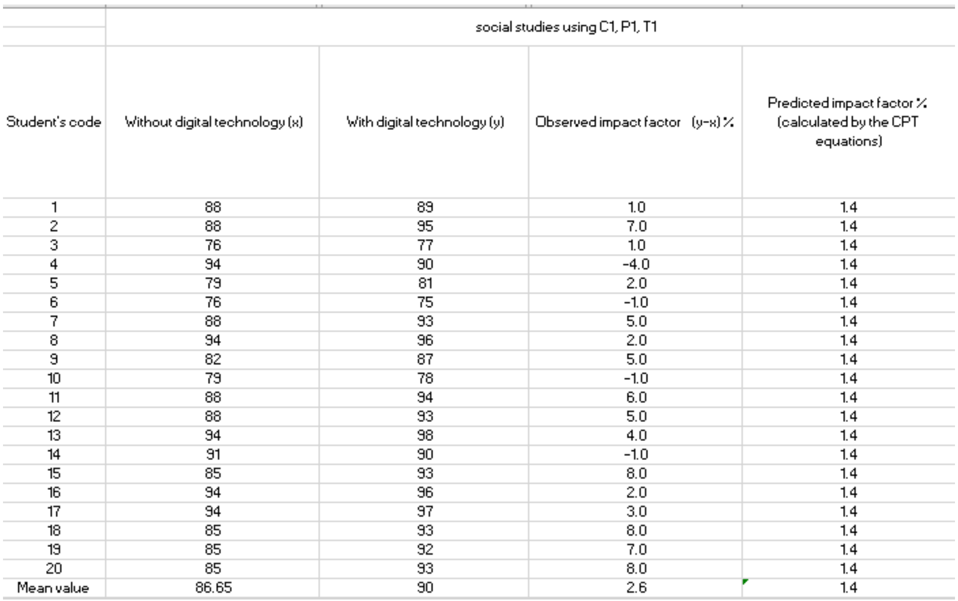
The Predicted and Observed Impact Factors

As shown in Figure 97, the mean observed impact factor in the case of using C3, P3, T3 was 0.022, and the mean predicted impact factor, as calculated from the CPT model, was found to be 0.042. However, in the case of using C1, P1, T1 the mean value of the observed impact factor was 0.026, while the mean value of the predicted impact factor based on the CPT model is 0.014, refer to Figure 98. Finally, as shown in Figure 99, in the case of C3, P3, T4, the mean observed impact factor was 0.108, which is higher than the predicted one (0.075). Based on these results, it can be asserted that the use of educational technology in social studies could improve students' attainment and learning. This finding goes in line with Braun and Risinger (1999), Molebash and Dodge (2003), who claimed that the use of educational technology to teach social studies could improve students' interest, confidence, thinking skills and attitudes towards social studies.



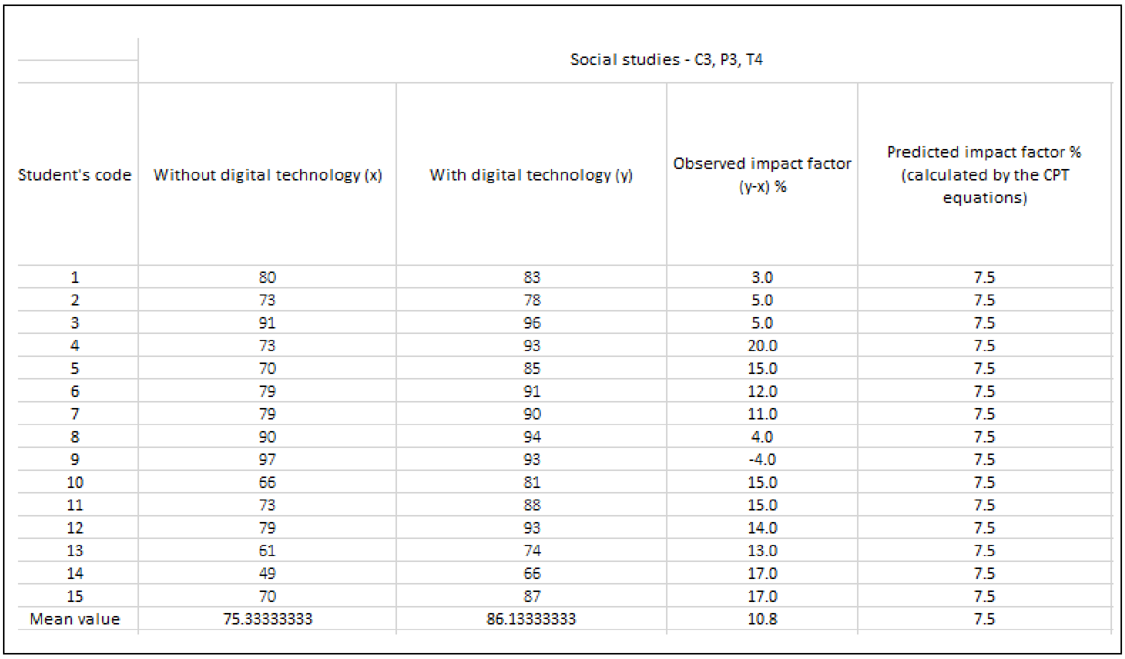
	Social studies C3, P3, T3			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	85	95	10.0	4.2
2	74	88	14.0	4.2
3	90	85	-5.0	4.2
4	93	95	2.0	4.2
5	97	94	-3.0	4.2
6	80	85	5.0	4.2
7	90	95	5.0	4.2
8	94	88	-6.0	4.2
9	90	94	4.0	4.2
10	80	82	2.0	4.2
11	87	88	1.0	4.2
12	80	88	8.0	4.2
13	94	90	-4.0	4.2
14	90	93	3.0	4.2
15	94	93	-1.0	4.2
16	94	99	5.0	4.2
17	69	67	-2.0	4.2
18	88	85	-3.0	4.2
19	83	81	-2.0	4.2
20	69	80	11.0	4.2
21	97	85	-12.0	4.2
22	89	82	-7.0	4.2
23	84	90	6.0	4.2
24	90	87	-3.0	4.2
25	93	88	-5.0	4.2
26	89	99	10.0	4.2
27	83	94	11.0	4.2
Mean value	86.88888889	88.51851852	2.2	4.2

Figure 97. Grade 9 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T3 to teach social studies



	social studies using C1, P1, T1			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y–x) %	Predicted impact factor % (calculated by the CPT equations)
1	88	89	1.0	1.4
2	88	95	7.0	1.4
3	76	77	1.0	1.4
4	94	90	-4.0	1.4
5	79	81	2.0	1.4
6	76	75	-1.0	1.4
7	88	93	5.0	1.4
8	94	96	2.0	1.4
9	82	87	5.0	1.4
10	79	78	-1.0	1.4
11	88	94	6.0	1.4
12	88	93	5.0	1.4
13	94	98	4.0	1.4
14	91	90	-1.0	1.4
15	85	93	8.0	1.4
16	94	96	2.0	1.4
17	94	97	3.0	1.4
18	85	93	8.0	1.4
19	85	92	7.0	1.4
20	85	93	8.0	1.4
Mean value	86.65	90	2.6	1.4

Figure 98. Grade 9 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C1, P1, T1 to teach social studies



	Social studies - C3, P3, T4			
Student's code	Without digital technology (x)	With digital technology (y)	Observed impact factor (y-x) %	Predicted impact factor % (calculated by the CPT equations)
1	80	83	3.0	7.5
2	73	78	5.0	7.5
3	91	96	5.0	7.5
4	73	93	20.0	7.5
5	70	85	15.0	7.5
6	79	91	12.0	7.5
7	79	90	11.0	7.5
8	90	94	4.0	7.5
9	97	93	-4.0	7.5
10	66	81	15.0	7.5
11	73	88	15.0	7.5
12	79	93	14.0	7.5
13	61	74	13.0	7.5
14	49	66	17.0	7.5
15	70	87	17.0	7.5
Mean value	75.33333333	86.13333333	10.8	7.5

Figure 99. Grade 11 students' marks with regard to digital and nondigital technology-based learning, as well as the mean values of the observed and predicted impact factors while using C3, P3, T4 to teach social studies

The difference between the two values (observed and predicted) of improvement in the case of using C3, P3, T3 is around 0.02 and in the case of using C3, P3, T4 is 0.033. Finally, the observed and predicted values were the closest in the case of using C1, P1, T1 with a difference between the two values equal to 0.012. Please refer to Table 55 and Figure 100.

Social Studies / **Strategy**	**Number of trials**	**The mean observed impact factor**	**The mean predicted impact factor**	**The difference between the observed and predicted impact factors**
C3, P3, T3	1	0.022	0.042	0.020
C3, P3, T4	1	0.108	0.075	0.033
C1, P1, T1	1	0.026	0.014	0.012

Table 55. The mean observed and predicted impact factors in the case of using C3, P3, T4; C3, P3, T4 and C1, P1, T1 to teach social studies.

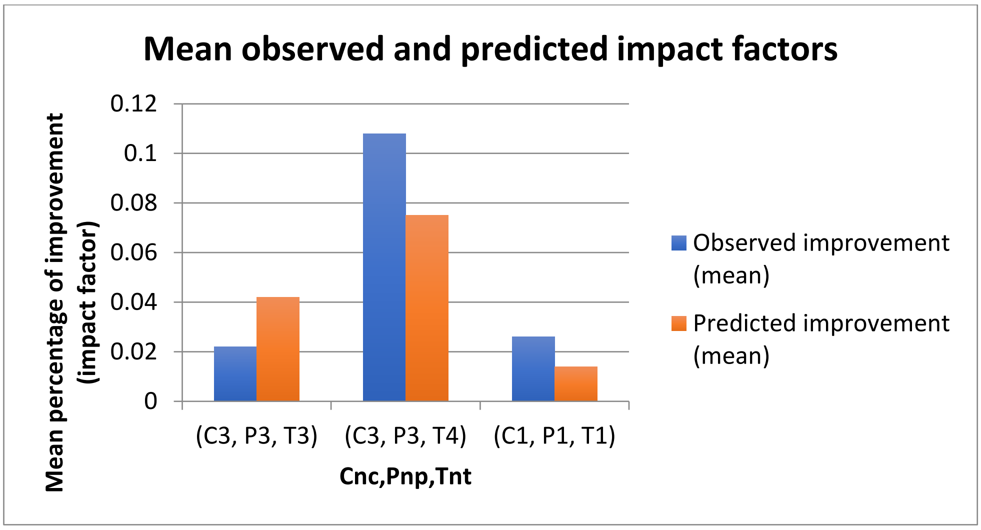


Figure 100. The mean observed and predicted impact factors (improvements) in the case of using C3, P3, T4; C3, P3, T4 and C1, P1, T1 to teach social studies.

As can be seen in Table 55 and Figure 100, amongst all strategies that were used to teach social studies in this research, the C3, P3, T4 strategy achieved the best-observed improvement. Regarding the other two strategies, there was an improvement, but not as high as in the case of the C3, P3, T4 strategy. As predicted by the CPT model, the achieved improvement in students' attainment, when using C3, P3, T3 should have been greater than the achieved improvement in the case of C1, P1, T1. However, what was observed was contrary to expectations since the observed improvement achieved using the C1, P1, T1 strategy was greater than the achieved improvement using C3, P3, T3 strategy, as shown in Table 55. This finding might be justified in many reasons, such as the level of difficulty of the content and whether it requires the use of digital technology or not, and also the students' academic level and attitudes towards learning might influence the achieved improvements. However, as an overall trend, it can be stated that the CPT model could predict values for the improvement in students' attainment that are close to the observed ones.

Statistical Description

Table 56 shows a statistical description of each CPT strategy used to teach Social Studies.

Case #	Subject Cnc Pnp Tnt	The mean observed impact factor, %	The mean predicted impact factor, % -	T-test	T-critical	Effect size (Cohen's D)	Correlation factor (R)	P-value	Σ X^2
1	Social studies using C1, P1, T1	2.60	1.40	2.48	2.09	0.51	0.89	0.02	$1.46*10^{-36}$
2	Social studies using C3, P3 T4	10.8	7.50	1.91	2.14	0.91	0.84	0.07	$5.10*10^{-16}$
3	Social studies using C3, P3 T3	2.20	4.20	2.04	2.05	0.23	0.74	0.05	$1.40*10^{-49}$

Table 56. The statistical description of the CPT strategies that were used to teach Social Studies.

The Chi-Square value was calculated in all cases and found to be less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies is a good one (Kothari, 2004), which can be seen in Table 56, Figure 101, Figure 102 and Figure 103.

Based on Table 56 the P-value was also calculated for all cases and found to be less than 0.05 in case 1, greater than 0.05 in case 2, and equal to 0.05 in case 3, which implies that the null hypothesis can be rejected in case 1 but cannot be rejected in case 2. In case 3, there is not sufficient evidence to reject or accept the null hypothesis since the P-value was found to be 0.05. The t-test: Paired Two Sample for Means was used to check the null hypothesis. The statistical value of the t-test was found greater than the critical value of the t-test in case 1 and less than the critical value in cases 2 and 3, which confirms that the null hypothesis can be rejected in case 1 and cannot be rejected in cases 2 and 3.

As shown in Table 56, the value of the Pearson correlation factor (r), in cases 1 and 2, indicates a strong positive correlation and a moderate correlation in case 3. Therefore, educational technology and students' attainment can be considered as dependent variables. Furthermore, the values of the effect size in all cases that are shown in Table 56 indicate a small (case 3), medium (case 1) and large effect (case 2) of educational technology on students' attainment (dependent variables).

Note: these calculations and the stated critical values were completed using Microsoft® Excel 2016.

Figure 101, Figure 102 and Figure 103 show the correlation between the students' marks with and without digital technology, i.e., how these marks fit with each other. The values of the coefficient of determination (r^2) were calculated in all cases; as they were 0.78, 0.71 and 0.56 for the cases 1 to 3 that were conducted to teach social studies respectively (refer to Table 56), which indicates that more than half of the data points in each case fall on the regression line.

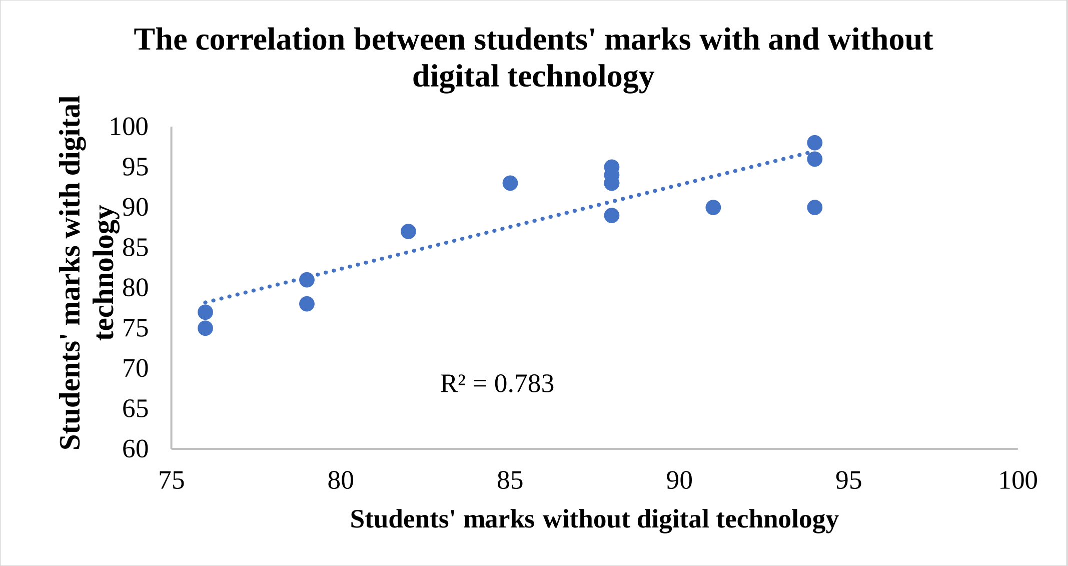


Figure 101. Students' marks with regard to digital and nondigital technology-based learning: case # 1 in Table 56.

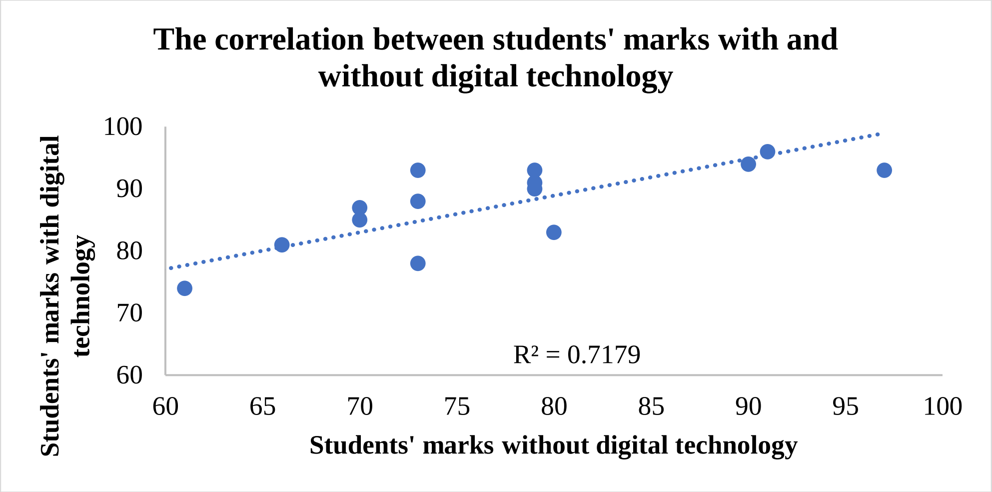


Figure 102. Students' marks with regard to digital and nondigital technology-based learning: case # 2 in Table 56.

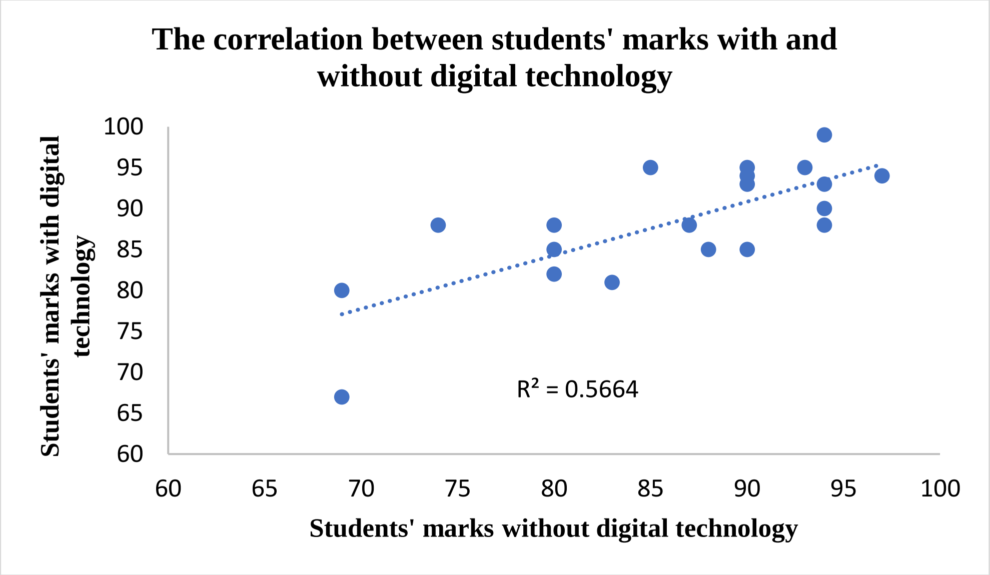


Figure 103. Students' marks with regard to digital and nondigital technology-based learning: case # 3 in Table 56.

Overall, based on the outcomes of the applied statistical functions', the researcher claims that the null hypothesis cannot be rejected. In other words, there was no significant difference between the means of predicted and observed impact factors (improvements). Thus, the CPT model is to be considered as a valid tool to predict the improvement in students' attainment.

6.2.5 Comparison of the Tested Humanities Subjects: English Language and Social Studies

The C3, P3, T4 strategy was used in both subjects: Social Studies and English language. As shown in Table 57 and Figure 104, the mean value of the observed impact factors was higher when the C3, P3, T4 strategy was applied to social studies, than when it was applied to the English language. However, the observed impact factor in both cases of using the C3, P3, T4 strategy is approximately in the same range since the difference between the two observed impact factors in both subjects was 0.014 (refer to Table 57). Therefore, it can be concluded that educational technology could impact both subjects in the same manner and could improve students' attainment as predicted by the CPT model.

Strategy / C3, P3, T4 **Subject**	**Mean value of the predicted impact factor**	**Mean value of the observed impact factor**
Social studies	0.075	0.108
English language	0.075	0.094

Table 57. The means of predicted and observed impact factors in the case of using C3, P3, T4 to teach Social Studies and English language.

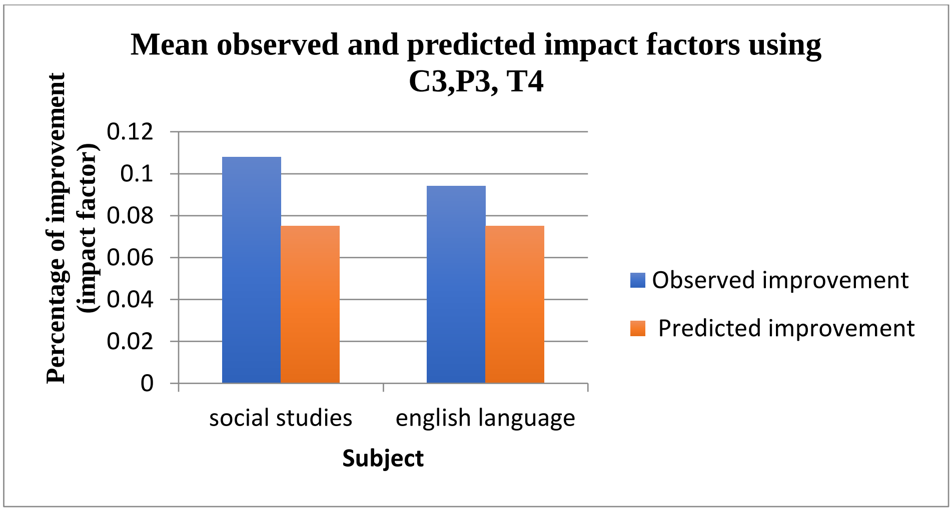


Figure 104. The means of predicted and observed impact factors in the case of using C3, P3, T4 to teach Social Studies and English language.

With regard to the C3, P3, T3 strategy, it was applied to teach social studies and English language. As shown in Table 58 and Figure 105, the mean value of the observed impact factor was higher when C3, P3, T3 was applied to social studies. However, the observed impact factor in both subjects using the C3, P3, T3 strategy is approximately within the same boundaries, since the difference between the two observed impact factors in both subjects was 0.007. Therefore, it can be concluded again that educational technology could improve students' attainment in both subjects as predicted by the CPT model. Though in both subjects, the observed improvement was less than the predicted improvement.

Strategy / C3, P3, T3 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Social studies	0.042	0.022
English language	0.042	0.015

Table 58. The means of predicted and observed impact factors in the case of using C3, P3, T3 to teach Social Studies and English language.

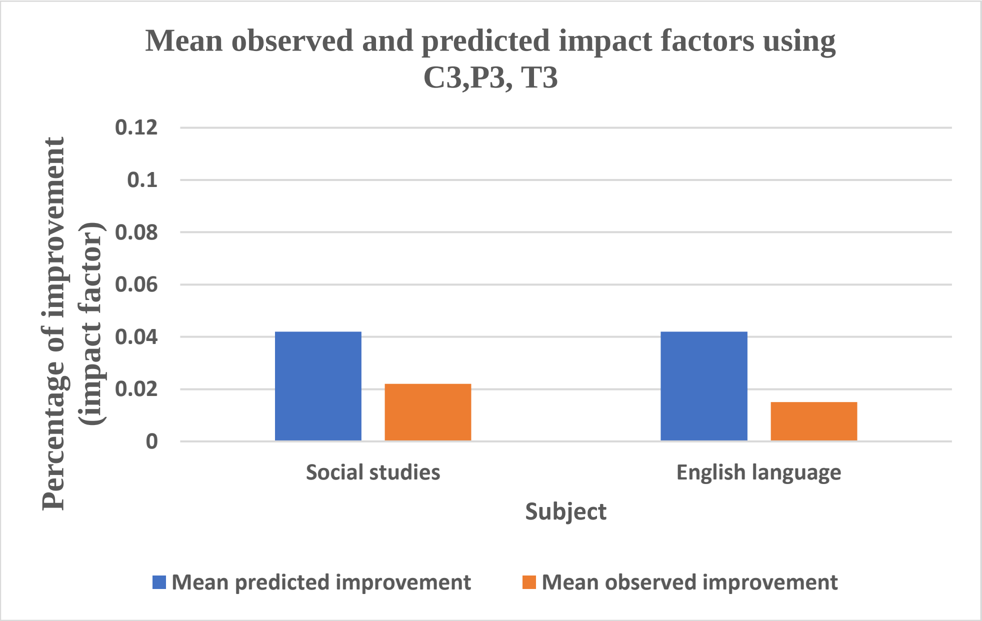


Figure 105. The means of predicted and observed impact factors in the case of using C3, P3, T3 to teach Social Studies and English language.

6.3 COMPARISON BETWEEN THE HUMANITIES AND THE SCIENCE SUBJECTS

The C3, P3, T4 strategy was used in subjects related to the humanities, social studies and English language, as well as other subjects related to science; physics, biology and mathematics. Based on results shown in Table 59 and Figure 106, it can be concluded that the use of educational technology could improve students' attainment in the humanities more than it could in the science subjects since the mean observed impact factor in the humanities subjects was higher than the mean observed impact factor in the case of science subjects. I would argue that the level of difficulties for both clusters (science and humanities) is not the same. In turn, this implies that the use of educational technology might improve students' understanding of a specific science concept, which might lead to improving students' attainment in the conducted exam. However, there is no guarantee that this improvement will be significant or equal to other improvements that can be achieved in other subjects related to humanities. As an overall view, it can be concluded that the C3, P3, T4 strategy worked more successfully with humanities than it did with science subjects, as shown in Table 59.

The mean observed impact factors in the science subjects when using C3, P3, T4: 0.032, 0.019 and 0.072, refer to table 50, so that the mean value would be 0.040. Regarding the humanities, the mean observed impact factors are 0.108 and 0.094, refer to table 57, hence the mean value of the impact factor is 0.101, as shown in Table 59.

Strategy / C3, P3, T4 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Humanities	0.075	0.101
Science	0.075	0.040

Table 59. The means of predicted and observed impact factors in the case of using C3, P3, T4 to teach Humanities and Science subjects.

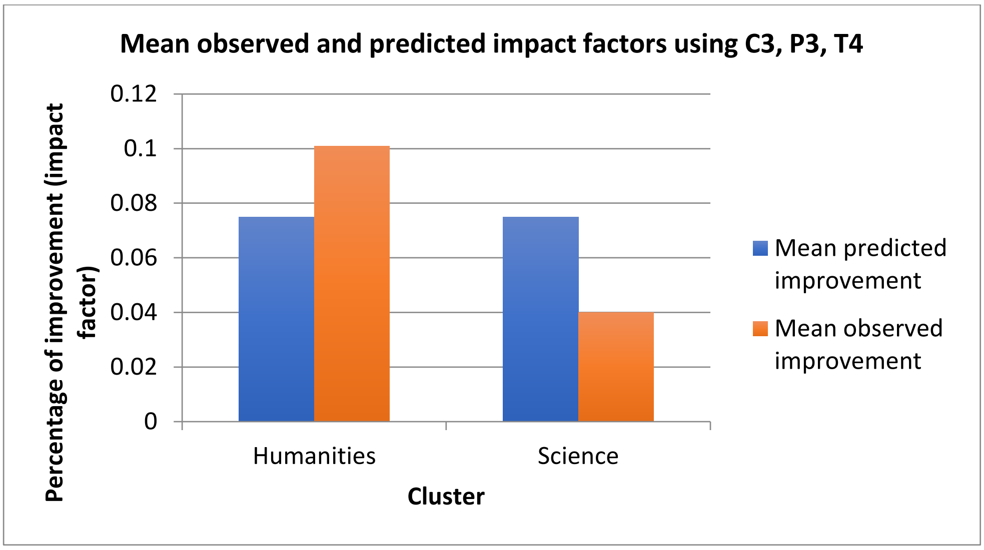


Figure 106. The means of predicted and observed impact factors in the case of using C3, P3, T4 to teach Humanities and Science subjects.

With regard to the C2, P2, T4 strategy, it was used with the English language and science subjects: physics, biology and mathematics. Based on the results that are shown in Table 60 and Figure 107, the C2, P2, T4 strategy could improve students' attainment in science more than it could in the English language. Thus, it can be stated that the C2, P2, T4 strategy is more suitable for Science subjects than the English language in particular and the humanities in general.

Strategy / C2, P2, T4 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Humanities / English language	0.110	0.044
Science	0.110	0.077

Table 60. The means of predicted and observed impact factors in the case of using C2, P2, T4 to teach Humanities and Science subjects.

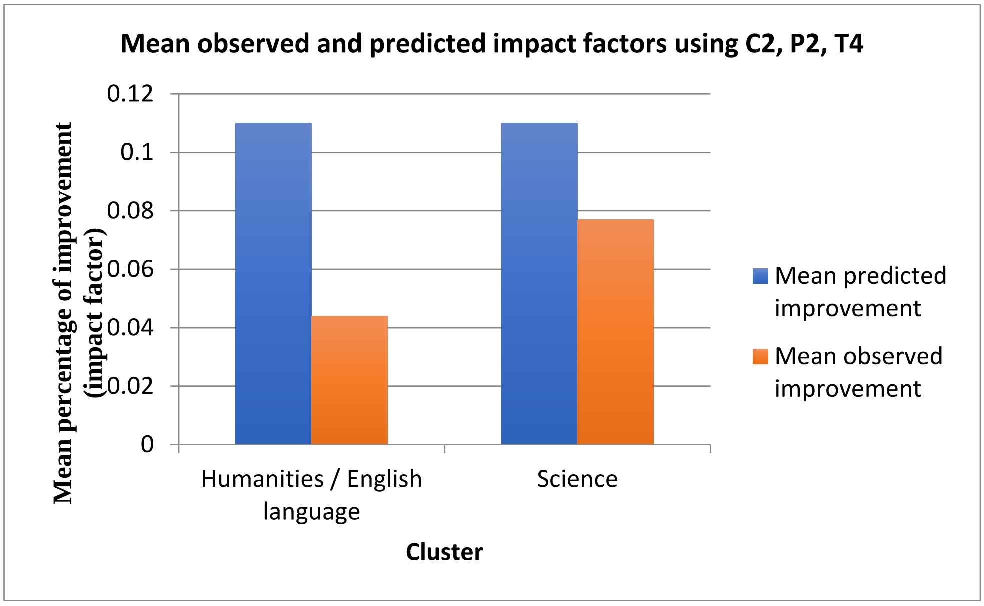


Figure 107. The means of predicted and observed impact factors in the case of using C2, P2, T4 to teach Humanities and Science subjects.

With regard to the C3, P3, T3 strategy, it was used in the humanities and science subjects. Based on Table 61 and Figure 108, it can be concluded that the use of the C3, P3, T3 strategy could improve students' attainment in the science subjects more than it could in humanities. It might also be said that C3, P3, T3 strategy is more suitable for science subjects than humanities. Being aware that the mean observed improvement in the case of science was very close to the expected improvement by the CPT model. Please refer to Table 61.

Strategy / C3, P3, T3 Subject	**Mean predicted impact factor**	**Mean observed impact factor**
Humanities	0.042	0.019
Science	0.042	0.041

Table 61. The means of predicted and observed impact factors in the case of using C3, P3, T3 to teach Humanities and Science subjects.

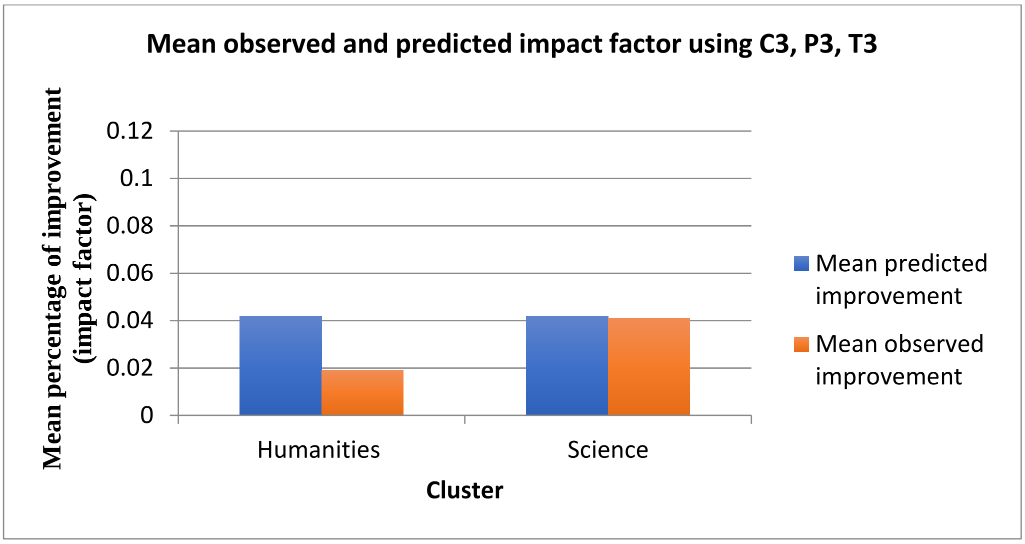


Figure 108. The means of predicted and observed impact factors in the case of using C3, P3, T3 to teach Humanities and Science subjects.

Overall view, educational technology has had a positive impact on students' attainment (at the level of the group). Furthermore, the means of predicted and observed impact factors were close to each other in the majority of the cases in stage three. Therefore, the researcher would suggest that the CPT model is a valid and reliable tool as a predictive model for the improvement in students' attainment due to the use of educational technology, i.e., the null hypothesis could not be rejected.

6.4 THE "SO WHAT?" ASPECT

Based on the data analysis of stages two and three (refer to sections 6.1 and 6.2), all CPT strategies achieved an improvement in students' attainment, which demonstrates the positive impact of educational technology on students' attainment. However, the data analysis of this study indicated that educational technology impacted positively on students' attainment when it was used with science subjects but less so when it was used with the humanities subjects.

Based on the mean values of the observed impact factor (please refer to Table 44, Table 46, Table 48, Table 50, Table 53 and Table 55), I would claim that the strategies shown in the Table 62 below are the most effective strategies to teach science and humanities subjects.

Subject	Strategy	Number of trials	Mean value of the observed impact factor	Mean value of the Predicted impact factor	The difference between the means of observed and predicted impact factors
Physics	C2, P2, T4	2	0.073	0.110	0.040
Biology	C3, P3, T4	2	0.071	0.075	0.004
Mathematics	C2, P2, T4	1	0.098	0.110	0.012
English language	C3, P3, T4	2	0.094	0.075	0.019
Social studies	C3, P3, T4	1	0.108	0.075	0.033

Table 62. The most effective strategies to teach science and humanities subjects.

Note: for a detailed description of the implementation of the digital technology-based learning (Cnc, Pnp, Tnt), and the nondigital technology-based learning (Cnc, Pnp, T0), i.e., the CPT strategies, please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

6.5 SUMMARY OF STAGE THREE

6.5.1 Summary of Stage Three. Part one: Science Subjects

Table 63, Figure 109, Figure 110 and Figure 111 show the mean values of the observed and predicted impact factors (improvements) in the science subjects. Also, it gives an overview of the statistical description of the CPT strategies that were applied to the science subjects in the third stage of this study.

No of studen ts	Grade / Gender	Subject Cnc Pnp Tnt	The mean observed impact factor, %	The mean predicted impact factor, %	Tstat	Tcritical	Effect size (Cohen's D)	Correlation factor (R)	P-value	Σ X^2
20	8 / F	Biology using C2, P2, T4	6.10	11.1	3.95	2.09	0.520	0.870	$8.00*10^{-4}$	$2.6*10^{-13}$
20	8 / F	Biology using C3, P3 T4	10.7	7.50	1.56	2.09	0.810	0.720	0.130	$1.10*10^{-38}$
20	11 / M	Biology using C3, P3 T4	3.50	7.50	2.60	2.09	0.421	0.670	0.017	$3.07*10^{-24}$
17	10 / M	Biology using C3, P3, T3	6.30	4.20	1.05	2.11	0.50	0.780	0.310	$1.33*10^{-49}$
20	10 / M	Biology using C3, P3, T3	8.0	4.20	1.39	2.09	0.530	0.780	0.180	$2.49*10^{-141}$
16	9 / M	Maths using C2, P2, T4	9.80	11.1	0.340	1.75	0.380	0.920	0.730	$2.31* 10^{-53}$
20	11 / M	Maths using C3, P3 T4	4.70	7.50	1.52	2.09	0.464	0.663	0.140	$3.106*10^{-31}$
14	10 / M	Maths using C3, P3, T3	1.90	4.20	1.84	2.16	0.320	0.665	0.090	$3.045*10^{-13}$
18	11 / F	Physics using C2, P2, T4	6.80	11.1	3.63	2.10	0.930	0.670	0.001	$4.70*10^{-9}$
18	11 / M	Physics using C2, P2, T4	7.80	11.1	2.45	2.10	0.869	0.769	0.025	$4.27*10^{-8}$
20	9 / F	Physics using C3, P3 T3	3.20	4.20	1.28	2.09	0.70	0.670	0.210	$4.93*10^{-6}$
21	11 / M	Physics using C2, P2, T4	7.40	11.1	1.29	2.08	0.364	0.785	0.210	$7.10*10^{-58}$

Table 63. The means of the observed and predicted impact factors in the science subjects and the statistical description of the CPT strategies applied.

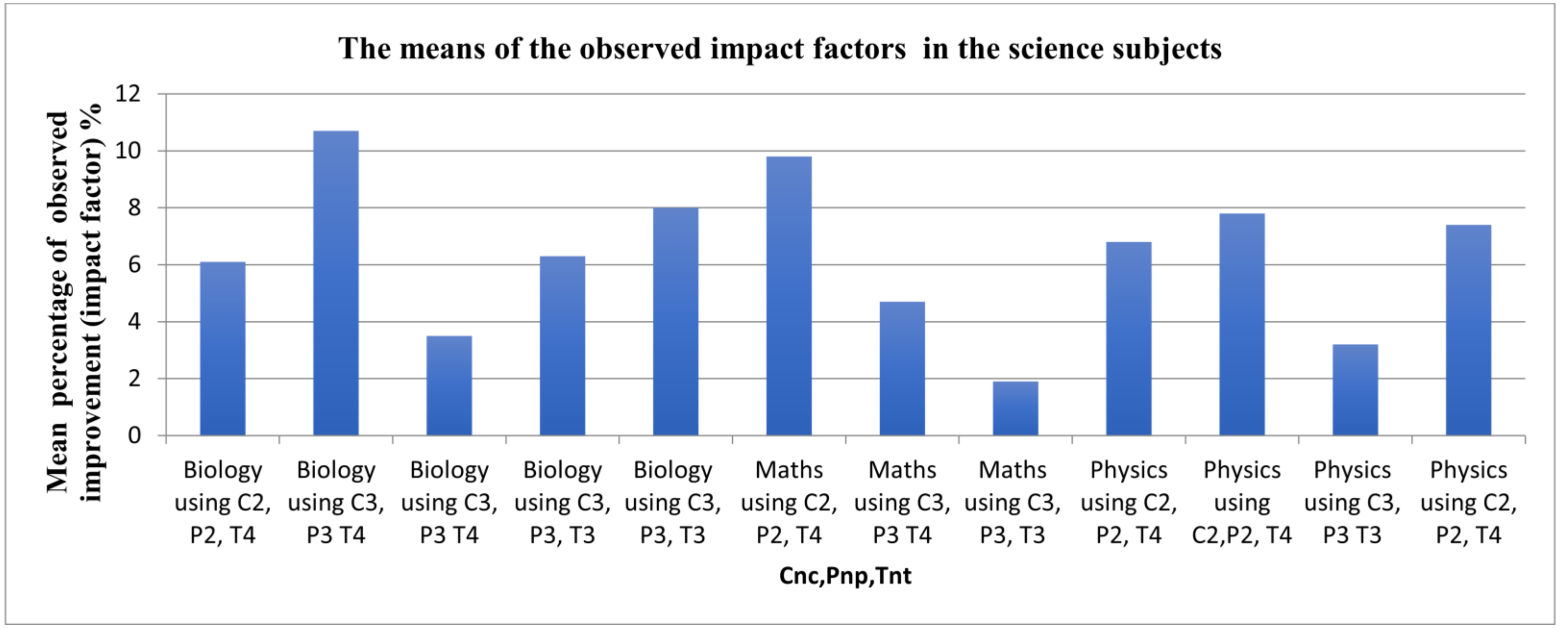


Figure 109. The means of the observed impact factors in the science subjects (ordered according to the subject) using different CPT strategies.

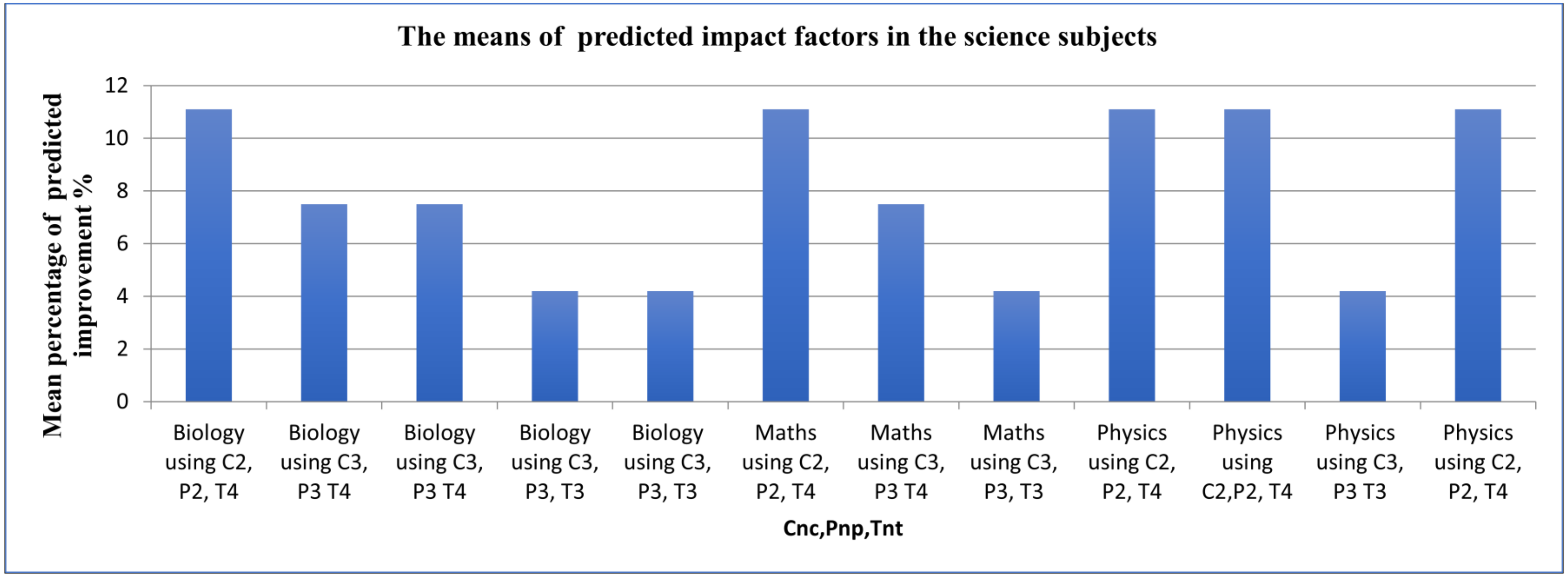
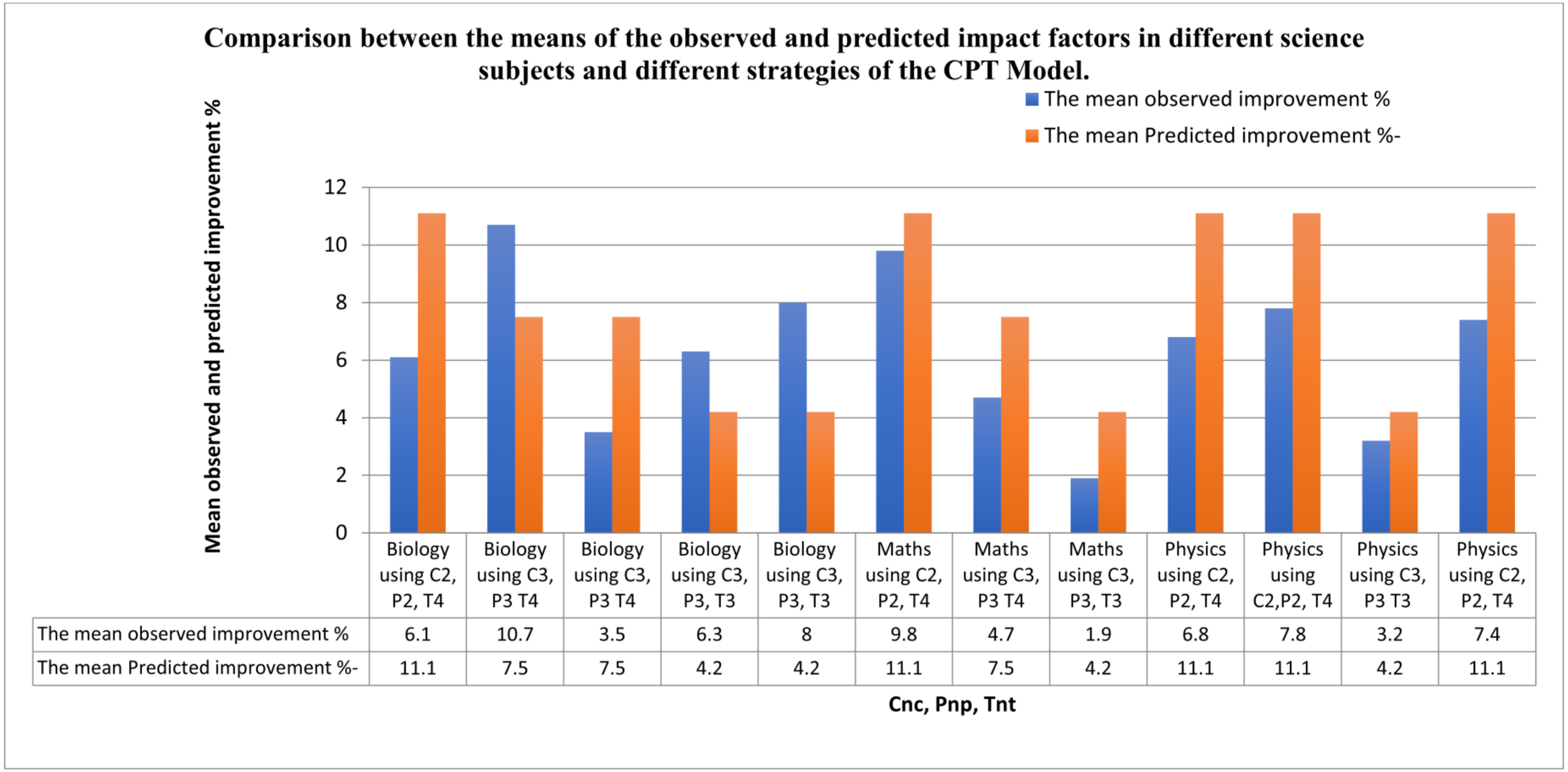


Figure 110. The means of the predicted impact factors in the science subjects (ordered according to the subject) using different CPT strategies.



	Biology using C2, P2, T4	Biology using C3, P3 T4	Biology using C3, P3 T4	Biology using C3, P3, T3	Biology using C3, P3, T3	Maths using C2, P2, T4	Maths using C3, P3 T4	Maths using C3, P3, T3	Physics using C2, P2, T4	Physics using C2,P2, T4	Physics using C3, P3 T3	Physics using C2, P2, T4
The mean observed improvement %	6.1	10.7	3.5	6.3	8	9.8	4.7	1.9	6.8	7.8	3.2	7.4
The mean Predicted improvement %-	11.1	7.5	7.5	4.2	4.2	11.1	7.5	4.2	11.1	11.1	4.2	11.1

Figure 111. Comparison between the means of the observed and predicted impact factors in the science subjects (Biology, Mathematics and Physics).

6.5.2 Summary of Stage Three. Part Two: Humanities Subjects

Table 64, Figure 112, Figure 113 and Figure 114 show the mean values of the observed and predicted impact factors (improvements) in the humanities subjects. Also, it gives an overview of the statistical description of the CPT strategies that were applied to the humanities subjects in the third stage of this study.

No of students	Grade/ Gender	Subject Cnc Pnp Tnt	The mean observed impact factor, %	The mean predicted impact factor, %	T-test	T-critical	Effect size (Cohen’s D)	Correlation factor (R)	P-value	ΣX^2
16	9 / M	English using C2, P2, T4	4.40	11.1	2.34	2.14	0.250	0.780	0.030	$3.40*10^{-43}$
16	9 /M	English using C3, P3 T4	8.80	7.50	0.560	2.14	0.70	0.920	0.580	$2.45*10^{-26}$
25	11 / M	English using C3, P3 T3	1.50	4.20	0.820	2.06	0.10	0.520	0.420	0.0
20	11 / M	English using C3, P3 T4	10.0	7.50	1.25	2.09	0.748	0.780	0.223	$1.60*10^{-35}$
20	9 / F	Social studies using C1, P1, T1	2.60	1.40	2.48	2.09	0.510	0.890	0.020	$1.46*10^{-36}$
15	11 / M	Social studies using C3, P3 T4	10.8	7.50	1.91	2.14	0.910	0.840	0.070	$5.10*10^{-16}$
27	9 / M	Social studies using C3, P3 T3	2.20	4.20	2.04	2.05	0.230	0.740	0.050	$1.40*10^{-49}$

Table 64. The means of the observed and predicted impact factors in the humanities subjects and the statistical description of the CPT strategies applied.

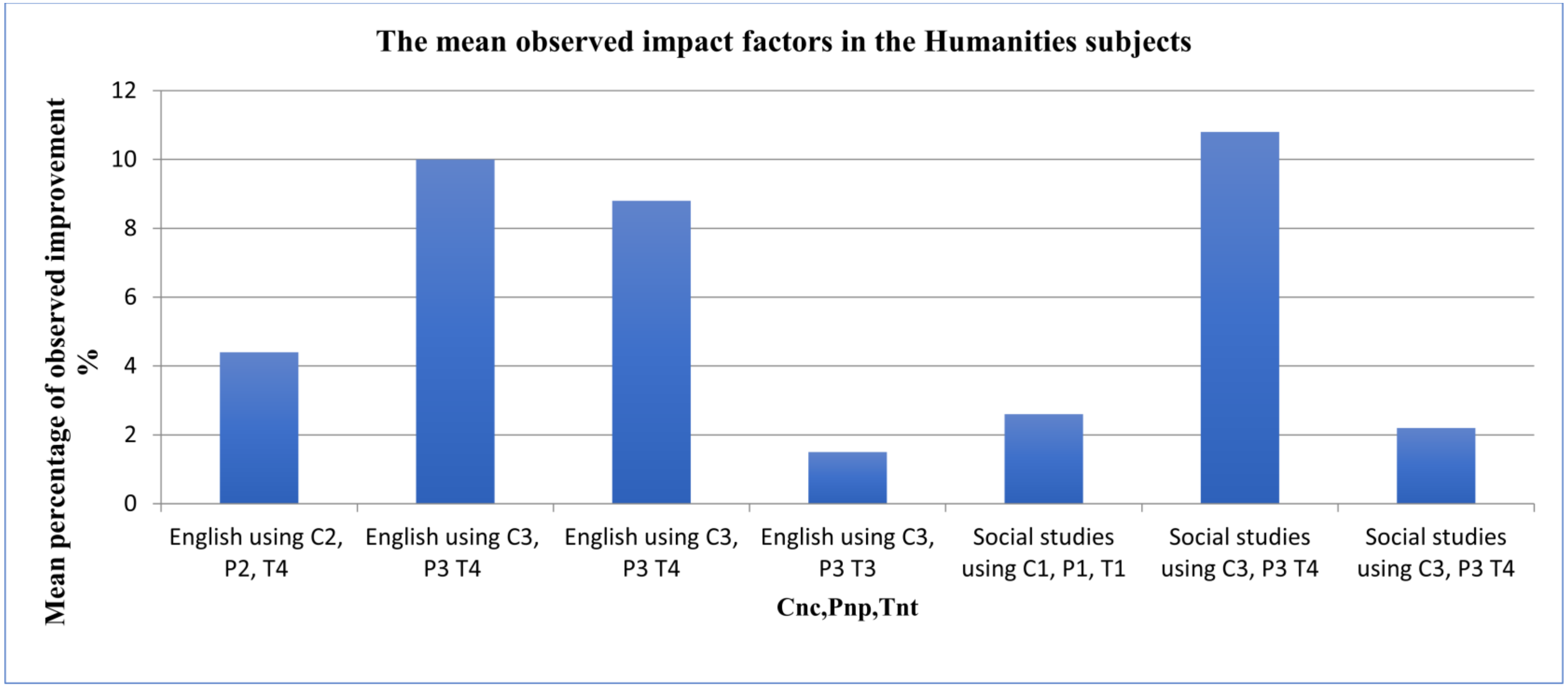


Figure 112. The means of the observed impact factors in the Humanities subjects (ordered according to the subject) using different CPT strategies.

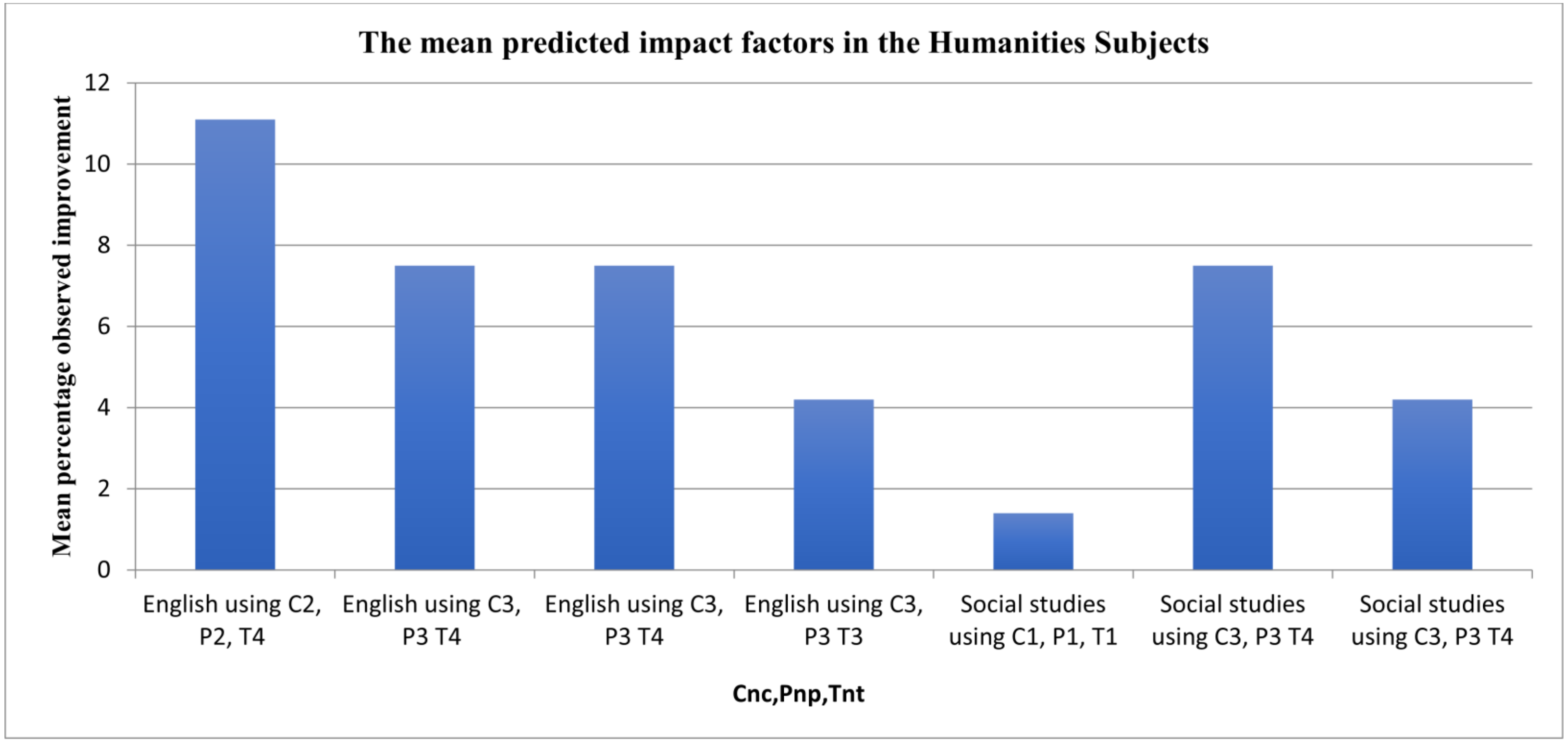
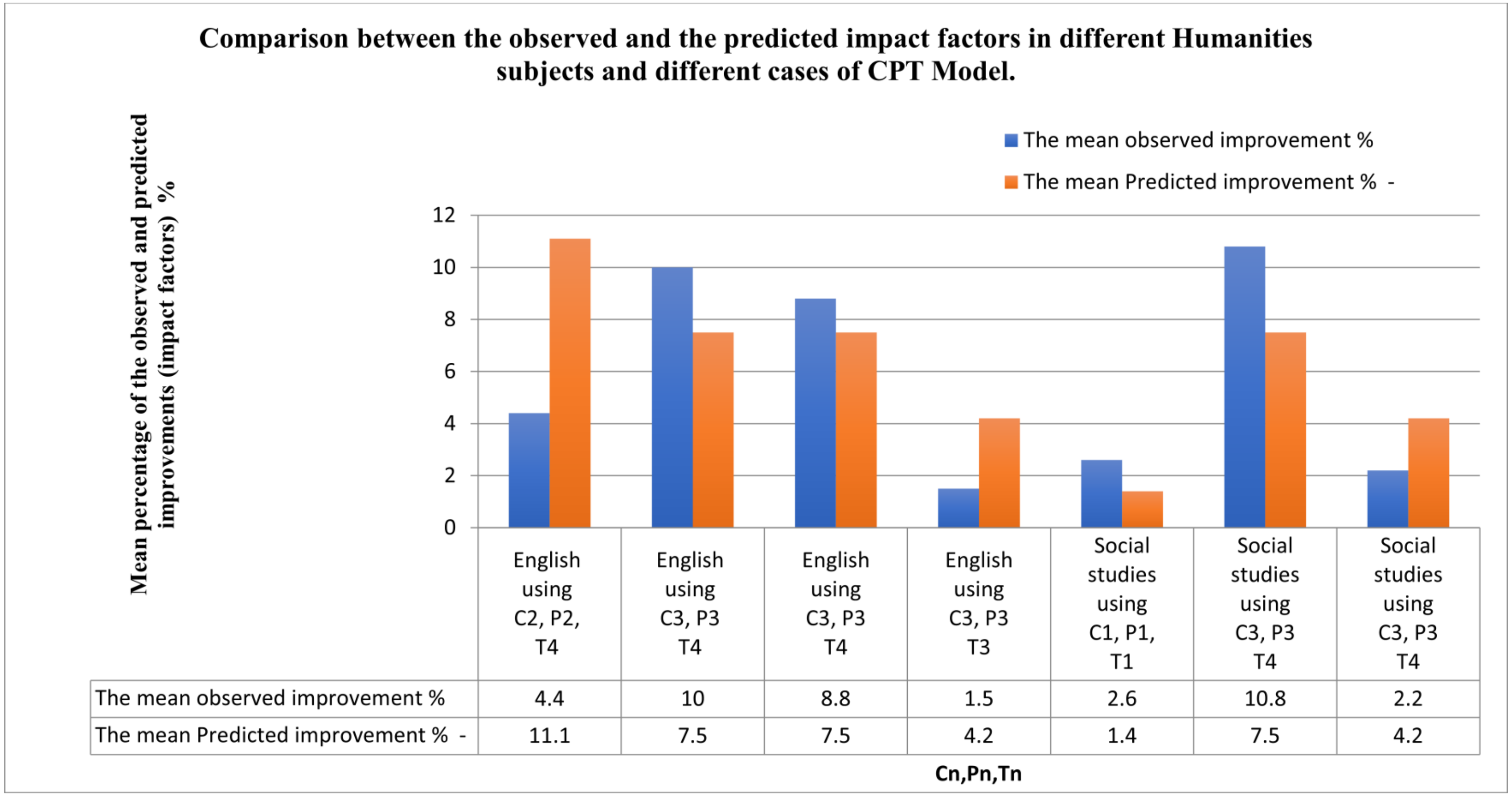


Figure 113. The means of the predicted impact factors in the Humanities subjects (ordered according to the subject) using different CPT strategies.



	English using C2, P2, T4	English using C3, P3 T4	English using C3, P3 T4	English using C3, P3 T3	Social studies using C1, P1, T1	Social studies using C3, P3 T4	Social studies using C3, P3 T4
The mean observed improvement %	4.4	10	8.8	1.5	2.6	10.8	2.2
The mean Predicted improvement % -	11.1	7.5	7.5	4.2	1.4	7.5	4.2

Figure 114. Comparison between the observed and predicted impact factors in the Humanities subjects (English language and Social studies).

6.5.3 Statistical Description of the Third Stage

As indicated previously in the methodology chapter, the data were analysed using the following statistical functions:

1. The effect size (Cohen's D). This test was used to measure the effect of using educational technology on students' attainment.
2. The Pearson Correlation coefficient. This test was used to check the relationship between the use of educational technology and students' attainment (the correlation between the variables). In other words, to check the correlation between students' marks with and without using digital technology in their learning.
3. The T-test was used to compare the means of data from two related samples, i.e., to check the difference between the means of expected and observed improvements in students' attainment whether it is significant or not.
4. The Chi-square test. This test was used to compare the observed frequency (observed improvement) in each group to the frequency which would be expected (predicted improvement). Thus, the researcher was able to determine whether there was, or there was no significant difference between the expected and observed improvements.
5. The P-value. This was used to measure the strength of the evidence against the null hypothesis by estimating the probability of obtaining an equally extreme or more extreme result than what was observed if the null hypothesis is correct.

Table 65, Table 66 and Figure 115 below show the mean values of the statistical functions (Chi-square value, P-value, T-test, Pearson correlation factor (R) and the Effect size (Cohen's D) for all cases, conducted in stage three, that are shown in Table 63 and Table 64, which includes science and humanities subjects.

The statistical function	Statistical description based on the mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size.
Chi-Square	As shown in Table 66, Chi-Square mean value was calculated and found to be less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies (improvements) is considered to be a good one. Hence, the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the expected and observed improvements.
P-value	As shown in Table 66 and Figure 115, P-value (the mean value) was calculated and found to be greater than 0.05, which implies that the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the expected and observed improvements.
T-test	The statistical mean value of t-test was found to be 1.805, which is less than the critical value of the t-test (2.08) as shown in Table 66, which implies that the null hypothesis cannot be rejected, i.e. there was no significant difference between the means of the expected and observed improvements
Pearson correlation factor	As shown in Table 66 and Figure 115, the mean value of the Pearson correlation factor (r) indicates a moderate positive correlation between the use of educational technology and students' attainment. Therefore, these two variables can be considered as dependent variables.
Effect size	As shown in Table 66 and Figure 115, the mean value of the effect size = 0.54, which can be located between medium effect and large effect of educational technology on students' attainment, which implies that the educational technology and students' attainment are dependent variables.

Table 65. Mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size.

Statistical function	Mean value
T-test	1.80
T-critical	2.08
Effect size (Cohen's D)	0.540
Pearson correlation factor (r)	0.760
P-value	0.180
$\Sigma\ X^2$	$7.04*10^{-50}$

Table 66. Mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size for all the cases in stage three.

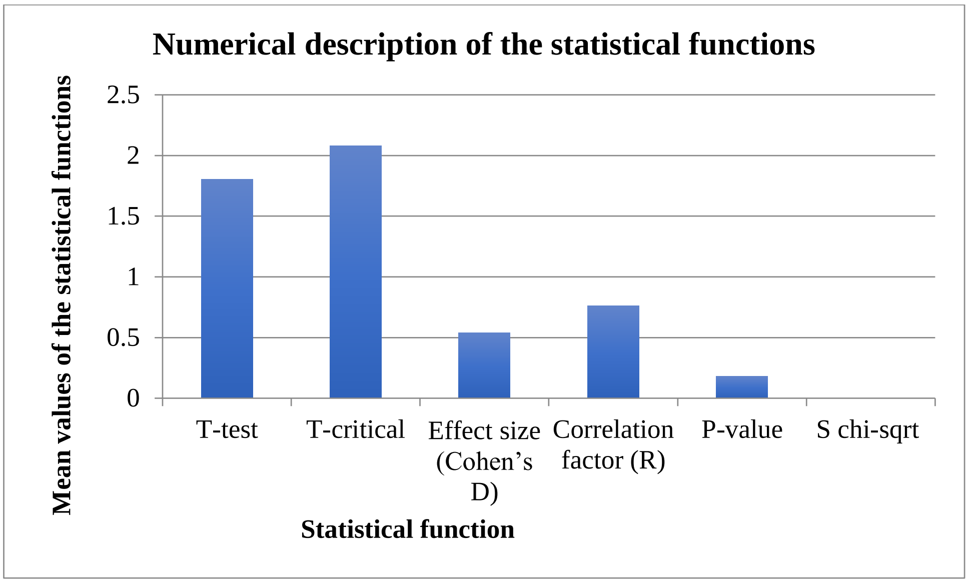


Figure 115. Mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size.

The CPT Model Accuracy

Table 67 and Figure 116 show a comparison between the mean values of the observed and predicted impact factors for all science subjects included in this study. As shown in Table 67, the two values of improvement are close to each other. Based on these values of improvement, the level of accuracy can be found by calculating the percent error, as shown below:

The Percent Error =

$$\frac{7.90 - 6.35}{6.35} x100\% = 24.4\%$$

Therefore, the CPT model accuracy (with regard to science subjects)

= 100 % - 24.4 %

Hence, the level of accuracy = 75.6 %

	Observed improvement (based on pre and post-tests)	**Predicted improvement (based on the CPT model)**
Mean percentage of improvement	6.35	7.90

Table 67. Mean observed and predicted improvements in the science subjects.

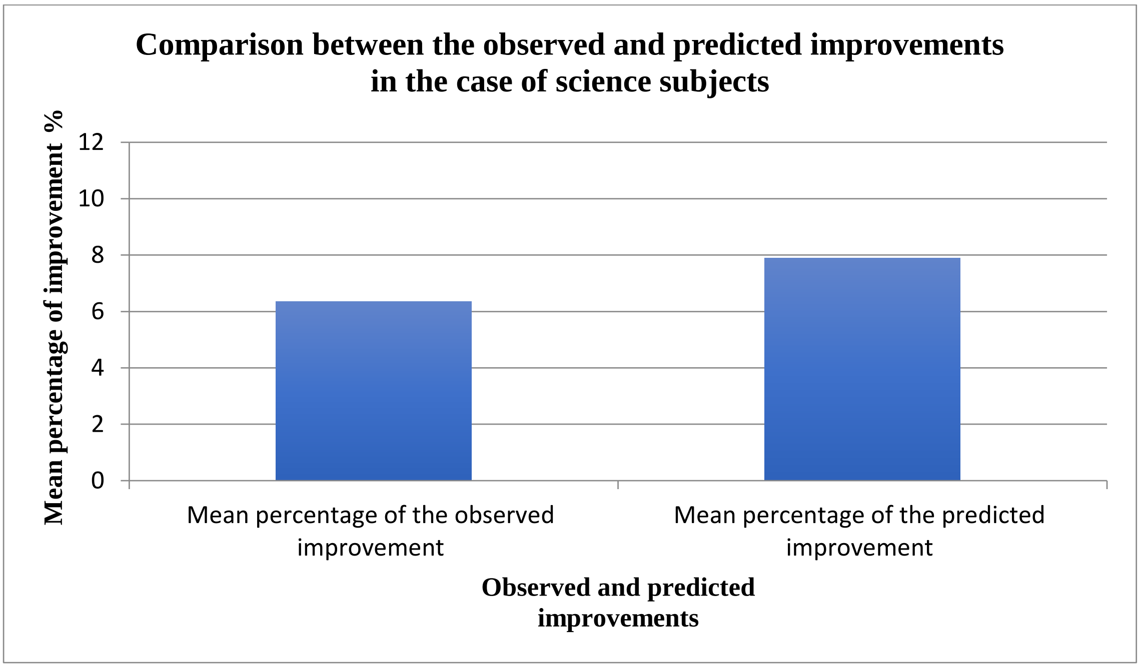


Figure 116. Mean observed and predicted improvements (impact factors) in the science subjects.

Table 68 and Figure 117 show a comparison between the mean values of the observed and predicted improvement for all humanities subjects included in this study. It can be seen that the two values of improvement are very close to each other, as shown in Table 68. Using these values of improvement, the level of accuracy could be found by calculating the percent error, as shown below:

The Percent Error =

$$\frac{6.2 - 5.76}{5.76} x100\% = 7.6\%$$

The CPT model accuracy (with regard to humanities subjects) = 100 % - 7.6 %

Hence, the level of accuracy = 92.4 %

	Mean observed improvement (based on pre and post-tests)	**Mean predicted improvement (based on the CPT model's equations)**
Mean percentage of improvement	5.76	6.20

Table 68. Mean observed and expected improvements of the humanities subjects

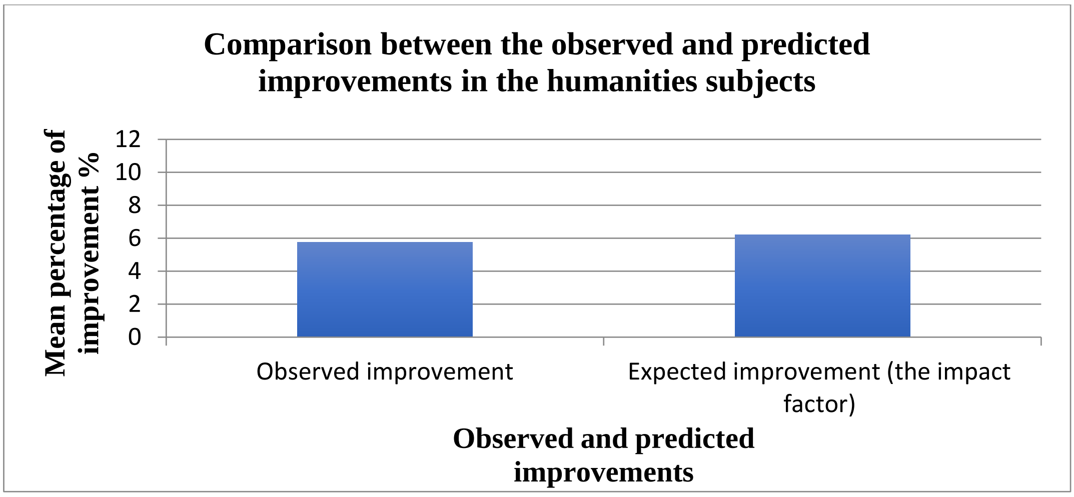


Figure 117. Mean observed and predicted improvements (impact factors) in the humanities subjects.

Overall, the means of observed and predicted impact factors and the calculated percentages of accuracy in both clusters, science and humanities, give strong evidence and credibility to the CPT model and its equations being considered as a valid and reliable tool that can predict the improvement in students' attainment using different learning scenarios (CPT strategies). This means that teachers and curriculum developers can decide in advance, which CPT strategy to apply to implement learning, so that learning outcomes can be maximised.

However, this study, including the CPT model, encountered some limitations, which will be discussed in the next chapter.

CHAPTER SEVEN –
Limitations of the Study

7 LIMITATIONS OF THE STUDY

INTRODUCTION

This chapter outlines some obstacles and limitations encountered during the progress of this study, such as limitations in the literature review, methodological issues, samples, technological functions and limitations in the CPT model and its equations.

Limitations of the literature review

Literature related to the impact of educational technology on students' attainment is reasonably extensive. However, it was limited by investigating this impact qualitatively, i.e., if it has a positive or negative effect on students’ learning. Unlike the purpose of this study as it presents a new research area was not examined previously, which is focused on measuring and predicting this impact quantitatively. Hence, teachers can locate the most effective strategy of learning. However, the researcher affirms that the available literature played a considerable role in this study since it has provided a comprehensive view of the main areas investigated in this study.

Limitations of the employed samples

The primary target of this research is to explore the impact of educational technology on students’ attainment. Thus, it was considered a priority that the selected participants should be familiar with digital technology and should have consistent access to digital technological tools. The researcher works in IAT as a physics teacher. Thus, the researcher knows the samples’ abilities and skills of using digital technology efficiently, which serve the purpose of this research. Being aware that this academic institution is the only institution in the United Arab Emirates that provides each student with a laptop, iPad and a range of virtual learning platforms since the moment they join the school so that there was a guarantee that students will be able to use digital technology for purposes of learning. Likewise, each classroom in IAT schools is equipped with many digital technological tools, such as a projector, wireless internet connection, smart whiteboard and smartpen (IAT, 2018a); unlike other schools where the use of digital technology is limited due to the lack of technological tools. Therefore, the researcher had to select participants randomly from IAT, as it would be risky to choose participants from other institutions might not have sufficient experience in using digital technology and might not have the digital technology itself which will affect the validity of the collected data negatively.

Limitations of the conducted informal interviews

The conducted interviews during this study were focus group-based. The questions asked to participants were purely academic, related to curriculum, pedagogy and digital technology, i.e., had no relationship with private details.

I confirmed to all participants that our speech during these informal interviews shall never be disclosed. However, there is a possibility that some of the participants reflected positive attitudes towards digital technology and different pedagogies, under the effect of the institution's policy, since the use of digital technology in the IAT is mandatory for all teachers. Moreover, participants' positive attitudes towards digital technology might have been influenced by various factors, such as other participants' responses or popular ideas, as well as general trends and thoughts of society. In other words, there is a possibility that the participants, during the informal interviews, revealed expected and accepted views; hence, they keep up with the dominating opinion.

I actively tried to encourage reticent participants. However, some participants were dominating the discussion. Accordingly, dominants' opinions cannot be considered as the group's opinion. In terms of group effects, the focus group may affect how the participants answered the questions. It is not clear to what extent group effects influenced the focus group's answers, but definitely, such effects cannot be entirely neglected. For more information, please refer to section 3.12.1.

I confirm that these limitations in the interviews did not impact the findings of this study, as these interviews were informal. No data were extracted from these interviews, and the sole purpose of conducting them was to form an initial idea about the components of the planned questionnaire.

Limitations in interpreting terms used in the questionnaire

I do acknowledge that question number seven in the questionnaire (please refer to Appendix 4 – Teacher's Questionnaire), might have been confusing for the participants. Therefore, before completing the questionnaire, a significant point was explained, to the participants, related to the implementation of the teaching and learning process. Any learning objective can be implemented using various pedagogical dimensions. For instance, the teacher can achieve a learning objective entirely using direct teaching at the beginning. After which, the teacher, in order to check students' understanding, can give them some tasks and different activities related to the same learning objective to be done using collaborative learning, within groups. After that, the teacher can direct the students to various learning platforms, such as simulations or different journals and ask them to construct new knowledge related to the same learning objective (constructivism). As such, the same learning objective is implemented using different pedagogical dimensions. Using different pedagogies to implement the same learning objective can be seen as a road map for students to reach deeper learning.

This argument suggests that there is no contradiction in the answer received from the participant, SMT1 (please refer to Appendix 5 – Teachers' Responses/ Raw Data), which stands for science male teacher one, who reported that direct teaching is always used, and cognitively active teaching mostly used. SMT1 response means that this teacher is using the direct approach and also the cognitively active teaching to implement the same learning objectives. Being aware that teachers in IAT apply different pedagogical dimensions to perform the same learning objective in order to reach more in-depth learning, as each pedagogical dimension has its own challenges, requirements and nature of tasks. Consequently, students' higher-order thinking skills, such as analysis, synthesis and critical thinking can be developed, which leads ultimately to improvement in students' learning.

Regarding the phrase regurgitating facts, it was used in the questionnaire and explained to the involved teachers through the lens of the local cultural background. Thus, based on cultural perspectives, I informed the teachers that this term means the same as the term, recalling facts, which, in terms of learning, has less negative connotations. I do acknowledge that if the phrase, regurgitating facts, was used in another culture, then there might be possible bias effects on participants' responses.

However, according to the culture where the questionnaire was applied, this term did not affect respondents’ answers, as it means recalling the facts, which is commonly used expression between teachers in the IAT.

Limitations in the activities and tasks carried outside the classroom

All activities, tasks and exams during this study were implemented inside the classroom. This decision was made by the researcher and the supervisory team, for several reasons.

First, to measure students' real attainment. If students were given exams to do it from home, there is no guarantee that they will do it on their own. There is a possibility that the students will receive the answers from others, such as private tutor, relatives or other students. Hence, the attainments measured would not reflect students’ real levels.

Second, cognitive and social constructivism, including the scaffolding process and collaborative learning, are main factors in this study. To ensure successful implementation of these factors, students did all the activities and tasks inside the classroom.

Third, part of this study relies substantially on digital technology. Therefore, students need the internet to implement educational tasks. The internet is offered free of charge for all teachers and students inside the campus. However, some students reported that they do not have the internet at home. Therefore, activities and tasks were implemented in the school. Hence, there is a guarantee that all students can use the internet to implement digital technology-based learning.

Fourth, regarding the tasks and activities related to nondigital technology-based learning. If it was given to students to do it from home, then there is a possibility that they would use digital technology tools to implement it, such as the Internet or specific software. This would harm the credibility of the results.

Finally, a significant portion of students is not willing to do homework. Giving them tasks to do it at home leads them to copy it from each other, i.e., according to Markussen et al. (2014) it creates a layer of students called the free riders.

Based on these reasons, I agreed with the involved teachers to implement all activities, tasks and assessments inside the classroom.

Limitations of the iPad's functions

Some participants in this research had iPads, but not laptops, so all the activities, such as accessing the LMS, completing assignments and checking the uploaded content were carried out with an iPad. This proved to have some drawbacks, which can be summarised as follows:

The problem with some of the virtual platforms is that they are barely supported on the iPad. This means that the process of downloading an assignment, completing it and then uploading to be marked and given feedback is problematic. The problem occurs when a student tries to upload the completed task back to the virtual platforms (online system). As the attach icon on the iPad will pop up and will ask to attach the file from specific locations (directory folders) which should have the needed file. However, the problem is that these directory folders are not located on the iPad, so though it can be easily located on the laptop, it is not possible with an iPad.

These folders are not located on the iPad due to the fact that the required files (the assignments) are saved in the applications themselves and not in separate folders (directory folders), which is the aim of the iPad that the applications (Apps) can save the files automatically. So that the only way to submit the file was to make capturing for each page separately to be submitted as a full file, eventually a massive number of files (pages) will be submitted from each student. However, this is impractical as the number of pages would be impossible to handle for the teacher, considering marking and feedback, which should be directed back to the student.

The solution to this problem was the traditional way of dealing with files: student downloads the file using the iPad, works on it using different apps then uses the email or Dropbox to send the file back to the teacher. However, this created another issue as the capacity of the email is only 500 MB, and in the case of the Dropbox is 2 GB. Neither capacity is adequate for the students' coursework.

Limitations of the learning management system (LMS)

The LMS itself does not offer its members the full service, as it does not have its own applications to allow students to be independent and apart from external applications do not belong to the LMS. This implies that students can download the file from the LMS, but to deal with it, they must have some external applications, such as the type with pdf, good reader or adobe reader. Being aware that some of the external applications are not free of charge.

Recommendations based on this study to develop the LMS

1. Create an application in the iPad with a name Directory folder that allows students to save their coursework in it. Hence, students can upload their work to the LMS or any other virtual learning platform.
2. Provide the LMS with its own applications to allow students to work (solve the assignments) inside the LMS itself without using any external application. This can be achieved by integrating the LMS and other Apps, such as Type on Pdf.
3. The management of a school should include in their programs some training sessions related to the use of LMS. Hence, students and teachers can use it effectively.

Limitations of the CPT model and its equations

The selected samples in this research can be considered as a representative sample of the specific population that was studied in IAT schools; please refer to section 3.17.2. Therefore, I would claim that the findings of this study can be generalised to this particular population only (IAT schools), but there is no guarantee that it can be generalised to other external populations. Which agrees with Bryman (2012) who stated that the findings of qualitative studies, such as educational research offer researchers a rich source of data, but do not provide results that can be generalised to external populations.

Furthermore, based on the data analysis of this study, the means of the predicted and observed improvements were compared and found to be in the majority of the cases close to each other. However, none of the cases showed that these means are equal to each other, which might be considered as a limitation of the CPT equations.

Limitations related to the definition of learning suggested by this thesis

The offered definition of learning in this thesis did not specify the nature of the learning environment if it is an authentic or merely abstract principle isolated from the context of use. This might be considered as limitations in the offered definition. For more details, please refer to section 2.1.1.

Limitations of the assessments conducted, and content delivered in this study

As agreed with the teachers involved in this study, the content and assessments conducted in the first and second situations (nondigital and digital technology-based learning) should have the same level of complexities, so that the impact of digital technology could be distinguished by the difference in students' attainment in both situations.

Webb's (Mississippi Department of Education, 2009) and Florida's (Cpalms.org, 2019) depth of knowledge (DOK) levels were employed to review the contents' level of complexities in both scenarios, refer to section 3.17.5.1. Moreover, the cognitive levels, of the exams conducted after nondigital and digital technology-based learning, were reviewed using Bloom's taxonomy, please refer to section 3.17.5.2. However, I do acknowledge that there is a possibility, in some cases, that the level of complexities, in the assessment conducted and the content delivered, was not completely identical.

Limitation related to both forms of the impact factor's equations (Equation 8 and Equation 9)

I do confirm that I tried to derive Equation 9, and prove mathematically that both equations, Equation 8 and Equation 9, are identical. I acknowledge that further research needs to be carried out to develop sustained proof of Equation 9. Being aware that both forms of the impact factor's equation, Equation 8 and Equation 9, could give identical results in most of the cases. However, there are a few cases where the results are slightly different. This would suggest that there are mathematical differences between both equations, minor differences as the values calculated using both equations are very close to each other, which requires more in-depth investigation. For more details, please refer to sections 5.2.2 and 5.2.3, including Table 34.

Limitations related to teachers' attitude

In each case of this study, both components of each CPT strategy, digital and nondigital technology-based learning, were implemented by the same teacher. Thus, a teacher's attitude and effect on teaching, learning, students, assessments, and marking would appear in both situations. Although the same attitudinal effects could prevail regarding teaching and learning with digital and nondigital approaches, teachers could nevertheless favour one approach rather than the other. In turn, this implies that a teacher's positive attitude towards digital approaches rather than nondigital approaches to learning could bias the findings in favour of digital approaches, and the vice versa. However, to minimise the influence of teachers' attitude on the findings of this study, several procedures were considered:

First, each teacher was asked to show the same positive attitude and be as objective as possible, regardless of their preferred teaching method, while implementing both learning scenarios, digital and nondigital technology-based learning. Teachers' positive attitudes, towards both learning scenarios, were noticed during the lesson observations; please refer to Appendix 7 – Samples of Collected Notes During Lesson Observations.

Second, the involved teachers were asked to create a positive learning environment in both scenarios. This includes the physical environment as safe, clean and well-equipped classrooms, digital or nondigital technology tools, as well as the positive, encouraging and friendly relationship between the teacher and students.

Third, the same pedagogical dimensions and kinds of the curriculum were applied in both scenarios, digital and nondigital technology-based learning. Please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

Fourth, Webb’s (Mississippi Department of Education, 2009) and Florida’s (Cpalms.org, 2019) depth of knowledge levels were employed to review the contents’ level of complexities in both scenarios, refer to section 3.17.5.1. Moreover, the cognitive levels, of the exams conducted after nondigital and digital technology-based learning, were reviewed using Bloom’s taxonomy, please refer to section 3.17.5.2 and section 3.17.5.3. As such, teachers, regardless of their attitude towards any of the learning scenarios, could judge the complexity levels of the contents delivered and exams conducted in both scenarios, digital and nondigital technology-based learning, please refer to section 3.17.5, Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons and Appendix 8 – Samples of the Exams Conducted During this Study.

I confirm that Webb’s and Florida’s depth of knowledge levels and Bloom’s taxonomy stages were discussed with the teachers involved in this study.

Finally, in both scenarios, digital and nondigital technology-based learning, teachers were requested to emphasise the constructivist educational beliefs that adopt the student-centred approaches to learning (Tondeur, et al., 2008). Hence, students, in both learning scenarios, could build their knowledge and develop their understandings; please refer to section 3.7.

Limitations of data collected during the pilot study (Teachers' previous records)

The purpose of including this limitation is to answer the following question:

The improvement in students’ attainment during the pilot study, is attributed to digital technology or other factors?

Teachers' previous records (mark books) were based on the students' results in grade nine. At the time the research was conducted, students could join the IAT in grade nine. Usually, the new students at IAT spend the first month without an iPad or a laptop, so that the manner of learning during this period and the conducted exams are based on nondigital technology-based learning. After students receive the iPads, their educational process and the conducted exams are based on digital technology-based learning. By comparing students’ marks in both exams, teachers could give approximate values for the achieved improvement in students’ attainment as an outcome of using educational technology and the percentage of the material (content) that was integrated with digital technology.

I do acknowledge that there is a possibility that other factors else digital technology, such as the pedagogical dimensions or content's level of complexity, played a considerable role in improving students' attainment. Unfortunately, this aspect during the pilot study could not be controlled, as these marks were previous marks, being aware that the CPT model was not developed yet. However, at that time, this sample was the only available sample, and the target was to form an initial understanding of the impact of educational technology on students' attainment. Therefore, this sample was used to build the initial idea of this research, with a plan to test all findings during the in-depth investigation of this research. I do confirm that this aspect was controlled during the main study using the CPT model. Therefore, I can claim that the improvement in students' attainment during the main study is attributed to digital technology only. This claim is explained in section 6.1.1, and described through examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

Limitation of documentation, including lesson observations

A few periods were observed by the researcher, as this was not part of the involved teachers' culture to be monitored by a colleague, and they would not allow this. In general, the teachers are sensitive towards being observed and monitored. Furthermore, I acknowledge that it was difficult to find anyone to participate, and they would not have done so if they were to be monitored by the researcher. However, several meetings with the involved teachers were conducted to explain what is required and how it should be done. But I do confirm that regular meetings with the involved teachers on individual bases were arranged, either to check their progress and understanding of the process or if they had any questions or needed some support and explanations. Scanned copy of the collected notes while attending some lessons are presented in Appendix 7 – Samples of Collected Notes During Lesson Observations.

Regarding the samples of students' exams, even though I informed the involved teachers that the IAT approved this study, teachers were sensitive towards letting the researcher keep the completed and marked exams for their students, as they considered it to be a risk to their jobs by going against school's policy, in case these papers are published later on. However, I do confirm that the involved teachers have shown me their marked exams, to make sure that it was marked as per guidelines that were shared with them at the beginning (please see marking procedures in section 3.17.5.3). Samples of the marking schemes were provided, please see Appendix 8 – Samples of the Exams Conducted During this Study.

Nevertheless, for the physics subject, I kept some samples of students’ exams in both scenarios (digital and nondigital technology-based learning). Please refer to Appendix 9 – Samples of Marked Exams – Students’ Responses.

CHAPTER EIGHT –

The Contributions of This Study to Knowledge and Future Studies

8 THE CONTRIBUTIONS OF THIS STUDY TO KNOWLEDGE AND FUTURE STUDIES

INTRODUCTION

This PhD study adds to educational technology literature by taking an original lens on the impact of using educational technology on students' attainment. The outcomes of this research were utilised to develop a model that can predict the improvement in students' attainment due to the complex interaction of three critical elements: the content of the curriculum (C), pedagogy (P), and digital technology (T). The developed model is called the CPT model, since it maps the relationship between the three elements (C, P and T) and the improvement in students' attainment (impact factor), using what is called in this study the CPT space.

The contributions of this study to knowledge can be demonstrated as follows.

8.1 A CONTENT, PEDAGOGY AND TECHNOLOGY (CPT) MODEL APPROACH TO THE TPACK MODEL

I would claim that this study could develop the TPACK model. The CPT model deals with the TPACK area (the common area between technology, pedagogy and content knowledge, refer to section 2.8) as a space to be called the CPT space, which is formed of an infinite number of points or CPT vectors. i.e. the common area between digital technology, pedagogy and content knowledge or what is known as TPACK, is no longer considered as a plane (2D) but as suggested by the CPT model, it is a space (3D) full of 3D vectors that represent the CPT strategies of learning.

The idea of vector space (for the purpose of this thesis the vector space is defined as a three-dimensional vector, formed of three components X, Y and Z) was applied to the findings of this study. This vector was developed and redefined in this study using three different components C, P and T, which are considered in this study as the components of the new vector (CPT vector), i.e. C, P and T replaced X, Y and Z, as shown in Figure 118 below.

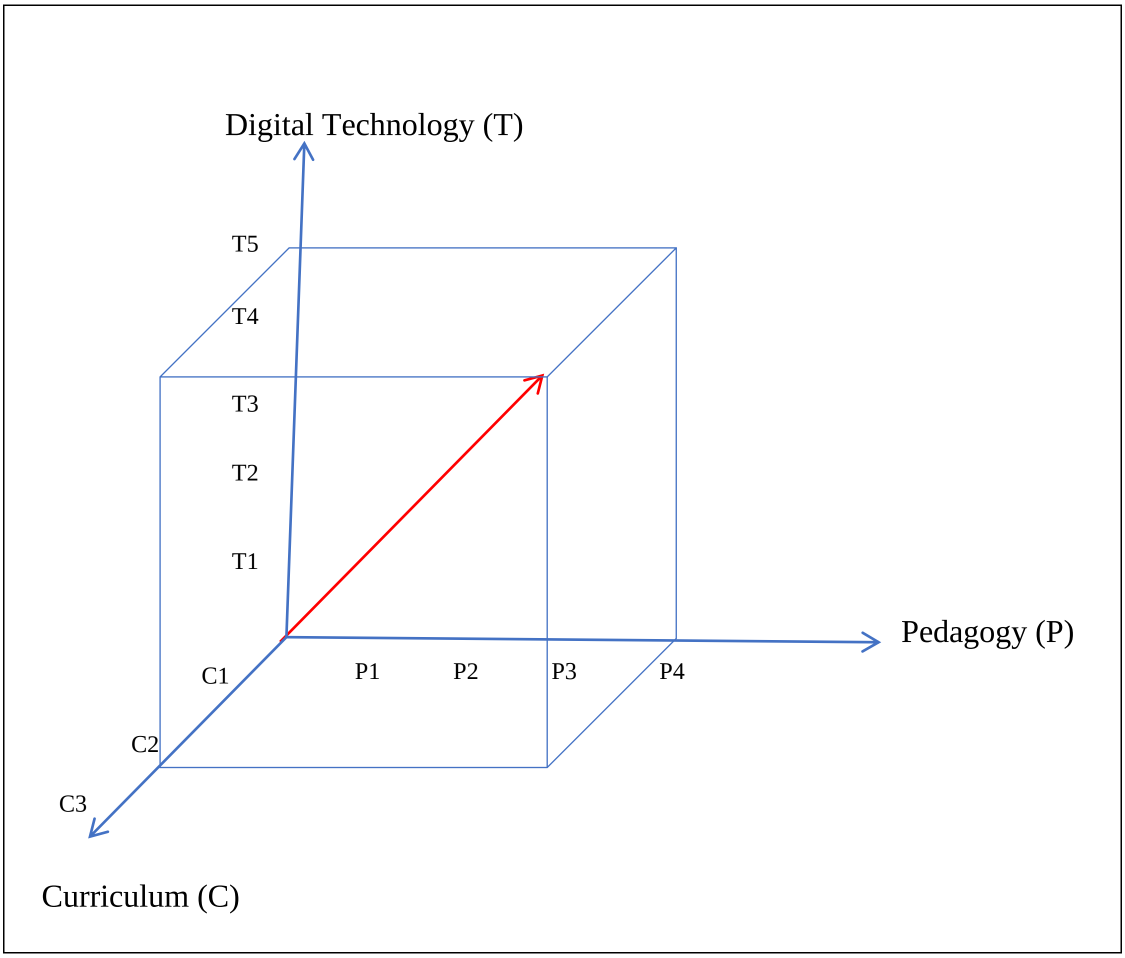


Figure 118. 3D vector space shows the point (2, 4, 1) in the CPT space, which is equivalent to (C2, P4, T5) in the CPT space.

The CPT model proposes an attempt to fill the knowledge gaps, as it guides teachers to locate the most effective strategy of learning, which can be located according to the CPT model using a three-dimensional vector measured by 3D equations (equations of the CPT model). These equations allow teachers to predict what is referred to in this study as the impact factor. For the purpose of this study, the impact factor is defined as the improvement in students' attainment due to the use of educational technology. For more details about the development of the CPT model, please refer to chapter 5

8.2 DEVELOPING SUITABLE CURRICULUMS AND PREDICTING THE IMPROVEMENT IN STUDENTS' ATTAINMENT (PREDICTIVE TOOL)

The potential impact of the findings of this research can be felt predominantly by educators and curriculum designers to develop suitable curricula that can fit with many groups of students regardless of their levels. Educators and curriculum developers will be able to predict the percentage of improvement in students' attainment and to design the curriculum in an effective strategy that can maximise learning outcomes.

Recommendations based on the findings of this study

During this research, several strategies were used to teach Science and Humanities subjects. Some of these strategies are common between both clusters, such as C3, P3, T4; C2, P2, T4; and C3, P3, T3. As shown in Table 69, Table 70 and Table 71. Students' attainment, in both clusters, was improved when using the CPT strategies to implement learning. Thus, I would claim the positive impact of educational technology on students' attainment. Furthermore, Table 69, Table 70 and Table 71 show that there was no significant difference between the means of predicted and observed impact factors (improvements), which may be seen as substantial evidence to support the validity of the CPT model as a predictive model.

The C3, P3, T4 strategy was used in subjects related to Humanities: Social Studies and English language, as well as other subjects related to Science: Physics, Biology and Mathematics. Based on the results shown in Table 69, *C3, P3, T4 strategy could improve students' attainment in humanities more than it could in the science subjects* since the observed improvement in the humanities subjects was higher than the observed improvement in the case of science subjects.

Strategy / C3, P3, T4 **Cluster**	**Mean predicted impact factor**	**Mean observed impact factor**
Humanities	0.075	0.101
Science	0.075	0.060

Table 69. The means of observed and predicted impact factors in the case of using C3, P3, T4 to teach humanities and science subjects.

The C2, P2, T4 strategy was used in teaching the English language, and other subjects related to science: Physics, Biology and Mathematics. Based on the results shown in Table 70 below, *the C2, P2, T4 strategy impacted students' attainment positively in both clusters, but it is more likely to improve students' attainment in the science than in the English language.* Therefore, I would claim that the C2, P2, T4 strategy is more suitable for Science subjects than Humanities.

Strategy/ C2, P2, T4 **Cluster**	**Mean predicted impact factor**	**Mean observed impact factor**
Humanities / English language	0.110	0.044
Science	0.110	0.077

Table 70. The means of observed and predicted impact factors in the case of using C2, P2, T4 to teach humanities and science.

The C3, P3, T3 strategy was used with humanities and science subjects. Based on Table 71, *the C3, P3, T3 strategy could improve students' attainment in the science subjects more than in social studies.* Therefore, it can be stated that the C3, P3, T3 strategy is more suitable for Science subjects than humanities, in particular, Social Studies.

Strategy / C3, P3, T3 **Cluster**	**Mean predicted impact factor**	**Mean observed impact factor**
Humanities	0.042	0.019
Science	0.042	0.041

Table 71. The mean values of the observed and predicted impact factors in the case of using C3, P3, T3 to teach humanities and science.

Based on the data analysis of stages two and three (refer to section 6.1 and 6.2), all CPT strategies achieved an improvement in students' attainment, which demonstrates the positive impact of educational technology on students' attainment. However, as can be seen in Table 69 and Table 70 the *C3, P3, T4 and C2, P2, T4 strategies achieved the most significant observed improvement in students' attainment when applied to teach both humanities and science subjects.*

Overall, *the data analysis of this study indicated that educational technology impacted students' attainment positively when it was used with science subjects but less so when it was used with the humanities subjects*.

Based on Table 44, Table 46, Table 48, Table 50, Table 53 and Table 55 the strategies, shown in Table 72, are the most effective strategies to teach subjects related to science and humanities.

Subject	**Strategy**	**Number of trials**	**The mean value of the observed impact factor**	**The mean value of the predicted impact factor**	**The difference between the means (observed and predicted impact factors)**
Physics	C2, P2, T4	2	0.073	0.110	0.040
Biology	C3, P3, T4	2	0.071	0.075	0.004
Mathematics	C2, P2, T4	1	0.098	0.110	0.012
English language	C3, P3, T4	2	0.094	0.075	0.019
Social studies	C3, P3, T4	1	0.108	0.075	0.033

Table 72. The most effective strategies to teach Science and Humanities subjects.

Note: refer to the data analysis (sections 6.1 and 6.2) and conclusions chapter (chapter 9) for more details about the most effective strategies to teach science and humanities subjects.

Note: for a detailed description of the implementation of the digital technology-based learning (Cnc, Pnp, Tnt), and the nondigital technology-based learning (Cnc, Pnp, T0), i.e., the CPT strategies, please refer to examples 1, 2 and 3 in Appendix 6 – Examples of Lesson Plans/ The Implementation of the CPT Lessons.

8.3 DEVELOPING THE CONCEPT OF DIFFERENTIATION IN THE CLASSROOM

The findings of this research can participate in developing the concept of differentiation in the classroom. The term differentiation is an approach to teaching and learning based on variety and diversity (Singh, 2014).

A teacher in the classroom needs to accommodate the content of the lesson to the students' level of thinking in order to match their abilities. Applying the concept of differentiation in the classroom needs many requirements, such as the use of many pedagogies and learning styles, to ensure that the material is accessible to all students. This claim agrees with Spillman (1991, p. 7) who stated: “The key to the differentiated curriculum is the flexible use by teachers of a wide range of activities and lesson organisations”.

Based on the findings of this study, the term differentiation in the classroom is defined as the process of adapting the content by the teacher using different methods and instruments. Hence, the content can be accessible to the majority of students. In turn, this implies that the term differentiation can be developed to exceed the differentiation in the content only to reach and cover more extensive areas, such as differentiation in the applied pedagogy, content knowledge and the digital technology used to implement learning.

1. **The differentiation in the applied pedagogy to implement the learning objectives.** Each learning objective can be achieved using a specific pedagogical dimension, and it might be implemented using more than one pedagogical dimension at the same time.

The Pedagogical dimensions, as stated in the CPT model are:

i) Direct teaching
ii) Constructive learning
iii) Cognitively active learning
iv) Social collaborative learning

Using one or more of these pedagogies to implement each learning objective can increase the number of students engaged in learning, as students have different mentalities and preferences in the way they prefer to learn, which implies that some students may prefer to learn using a specific pedagogy while others might prefer another pedagogy. Therefore, applying several pedagogies to implement learning can ensure covering several layers of mentalities in the same classroom, which leads to maximising learning outcomes.

2. **Differentiation of content knowledge**. Based on the CPT model, the differentiation in the content knowledge does not mean to reduce the amount of content, which is delivered to low achievers or to increase it for high achievers. But it means that the same content should be introduced to all students, using different forms (shapes) of the content knowledge, which maximises the number of attracted and engaged students in learning, instead of being introduced in one form for all students, which minimises the number of the engaged students.

Based on the CPT model, the content can be introduced and delivered in many forms, such as:

i) Theoretical content, which can be displayed using textbooks, lecture notes and presentations.

ii) Interactive content. This kind of content can be represented by simulation such as Phet simulation, which is created by the University of Colorado (2018).

iii) Practical content: a simple experiment can be conducted during the lesson time or examples provided from the real-life applications.

3. **Differentiation in digital technology and resources** that are used to implement learning, such as the iPad, laptop, media, applications (Apps), simulations, external journals and online libraries.

These techniques of differentiation were used in this study while delivering the content and assessing the participating students; it has been noticed that these techniques had a positive impact on students' academic performance and attainment.

8.4 CONTRIBUTING TO KNOWLEDGE BY A NEW EDUCATIONAL TERM (TRANOLOGY)

The findings of this study contribute to knowledge by a suggestion of a new academic term called **Tranology**, which is a combination of two main kinds of learning, traditional-based learning and digital technology-based learning. For more information about the combination of Tranology, please refer to section 2.9.

The implementation of Tranology requires digital technology to be used as a supplement to traditional learning, not as a replacement. Therefore, traditional learning, which is represented by textbooks, papers (notebooks), pens, i.e., nondigital technology-based learning, should be integrated with digital technology-based learning, represented by computers, smart devices and diverse applications (Apps). I would suggest that this integration produces a full learning experience with a new title which is *Tranology based learning*. An ideal Tranology requires a student to be an active learner in both cases; traditional and technology-based learning.

Furthermore, I would suggest calling the traditional learning (nondigital technology-based learning) as *PNP based learning* which stands for paper and pen-based learning.

What makes Tranology different?

The answer to this question can be demonstrated by comparing two classes A and B. The two classes are studying the same topic. Students in class A are using the classical model of learning (direct teaching), where the teacher explains on the board, students copy the lecture notes from the board. Students need to memorise the topic in order to pass the examination. As such, students are evaluated according to their ability to memorise rather than their critical thinking abilities (passive learners).

In contrast, students in class B are studying the same topic but with different delivery methods. The students in class B are using traditional tools, such as lecture notes, pens, notebooks in addition to computer software and the Internet so that they can have access to external resources including articles, simulations and virtual learning platforms, allowing them to discuss and share ideas. I would argue that this approach to learning is *Tranology*-based learning, where students use both traditional and digital technological tools, and the teacher's role is to monitor, give guidance and distribute tasks. For instance, in the case of studying subjects related to science, students in this class will be able to connect the theoretical side of the material with the practical side by conducting experiments. Data will be collected, a software programme, such as Matlab, C++, Fortran will be used by students to analyse the data. Supported by digital technology, students will have the possibility to compare their findings with external sources of knowledge, such as recently published papers, which can lead students to build new knowledge.

The students in class B have to go through many stages, starting from the stage of using traditional tools to the stage of using digital technological tools for further research. Therefore, students will be more involved in their own learning. These stages offer students an intensive experience and new knowledge, as well as the connection between content knowledge and digital technology. This experience can have a positive impact on students' academic performance. For instance, students in class B might build new knowledge or create new models in the subject they are studying. In contrast, the initiative and innovation for class (A) will likely be minimal as these students' resources are limited by a teacher and a textbook.

I designed Figure 119 below to visualise the three main elements that can form *Tranology-based learning*. As shown in Figure 119, these three components are placed at the three corners of a triangle.

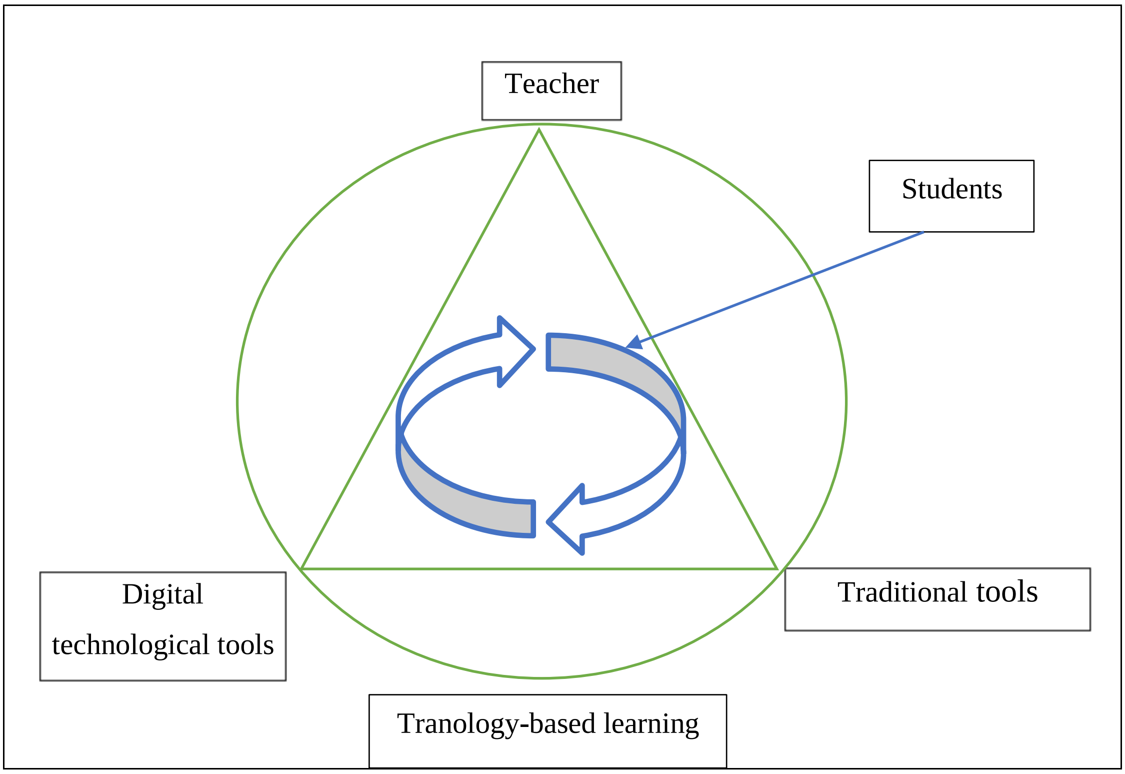


Figure 119. The main elements of *Tranology-based learning*.

Based on Figure 119, I would claim that Tranology process is divided into three stages. Firstly, students receive knowledge from a teacher. Secondly, students need to practice the gained knowledge manually using traditional tools, which makes them stronger practitioners, especially in problem-solving activities. Finally, students need to use digital technology for further research. As such, students expand their horizon, which promotes their critical thinking abilities. Passing through these three stages successfully can shift students from the stage of being knowledge consumers to another one where students become knowledge producers.

8.5 CONTRIBUTING TO KNOWLEDGE BY A NEW RESEARCH AREA (MATHEMATICS BEHIND EDUCATION)

This research can be considered as an entrance to a new research area that can be identified as the mathematics behind education. The findings of this study propose a new model with 3D equations (the equations of the CPT model) that deal with the relationship between content, pedagogy and digital technology, mathematically. Based on the data analysis of this study, these equations have the power to predict the impact factor (the improvement in students' attainment due to the use of educational technology) quantitatively. Being aware that these equations are mathematical equations that were developed, in this study, using the concept of the vector space as shown below (refer to chapter 5, Equation 8, Equation 9 and Equation 10).

Equation 8

$$\text{The impact factor (R)} = \sqrt{Cnc^2 + Pnp^2 + Tnt^2} - \sqrt{Cnc^2 + Pnp^2}$$

The impact factor can be calculated using the following formulas as well:

Equation 9

$$R = R_o (N)^2$$

R_o is the threshold impact factor.

The threshold impact factor (improvement) can be calculated using the following formula:

Equation 10

$$R_o = \sqrt{Cnc^2 + Pnp^2 + 0.2^2} - \sqrt{Cnc^2 + Pnp^2}$$

For more details about the mathematical aspects of the CPT model and its equations, please refer to chapter 5

8.6 FUTURE SCIENTIFIC UNDERSTANDING AND THEORETICAL INSIGHTS OF THE CPT MODEL

The CPT-S curvatures

Being influenced of the work done by Albert Einstein, who developed the concept of space-time, a mathematical model that combines the three dimensions of space (x, y and z) and the one dimension of time to create a four-dimensional space-time (x, y, z and t), including the curvatures in the space-time. As a plan for future work, I would argue that the four-dimensional idea applies to this study. Hence, the CPT model will be transformed from three-dimensional model (C, P and T) to four-dimensional model (4-D) that comprises the three dimensions of curriculum, pedagogy and digital technology (C, P and T) and the one dimension of a student's attitude towards learning (S) to produce 4-D model called the CPT-S model.

As an initial visualisation, the CPT-S, can be imagined as a net, students are standing on it. I would define the CPT-S net as the net of learning knitted by the interaction of four interrelated elements: curriculum, pedagogy, digital technology and student’s attitude towards learning. Considering the three spheres, in Figure 120, are three different students with three different attitudes towards learning, standing on the CPT-S net. As an outcome of having different attitudes, which might be evaluated as positive, neutral or negative, students’ levels of understanding (depths of knowledge) are different. Consequently, as shown in Figure 120, the curvatures’ depths in the CPT-S net are different, which will be reflected in their attainments in particular, and academic accomplishments in general.

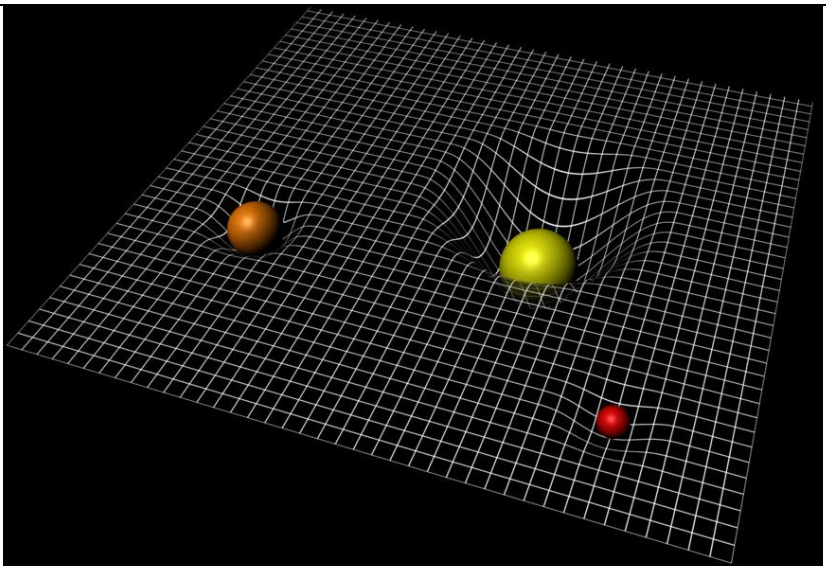


Figure 120. The CPT-S curvatures © 2015 ESA–C.Carreau

Based on these assumptions, I would argue that a student’s attitude toward learning determines two factors.

First, the depth of learning and understanding, which is represented by the depth of the curvature made in the CPT-S net, as shown in Figure 120.

Second, the degree of accuracy of the CPT model equations. In this perspective, based on the data analysis of this study, the predictions made by the CPT model equations (predicted impact factors or improvements) were not exactly equal to the observed ones. I would argue that the difference between the two values of improvements, predicted and observed, can be narrowed by considering students' attitudes toward learning in the CPT model equations.

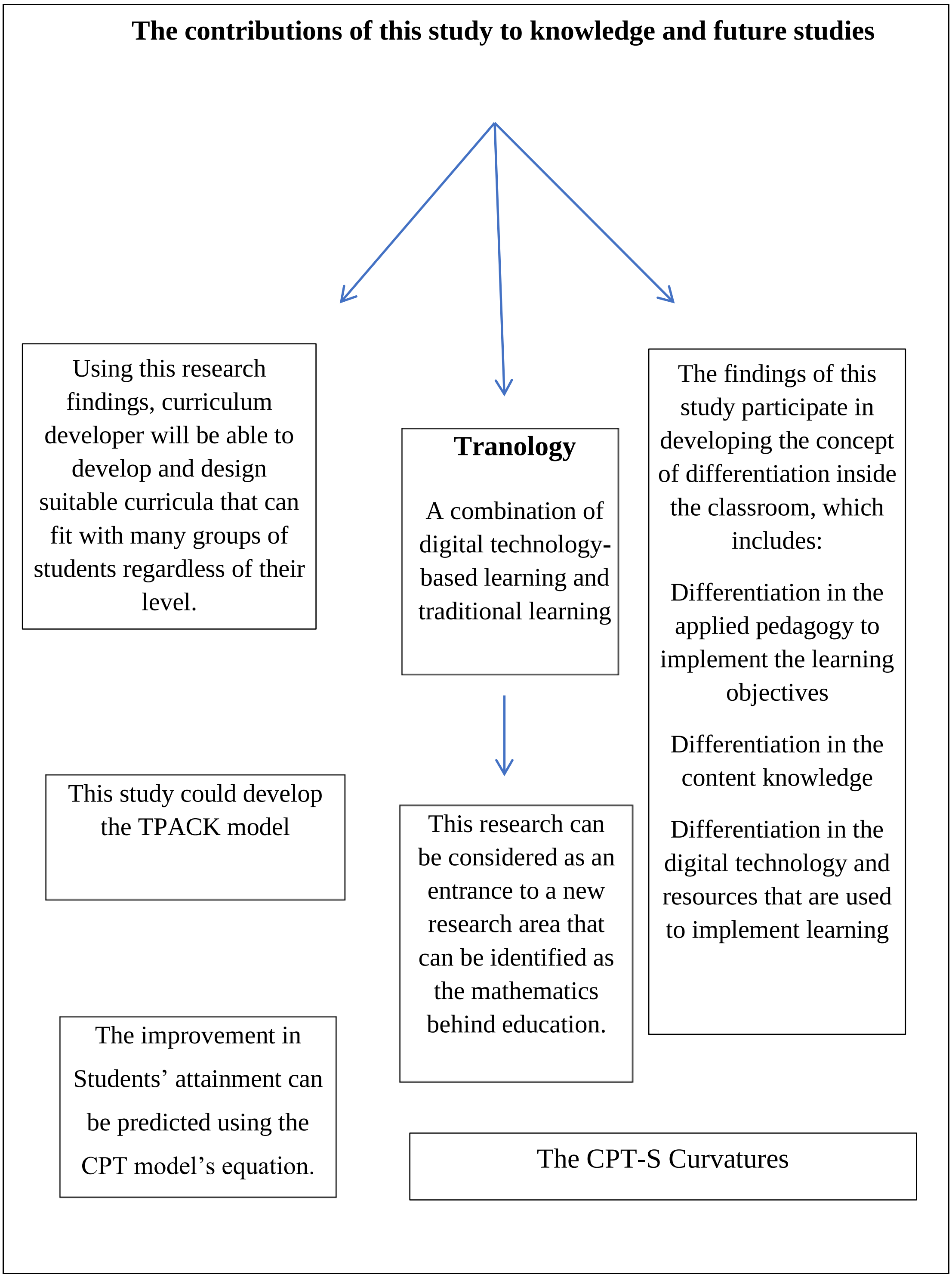
Proving or disproving these ideas and hypothesis requires further research to be carried out in the following areas:

i. Investigate and measure a student's attitude towards learning quantitatively.
ii. Develop the equations of the CPT model. Hence, a student's attitude (S) can be inserted into new equations related to the CPT-S model.
iii. Investigate the relationship between student's attitude towards learning and the depth of the curvature made in the CPT-S net.
iv. Transform the three-dimensional model, CPT, to four-dimensional model, CPT-S.

Furthermore, as a future plan, I would suggest applying the CPT model to a different ethnic group of students, with different socio-economic status. For example, in an area that is not that well-developed, or at least does not have the financial possibility to supply all these digital technology tools to their students and teachers.

In terms of mathematics, extensive research needs to be carried out to derive Equation 9. As explained in section 5.2.2 and chapter 7, there are a few cases where Equation 8 and Equation 9 produce results that are slightly different, refer to Table 34. In turn, this may indicate that there might be undiscovered minimal differences between both equations of the impact factor (Equation 8 and Equation 9). Thus, extensive research in the future is required to discover what are these differences.

Figure 121 shows a summary of the main contributions of this study to knowledge and future studies.



The contributions of this study to knowledge and future studies

Using this research findings, curriculum developer will be able to develop and design suitable curricula that can fit with many groups of students regardless of their level.

Tranology

A combination of digital technology-based learning and traditional learning

The findings of this study participate in developing the concept of differentiation inside the classroom, which includes:

Differentiation in the applied pedagogy to implement the learning objectives

Differentiation in the content knowledge

Differentiation in the digital technology and resources that are used to implement learning

This study could develop the TPACK model

This research can be considered as an entrance to a new research area that can be identified as the mathematics behind education.

The improvement in Students' attainment can be predicted using the CPT model's equation.

The CPT-S Curvatures

Figure 121. The contributions of this study to knowledge and future studies.

CHAPTER NINE –

Conclusions

9 CONCLUSIONS

This research examined three critical elements C, P and T (C –the content of the Curriculum, P –Pedagogy and T – Digital Technology). During the pilot study, teachers' thoughts and beliefs regarding the use of educational technology were investigated using a questionnaire. The analysed data, which was collected from the questionnaire and the teachers' previous records, showed that most of the teachers agreed about the positive impact of using educational technology. The outcomes of the pilot study were employed to develop a new model, the CPT model, which maps the relationship between these elements and measures their effect on learning and students' attainment. The validity of the developed model as an outcome of the pilot study was checked in stages two and three (the in-depth investigation).

The potential impact of the findings of this research can be used by educators and curriculum developers to develop and design suitable curricula that can fit with diverse groups of students, regardless of their level. These findings allow educators and curriculum developers to predict the improvement in students' attainment and design the curriculum using the most effective strategies that can maximise the learning outcomes.

The primary goals of this study were to measure the impact of using educational technology on students' attainment quantitatively and to develop a predictive model that can predict the improvement in students' attainment as an outcome of using educational technology. The developed model (the CPT model) maps the relationship between three elements: digital technology, pedagogy and curriculum. Thus, the improvement in students' attainment could be predicted quantitatively.

The findings of this study can develop the concept of differentiation inside the classroom. Based on the CPT model, the concept of differentiation can be divided into three types: differentiation in the applied pedagogy to implement learning, differentiation in the content knowledge (interactive, practical and theoretical), as well as differentiation in digital technology and resources.

This study contributes to knowledge by introducing a new educational term, **Tranology**, which is a combination of two modes of learning, traditional learning and digital technology-based learning to form a new system of learning that can be called **Tranology-based learning.**

The CPT model deals with the TPACK area (the common area between technology, pedagogy and content knowledge) as a space to be called the CPT space, which is formed of an infinite number of points or vectors. i.e. the common area between technology, pedagogy and content knowledge or what is known as TPACK, is no longer considered as an area or a plan (2D) but as suggested by the CPT model, it is the CPT space (3D) full of 3D vectors (CPT vectors that represent the CPT strategies.

How precisely can the best point (most effective strategy of learning) be located in the CPT space, or even in the TPACK area?

Many researchers investigated the relationship between the content of the curriculum, pedagogy and digital technology, such as Mishra and Koehler (2006), Angeli and Valanides (2009) Graham (2011), Voogt et al. (2012). However, none of the researchers dealt with this relationship or with its impact on students' learning and attainment mathematically, which makes it challenging to find an answer to the above question. Therefore, in this study, I tried to fill this knowledge gap by developing a new model that deals with the elements above (C, P and T) mathematically or quantitatively.

The findings of this study propose an attempt to answer the above questions by developing a new model with 3D equations. The CPT equations can predict the impact factor (the improvement in students' attainment as an outcome of using educational technology) quantitatively. This will enable teachers to determine in advance the most effective strategy of learning. It is important to remember that these 3D equations are mathematical equations established on the basis of the vector space concept. Thus, the CPT model and its equations can be considered as an entrance to a new research area that can be called mathematics behind education. Refer to the contribution to knowledge chapter in this thesis, chapter 8.

For the purpose of checking the validity and reliability of the CPT model, the model was tested in stages two and three of this study. The third stage confirmed the results of the second stage and both stages had confirmed the findings of the pilot study (the first stage). The data analysis of stages two and three showed that in the majority of the investigated cases, there was no significant difference between the means of the observed and predicted impact factors. This implies that the CPT model can be considered a valid and reliable model that can be used to i) predict the improvement in students' attainment as an outcome of using educational technology; ii) help teachers to choose the most effective CPT strategy to achieve the best learning outcomes, and iii) assist curriculum developers in designing the curriculum using specific CPT strategies that are suited to different levels of students, since the CPT strategies promote the concept of differentiation as explained in the contributions to knowledge chapter.

The second stage of this research showed that the observed and predicted impact factors for different CPT strategies (Cnc, Pnp, Tnt) were very close to each other, and it was the closest in the case of using the C3, P3, T4 strategy to teach physics (see Table 73). In this strategy, three kinds of the curriculum were used (theoretical, practical and interactive), three pedagogical dimensions and 80% of the content was integrated with digital technology.

Additionally, the effect size was the highest in the case of C3, P3, T4 as well. It was equal to 0.85, which is described as a substantial effect of educational technology on students' attainment. Based on these findings, it seems possible to conclude that the use of different pedagogies and intensive use of digital technology to deliver the content can raise students' level of understanding and improve their attainments in physics.

Case #	**No of students**	**Cnc Pnp Tnt**	**The mean observed impact factor (out of 100)**	**The mean predicted impact factor (out of 100)**	**Pearson correlation factor**	**T-test**	**T-critical**	**Effect size**	**P_{value}**	**ΣX^2**	**The final result based on ΣX^2 and the p_{value}**
2	35	**C3** **P3** **T4**	8.10	7.50	0.730	0.530	2.030	0.850	0.590	$3.71*10^{-24}$	*NO significant difference between the expected values and the observed values.*

Table 73. The means of observed and predicted impact factors in the case of using C3, P3, T4 to teach physics.

Based on the values of the Chi-square, T-test and P-value in all tested cases in stage two, the null hypothesis could not be rejected. In turn, this means that there was no significant difference between the means of the predicted improvement (the impact factor), which was calculated using the CPT model's equations and the mean of the observed improvement (observed impact factor), which was collected from students' assessments (pre and post-tests). The findings of stage two could not reject the null hypothesis, which gives credibility to the CPT model and its equations. However, I could not claim the validity of the CPT model before going through an in-depth investigation, which took place in stage three. Hence, in stage three, the CPT model was applied to other fields and broader samples to check its validity. Therefore, in every investigated case during stage three, the observed impact factor in students' attainment was measured and compared with the predicted one.

The data analysis of stage three was consistent and showed that there was no significant difference between the means of the predicted and observed impact factors. Therefore, the null hypothesis could not be rejected.

Stage three consisted of two parts: the first part covered subjects related to science: physics, biology and mathematics; while the second part covered subjects related to humanities: Social Studies and English language.

The Science Subjects

Different strategies were applied to teach science subjects such as C3, P3, T3; C2, P2, T4 and C3, P3, T4. The majority of these strategies achieved an improvement that was close to the predicted improvement by the CPT model.

The C2, P2, T4 strategy proved higher effectivity than C3, P3, T3 in teaching **physics** as the actual (observed) improvement in students' attainment in the case of using C2, P2, T4 was higher than the achieved improvement using C3, P3, T3. However, the predictions of the CPT model in both cases were close to the actual values of improvement, since the difference between the mean observed improvement and the mean predicted improvement in the case of C3, P3, T3 was 0.01, while in the case of using C2, P2, T4 it was less than 0.04 (see Table 74 and Table 75). Therefore, the researcher would conclude that these two strategies are effective in teaching physics.

Strategy / C2, P2, T4 Subject	Mean predicted impact factor	Mean observed impact factor
Physics	0.110	0.073

Table 74. The means of actual (observed) and predicted impact factors in the case of using C2, P2, T4 to teach physics.

Strategy / C3, P3, T3 Subject	Mean predicted impact factor	Mean observed impact factor
Physics	0.042	0.032

Table 75. The means of actual (observed) and predicted impact factors in the case of using C3, P3, T3 to teach physics.

Three different strategies were used to teach **biology**; the data analysis showed some consistency between two of them C3, P3, T3 and C3, P3, T4. Both strategies achieved significant improvement and close to what was expected by the CPT model. The mean observed impact factor in the case of using C3, P3, T3 was 0.072, and the mean predicted impact factor, as calculated using the CPT model equations was 0.042. Regarding the second strategy, C3, P3, T4, the mean observed impact factor was 0.071, and the mean predicted impact factor was 0.075. The improvement achieved using both strategies is within the same boundaries. Please refer to Table 76 and Table 77.

Finally, in the case of using C2, P2, T4 to teach biology, there was a discrepancy between the mean value of observed impact factor, which was 0.061, and the mean predicted impact factor, which was 0.111, please refer to Table 78. *Based on these findings, it would appear conclusive that the C3, P3, T4 strategy is the most effective strategy to teach biology*.

Strategy / C3, P3, T3 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Biology	0.042	0.072

Table 76. The means of observed and predicted impact factors in the case of using C3, P3, T3 to teach Biology.

Strategy / C3, P3, T4 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Biology	0.075	0.071

Table 77. The means of observed and predicted impact factors in the case of using C3, P3, T4 to teach Biology.

Strategy / C2, P2, T4 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Biology	0.110	0.061

Table 78. The means of observed and predicted impact factors in the case of using C2, P2, T4 to teach Biology.

Three different strategies were used to teach **mathematics**: C3, P3, T3; C3, P3, T4 and C2, P2, T4. Based on the findings shown in Table 79, Table 80 and Table 81, it appears that the only CPT strategy that reached the expectations by achieving a significant observed improvement very close to the predicted one was the C2, P2, T4 strategy.

Strategy / C3, P3, T3 Subject	Mean value of the predicted impact factor	Mean value of the observed impact factor
Mathematics	0.042	0.019

Table 79. The means of the observed and predicted improvements in students' attainment in the case of using C3, P3, T3 to teach mathematics.

Strategy / C3, P3, T4 Subject	Mean predicted impact factor	Mean observed impact factor
Mathematics	0.075	0.047

Table 80. The means of the observed and predicted impact factors in the case of using C3, P3, T4 to teach mathematics.

Strategy / C2, P2, T4 Subject	Mean predicted impact factor	Mean observed impact factor
Mathematics	0.110	0.098

Table 81. The means of the observed and predicted impact factors in the case of using C2, P2, T4 to teach mathematics.

As shown in Table 79, Table 80 and Table 81, the means of the predicted and observed impact factors in all cases stayed within the same boundaries as the differences between the two values (observed and expected) in the three cases ranged from 0.012 and did not exceed 0.028, which gives credibility to the CPT model's equations as a predictive model for the improvement in students' attainment as an outcome of using educational technology. Based on Table 79, Table 80 and Table 81, *the observed improvement in students' attainment was the highest in the case of using C2, P2, T4. Furthermore, the observed and expected improvements were the closest in the case of C2, P2, T4 as well. Therefore, the researcher states that the C2, P2, T4 strategy is the* *most effective strategy amongst other strategies that were applied to teach mathematics in this study*.

Which Strategies are the Most Effective to Teach Science?

Regarding, C3, P3, T3 strategy, which was used to teach the science subjects included in this study: Physics, Biology and Mathematics. Overall, the observed and expected improvements were close to each other in all subjects. However, as shown in Table 82, using C3, P3, T3 to teach mathematics did not reach the expectation. In other words, this strategy did not work well with mathematics, since the observed improvement was 0.019 or 1.9% and the expected improvement according to the CPT model is 0.042.

In addition to Mathematics, the C3, P3, T3 strategy was used to teach physics and biology as well. As shown in Table 82, *the mean value of the observed improvement was the highest when this strategy was applied to biology, followed by physics and finally the mathematics.*

Strategy / C3, P3, T3 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Physics	0.042	0.032
Mathematics	0.042	0.019
Biology	0.042	0.072

Table 82. The means of the observed and predicted impact factors in the case of using C3, P3, T3 to teach physics, mathematics and biology.

The C2, P2, T4 strategy was used to teach the three subjects: physics, mathematics and biology. *As shown in Table 83, the mean value of the observed improvement was the highest when C2, P2, T4 was applied to teaching mathematics, followed by physics and finally, biology.*

Strategy / C2, P2, T4 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Physics	0.110	0.073
Mathematics	0.110	0.098
Biology	0.110	0.061

Table 83. The means of the observed and predicted impact factors in the case of using C2, P2, T4 to teach physics, mathematics and biology.

The C3, P3, T4 strategy was used to teach mathematics and biology. As shown in Table 84, *the mean value of the observed improvement was the highest when C3, P3, T4 was applied to teaching biology.* The mean observed improvement was very close to the expected one in the case of biology, as the difference between the two mean values of improvement (observed and predicted) was 0.004, which can be negligible. Unlike the case of mathematics, where the gap between the observed and the expected improvement was around 0.03, which, though not a wide variance, but it cannot be regarded as negligible.

Strategy / C3, P3, T4 **Subject**	**Mean predicted impact factor**	**Mean observed impact factor**
Mathematics	0.075	0.047
Biology	0.075	0.071

Table 84. The means of the observed and predicted impact factors in the case of using C3, P3, T4 to teach mathematics and biology.

Overall, it can be concluded that the mean observed improvement in the cases of mathematics, biology and physics was within the boundaries of the predicted ones, and the trend was the same in all cases.

The Humanities Subjects

C3, P3, T3; C2, P2, T4; C1, P1, T1 and C3, P3, T4 strategies were applied to teach the humanities subjects: English language and Social studies. Most of these strategies achieved an improvement that was close to the one predicted by the CPT model.

Three different strategies were used to teach **the English language**: C3, P3, T3; C3, P3, T4 and C2, P2, T4. As shown in Table 85, the C3, P3, T4 strategy achieved more significant improvement than the improvement, which was obtained using C2, P2, T4, or C3, P3, T3. Therefore, the researcher would claim that *the C3, P3, T4 strategy is more effective than the other strategies that were used to teach the English language*.

English language / **Strategy**	**Mean observed impact factor**	**Mean predicted impact factor**
C3, P3, T4	0.094	0.075
C2, P2, T4	0.044	0.110
C3, P3, T3	0.015	0.042

Table 85. The means of the observed and predicted impact factors in the case of using C3, P3, T4; C2, P2, T4 and C3, P3, T3 to teach the English language.

In the case of **social studies**, three different strategies were applied: C3, P3, T3**;** C1, P1, T1 and C3, P3, T4. As shown in Table 86, the mean observed improvement was the highest in the case of using C3, P3, T4 at 0.108, while the lowest observed improvement was in the case of C3, P3, T3, at 0.022. Therefore, the researcher may conclude that *the C3, P3, T4 strategy might be considered as one of the most effective strategies that can be used to teach social studies.*

As shown in Table 86, the difference between the means of observed and expected improvements ranged from 0.012 to 0.033, which gives substantial evidence that the null hypothesis cannot be rejected, as there was no significant difference between the means of observed and expected values, which supports the validity of the

CPT model and its equations.

Social Studies / Strategy	Mean observed impact factor	Mean predicted impact factor
C3, P3, T3	0.022	0.042
C3, P3, T4	0.108	0.075
C1, P1, T1	0.026	0.014

Table 86. The means of observed and predicted impact factors in the case of using C3, P3, T3; C3, P3, T4 and C1, P1, T1 to teach social studies.

Which Strategy is the Most Effective to Teach Humanities?

The C3, P3, T4 strategy was used in both subjects: social studies and English language. As shown in Table 87, *the mean value of the observed improvement was higher when C3, P3, T4 was applied to teaching social studies, then the English language*. However, as can be seen in Table 87, the observed improvement in both cases (English and social studies) using the C3, P3, T4 strategy is in the same range, as the difference between the two observed values is approximately 0.014. Consequently, one can conclude that educational technology impacts both subjects positively since it improves students' attainment as predicted by the CPT model.

Strategy / C3, P3, T4 / Subject	Mean predicted impact factor	Mean observed impact factor
Social studies	0.075	0.108
English language	0.075	0.094

Table 87. The means of the observed and predicted impact factors in the case of using C3, P3, T4 to teach social studies and English language.

Statistical Description

Several statistical functions were applied to the findings of this study, including the in-depth investigation, to check i) the relationship between the use of educational technology and students' attainment, ii) the null hypothesis and iii) the validity and reliability of the CPT model and its equations. The outcomes of these statistical tests can be summarised as follows:

As shown in Table 88, the Chi-Square test and t-test were used to compare the observed frequency (observed improvement) in each group to the frequency which would be expected (predicted improvement) and to check the difference between the means of the expected and observed improvements if it is significant or not. Chi-Square mean value of all cases conducted was calculated and found to be less than the critical value in X^2 distribution table, which implies that the fit between the observed and expected frequencies (improvements) is a good one. The statistical mean value of the t-test of all cases conducted was found to be 1.80, which is less than the t-test critical mean value (2.08). The mean P-value was also calculated for all cases in stages two and three and found to be greater than 0.05.

As shown in Table 88, the effect size and Pearson correlation coefficient were applied to the findings, to check the relationship between educational technology and students' attainment. The mean value of the Pearson correlation factor (r) indicates a moderate positive correlation between the use of educational technology and students' attainment. Therefore, these two variables can be considered as dependent variables.

As shown in Table 88, the mean value of the effect size of all conducted cases, which includes science and humanities is equal to 0.54; this value can be located between the medium and significant effect of educational technology on students' attainment. This finding agrees with that of Sung et al., who stated:

> One hundred ten experimental and quasi-experimental journal articles published during the period 1993-2013 were coded and analysed. Overall, there was a moderate mean effect size of 0.523 for the application of mobile devices to education. (Sung, et al., 2016, p. 252)

Based on these outcomes of the statistical functions, the null hypothesis could not be rejected, i.e., there was no significant difference between the means of the predicted and observed impact factors. Please refer to Table 88. These findings give credibility to the CPT model and its equations to be considered as a valid and reliable tool that can predict the improvement in students' attainment in different learning scenarios (CPT strategies).

Statistical function	**Mean value**
T-test	1.80
T-critical	2.08
Effect size (Cohen's D)	0.540
Pearson correlation factor (r)	0.760
P-value	0.180
$\Sigma\ X^2$	$7.04*10^{-50}$

Table 88. The mean values of Chi-Square, P-value, T-test, Pearson correlation factor and the Effect size of all conducted cases in both clusters, science and humanities.

Error analysis

Overall, the mean value of the observed impact factors in the science subjects (all cases conducted in physics, biology and mathematics) was 6.35%, and the mean value of the predicted impact factors was found to be 7.9%. The values (observed and expected) are close to each other; the percent error was calculated and found to be 24.4 %, which implies that the percentage of accuracy in predicting the improvement in students' attainment is 75.6 %. As regards humanities subjects, the mean value of the observed impact factors, including all cases conducted in the English language and Social Studies, was 5.76 %, and the predicted impact factor was 6.2 %. The percent error was calculated and found to be around 8 %, which implies that the rate of accuracy is approximately 92 %. This can be considered as reliable evidence to support the validity of the CPT model and its equations.

The Limitations of this study

The researcher during this study encountered some obstacles and limitations, such as:

- Limitations in the literature reviews that are focused on measuring and predicting the impact of educational technology on students' attainment quantitatively.
- Limitations of the employed samples, since this study investigates the impact of educational technology on students' attainment. Thus, it was considered a priority that the selected participants should be familiar with digital technology and should have consistent access to digital technological tools. Therefore, I had to select participants randomly from IAT (purposive samples), please refer to section 3.9.1.1
- Limitations of the iPad's functions and some virtual platforms, such as the learning management system.
- Limitations in interpreting terms used in the questionnaire
- Limitations related to the conducted informal interviews (focus group).
- Limitations of the activities and tasks carried outside the classroom as all activities, tasks and exams during this study were implemented inside the classroom.
- The offered definition of learning did not specify the nature of the environment if it is an authentic or merely abstract principle. This might be considered as limitations in the offered definition.
- Limitations of the CPT model, the means of the predicted and observed impact factors were compared and found to be in the majority of the cases close to each other. However, none of the cases showed that these means are equal to each other, which might be considered a limitation of the CPT equations.
- Limitations of the assessments conducted, and content delivered in this study.
- Limitations related to both forms of the impact factor's equations (Equation 8 and Equation 9)
- Limitations related to teachers' attitude
- Limitations of data collected during the pilot study
- Limitation of documentation, including lesson observations

As a **future scientific understanding and theoretical insights of the CPT model**, I would suggest the CPT-S curvatures, which I defined as four-dimensional model (4-D) that comprises the three dimensions of curriculum, pedagogy and digital technology (C, P and T) and the one dimension of a student's attitude towards learning (S) to produce 4-D model called CPT-S, please refer to section 8.6.

This research consists of five questions; The findings of this study have yielded significant information that has been utilised to answer the five research questions.

<u>Question 1 and Question 2</u>

1. Is there any relationship between the use of educational technology and students' attainment?
2. If there is a relationship between educational technology and students' attainment, then does it have a positive or negative effect on students' attainment?

Based on the data collected in stages 1, 2 and 3 of this study, the researcher can conclude that there is a relationship between educational technology and students' attainment. The statistical functions that were used to analyse the data showed that the students' attainment was improved as an outcome of using educational technology. In other words, the use of educational technology has a positive impact on students' attainment. This conclusion can be supported by the calculation of the effect size and the Pearson correlation factor. The mean value of the effect size in the science subjects was 0.567, while the mean value of the effect size in the humanities was 0.493, whilst the overall value of the effect size for all conducted cases (science and humanities) was 0.54, which can be described as a moderate effect of educational technology on students attainment (Cohen, 1988; Coe, 2002). This implies that educational technology and the students' attainment are dependent variables. Please refer to Table 64, Table 65 and Table 88.

The mean value of the Pearson correlation factor in the science subjects was found to be 0.75, while in the humanities subjects, it was 0.78. The overall value of the Pearson correlation factor for all cases conducted (science and humanities) was 0.76. Therefore, the correlation can be described as a moderate to the strong positive relationship, which validates the relationship between the use of educational technology and students' attainment and confirms the positive impact of educational technology on students' attainment. Please refer to Table 64, Table 65 and Table 88.

Question 3 and Question 4:

3. Is there any relationship between the content of the curriculum, pedagogy and digital technology? If the answer is yes, can a mathematical model represent this relationship?
4. Can this model be a reliable tool to be used as a predictive model to measure in advance the improvement in students' attainment due to the use of educational technology?

The third and fourth questions in this research were about the relationship between the content of the curriculum (C), pedagogy (p) and, digital technology (T) and the possibility of developing a mathematical and statistical model consisting of these elements; that can predict the improvement in students' attainment. The researcher would admit that it is unusual and not familiar to deal with education from a mathematical perspective or to predict the impact of using educational technology on students' attainment quantitatively, by mapping the relationship between three elements (C, P and T) to form one unit or a vector in space (3 D).

I would suggest that the relationship between digital technology, pedagogy and content knowledge can be visualised by placing these elements on the corners of a triangle. Each one of these elements can impact the other one, as shown in Figure 122. Based on the findings of this study, digital technology guarantees a reasonable level of support for the pedagogy and content knowledge, as it facilitates sharing knowledge, offering students access to external resources which supports the content and also it can develop new methods of teaching, which maximises the learning outcomes and improves students' academic performance.

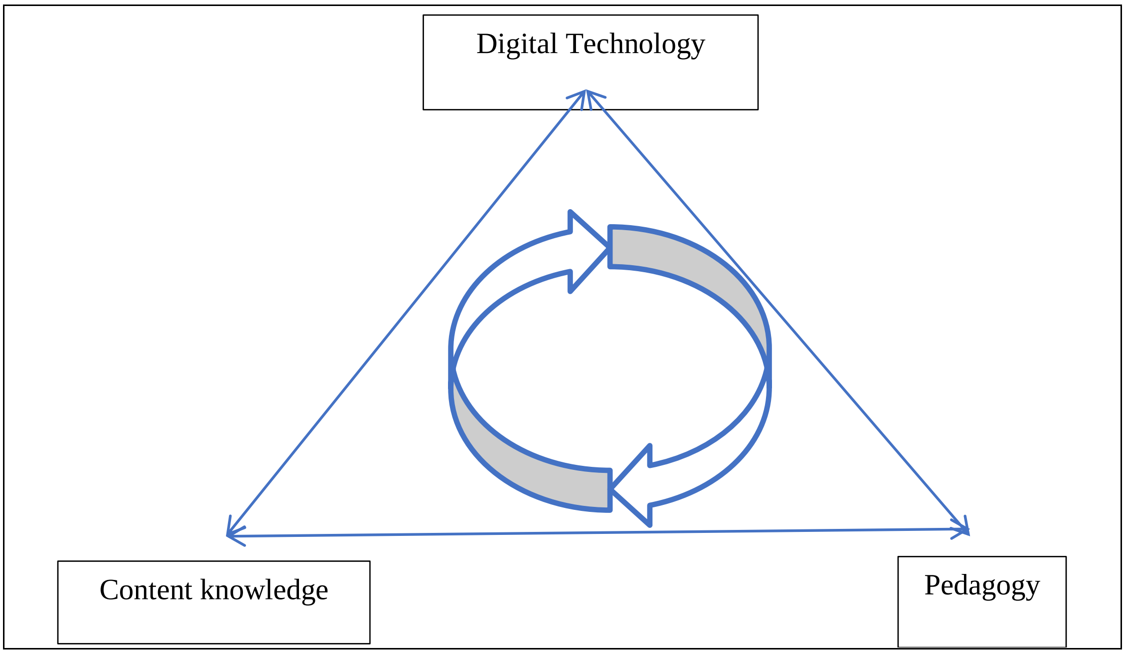


Figure 122. The relationship between digital technology, pedagogy and content knowledge.

Based on the data analysis of all stages carried out in this study as shown in Table 63 and Table 64, it can be concluded that there is a relationship between the content of the curriculum, digital technology and pedagogy. This relationship has been mapped as a 3D vector in the CPT space and represented mathematically using the concept of vector space. Refer to Figure 42, Equation 8, Equation 9 and Equation 10. In the first stage of this study, the researcher dealt with three factors C, P and T (C –the content of the Curriculum, P –Pedagogy and T – Technology (digital)). The findings of the pilot study influenced the research approaches. The concept of vector space that is defined using three components X, Y and Z was used in this study to develop a new vector that consists of the new components C, P and T instead of X, Y and Z, as shown in Figure 42, which was the initial step in the process of developing the new model. The CPT model represents the relationship between the curriculum, digital technology and pedagogy. For more details, please refer to chapter 5.

The analysed data in stages two and three have shown that the CPT model has the power to predict the likely improvement in students' attainment as an outcome of using educational technology. The magnitude of any vector in the CPT space depends mathematically on three factors (C, P, T) as shown in Equation 8, Equation 9 and

Equation 10, this finding suggests that there is a relationship between the content of the curriculum, pedagogy and digital technology.

The fourth question of this research regarded the reliability and validity of the developed model. As shown in stages two and three, the equations of the CPT model offered reliable results since the observed results were close to the predicted results that were calculated using the CPT model equations. Moreover, based on the outcomes of the statistical functions that were used in stages two and three, it can be concluded that the CPT model is a valid and reliable predictive model for the improvement in students' attainment due to the use of educational technology. Please refer to Table 63 and Table 64.

The researcher asserts that the findings of this research have an internal validity since this study measured and investigated what was intended to be measured and examined. This study could determine the impact of educational technology on students' attainment qualitatively, could measure the impact factor of educational technology on students' attainment quantitatively, and develop a new model that can predict the improvement in students' attainment.

However, the researcher cannot claim that the findings of this research have external validity since these findings cannot be generalised to external populations. The findings of this study can be generalised to the specific population, which was studied in IAT schools, but there is no guarantee that it can be widespread to external communities.

As an essential mathematical finding of this study, other forms, of the main equation of the CPT model (Equation 8), have been discovered. As shown below:

The original equation:

The predicted impact factor (R) $= \sqrt{Cnc^2 + Pnp^2 + Tnt^2}$ - $\sqrt{Cnc^2 + Pnp^2}$

The predicted improvement or the impact factor shown above can be calculated using the following formulas (the new form of the main equation) as well:

Equation 9

$$R = R_o\,(N)^2$$

Where R is the predicted impact factor,

N is the digital technology integration level takes values from 1 to 5.

R_o is the threshold impact factor, which can be calculated using the following formula:

$$R_o = \sqrt{Cnc^2 + Pnp^2 + 0.2^2} - \sqrt{Cnc^2 + Pnp^2}$$

Table 89 shows identical results calculated using both forms of equations.

Cnc, Pnp, Tnt	**The predicted impact factor** $\mathbf{R = \sqrt{Cnc^2 + Pnp^2 + Tnt^2} - \sqrt{Cnc^2 + Pnp^2}}$	**The predicted impact factor** $\mathbf{R = R_o (N)^2}$
C1, P1, T1	0.014	0.014
C1, P1, T2	0.056	0.056
C2, P2, T4	0.111	0.110
C3, P3, T4	0.075	0.075

Table 89. The calculations of the impact factor using the original equation and the new form of the original equation.

Questions 5: What are the implications of using the predictive tool for curriculum planning?

The findings of this research can assist educators and curriculum developers, to design suitable curriculums that are suitable for diverse groups of students, regardless of their level, enabling them to predict the improvement in students' attainment and design the curriculum in the most effective strategy for maximising learning outcomes.

The CPT model enables teachers to deliver the content using specific CPT strategies, which makes provision for individual differences between students, where three kinds of content: theoretical, practical and interactive, as well as four pedagogical dimensions can be considered as the communication channels with students. Different levels of digital technology integration can be used to introduce and develop the content in various manners so that it can be adapted to students of different abilities.

Finally, based on the findings of stages one, two and three, it can be concluded that the CPT model is a reliable and valid tool. It can be used as a predictive model to measure in advance the improvement in students' attainment. Moreover, it can contribute to other areas, such as the concept of differentiation in learning. Regarding the area of curriculum design, the CPT model has demonstrated how it is possible to combine a variety of contents with different pedagogical dimensions and different levels of digital technology integration to create a curriculum that can suit any student, whatever their level, and enable the teacher to design a programme that makes provision for individual differences in order to maximise learning outcomes. Refer to chapter 8 (The Contributions of this Study to Knowledge and Future Studies).

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APPENDICES

APPENDIX ONE

Statistical Functions

APPENDIX 1 – STATISTICAL FUNCTIONS

Many statistical tests were used in this study for the following purposes:

i) compare the observed and expected data.

ii) check the null hypothesis of this study.

iii) check the impact of educational technology on students' attainment.

iv) test the validity of the developed model in this study (the CPT model).

Pearson Correlation Coefficient

The Pearson Correlation factor is calculated to check the existence and the strength of a relationship (the correlation between the variables). This statistical function is used to check how the collected data are related to each other (University of Sussex, 2009; Mukaka, 2012). In this study, the Pearson Correlation factor was applied to explore the relationship between the use of educational technology and students' attainment, which was achieved by checking the relationship between students' marks with and without using digital technology.

The correlation coefficient (factor) ranges from -1 to +1, "depending on whether the slope is positive or negative (correlation or anti-correlation)" (Hall, 2015, p. 2). If a correlation factor is considerably close to 0, but either positive or negative, it indicates weak or no relationship between the two variables. If a correlation factor is close to +1, it implies a positive relationship between the two variables, with a rise in one of them being associated with increases in the other one. If a correlation factor is close to -1, then it implies a negative relationship between the two variables, with a rise in one of them being associated with a decrease of the other one (University of Regina, n.d.). Therefore, the relationship, or the correlation between any two variables, must be one of the following (Statistics How To , 2018). Please refer to Figure 123.

i) There is a positive relationship between the variables.

ii) There is no relationship between the variables.

iii) There is a negative relationship between the variables.

For better understanding, here are examples of the previously mentioned relationships between variables:

i) Positively related – the more I study my subjects, the better results I score in the exams.

ii) Not related – as I study my subjects, my performance remains completely constant.

iii) Negatively related – the more I study my subjects, the worse results I score in the exams.

This figure has been removed due to Copyright restrictions.

Figure 123. Scatterplot of x and y, Pearson’s correlation factor (Statistics How To , 2018).

Summary:

The Pearson correlation coefficient checks the existence and the strength of a relationship (the correlation between the variables).

Chi-square TEST and P-value

The Chi-square test compares the observed frequency in each group to the frequency, which would be expected. This test can be used as a test of goodness of fit since it allows researchers to check how well the theoretical (expected) distribution fits the observed (actual) data (Kothari, 2004). “The chi-square test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories” (Maben, 2018, p. 1).

Each value of Chi-Square should meet a P-value in the Chi-square distribution table. If the calculated value of Chi-square is less than the table value at a certain level of significance (for instance, at P-value = 5 %), then the fit is considered to be a good fit. On the other hand, if the calculated value of Chi-square is higher than its table value at a certain level of significance, then the fit is not considered to be a good one (Kothari, 2004; Henry County Schools, 2004).

The Chi-square value can be calculated using the following formula:

$$X^2 = \sum \frac{(O - E)^{\,2}}{E}$$

Where O is the observed value, and E is the expected value.

Calculating the Chi-Square value and comparing it against a critical value in the X^2 statistical distribution table offers a researcher the ability to assess if the observed measurements are significantly different from the expected measurements (Turner, 2014).

In this study X^2 test was used to compare the observed frequency (observed improvement) in each group to the frequency which would be expected (predicted improvement). Thus, the researcher was able to determine whether there was or there was no significant difference between the means of expected and observed impact factors.

Measuring the P-value enables the researcher of this study to check the strength of the evidence against the null hypothesis by estimating the probability of obtaining an extreme or more extreme result than what was observed if the null hypothesis is correct. (Dahiru, 2008; Statistics Solutions , 2018).

As stated by Rumsey (2016) and Fenton and Neil (2012):

i. A low *p*-value (usually ≤ 0.05) indicates strong evidence against a null hypothesis. In other words, there is a higher disagreement (might be considered as a disagreement) between the observed and the null hypothesis so that the null hypothesis can be rejected.

ii. A high *p*-value (> 0.05) indicates weak evidence against a null hypothesis, which implies that there is a minor disagreement (might be considered as an agreement) between the observed data and the null hypothesis so that the null hypothesis cannot be rejected (fail to reject the null hypothesis).

iii. *P*-values very close to (0.05) then there is no evidence for or against the null hypothesis.

Summary:

Based on the previous description of P-value, the following points can be highlighted:

i) the P-value is a measure of the strength of the evidence against the null hypothesis.

ii) the P-value estimates the probability of obtaining an extreme or more extreme result than what was observed if the null hypothesis is correct.

iii) the smaller the p-value, the more significant the evidence against the null hypothesis.

Example: Sarah is selling peanut chocolates. Recently she has received complaints that the chocolates have fewer peanuts in them than they are supposed to. As written on each packet, each 200 g (packet) of chocolate contains 70 g of peanuts or more. Sarah cannot open up all the packages to check as then she would not be able to sell any, so she decides to apply a statistical test on a sample of the chocolate bars.

The null hypothesis (H_0): The peanut chocolate bars as they should be or the statistical mean or average mass of peanuts in the packet is equal to 70 grams (H_0: μ = 70 g).

The alternative hypothesis (H_A): The mean mass of peanuts in the packet is less than 70 grams ($H_{A:}$ $\mu \neq 70$ g).

Sarah decides to run the statistical test by taking a random sample of 20 packets of peanut chocolate from the current stock. She melts down the chocolate and weighs the peanuts from each packet.

If all of the values were lower than 70 grams with a mean of 30 grams, for instance, it would be quite evident that the chocolate bars did not have the required amount of peanuts. Sarah found that the mean mass of peanuts in each packet is 68.7 grams. Does this provide enough evidence that the bars do not have the required amount of peanuts?

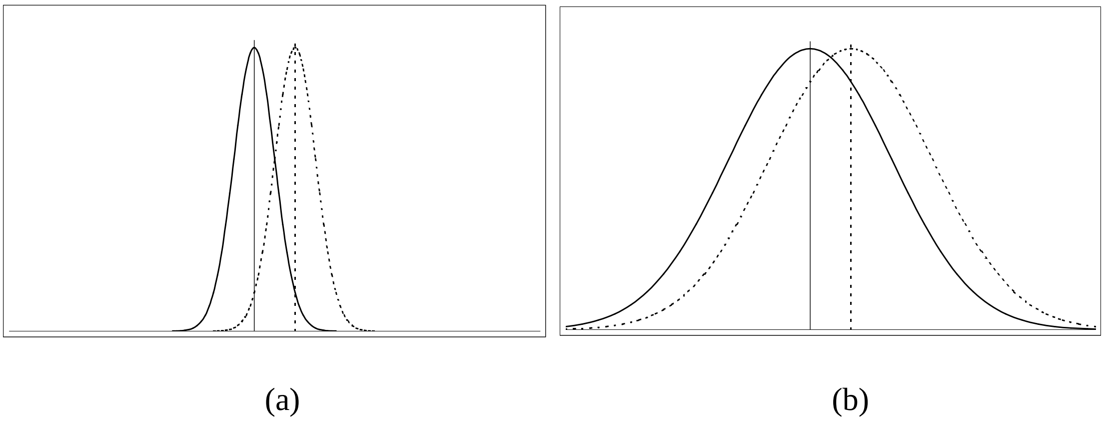
This question can be answered using the P-value, comparing with the mean of 70 grams, Sarah found that the P-value = 0.18. Judging from the data, which she has, there is 18 % chance of getting a mean as low as this or lower (less than 70 grams a packet). This P-value of 0.18 does not provide enough evidence to reject the null hypothesis since this value is greater than the significance level of P-value, which is usually 0.05. In other words, Sarah does not have the evidence to say that the bars are short of peanuts (failed to reject the null hypothesis). Therefore, if the P-value turns out to be very small (less than 0.05), then the null hypothesis is rejected since the smaller the P-value is, the stronger evidence that the null hypothesis is wrong. However, in Sarah 's case, the P-value is 0.18, which is higher than 0.05, so that the null hypothesis is probably correct and cannot be rejected; this is called a non-significant result.

Effect Size

Cohen’s D or the effect size is used to measure the difference between two means. This means that this statistical test estimates the distance that the means of two groups of data have shifted from each other, as shown in Figure 124. The effect size depends on the overlapped area and how the results spread (Borenstein, et al., 2009). If the difference between the means is greater than the overlapped area, then the difference would be significant and vice versa (Coe, 2002, p. 2). Keselman *et al.* (1998) and Coe (2002) suggested that an effect size is an essential tool in reporting and interpreting effectiveness and it can answer questions such as, is it valid or not? How well does it work? How effective is it?

In the year 2000, Dowson conducted an experiment to investigate the effect of the time of day on learning: do children learn better in the morning or afternoon? The group consists of 38 students; half of them were randomly allocated to do their tests in the morning (at around 9:00 am) and the other half in the afternoon (3:00 pm). As stated by Dowson, their level of understanding was measured and judged by the number of the correct answers (out of 20), cited in Coe (2002).

The morning group scored 15.2 as a mean score, and the afternoon group scored 17.9. The means' difference = 2.7, but the question is how big (significant) is this difference? Can it be negligible? Since there is no clear scale or frame available on which to compare the difference with it, the effect size can replace the scale and give the answers to such questions.



(a)

(b)

Figure 124 The effect size depends on the overlapped area (Coe, 2002).

The effect size can be calculated using the following formula:

$$\text{Effect Size (Cohen's d)} = \frac{\text{Mean of experimental group} - \text{Mean of control group}}{\text{Standard deviation}}$$

Where the experimental group is the treated group, which consists of the observed results, while the control group is the untreated one, which consists of the expected results (Durlak, 2009).

Using the previous formula, Dowson could calculate the effect size, as the standard deviation (SD) was found to be 3.3, so that the effect size was (17.9 – 15.2)/3.3 = 0.8. This is interpreted according to Cohen as a significant effect.

Cohen (1988) described an effect size of 0.2 as small and provided to explain it the case that the difference between the heights of 15-year-old and 16-year-old girls in the US. An effect size of 0.5 is represented as medium and is large enough to be noticeable to the naked eye. A 0.5 effect size resembles the difference between the heights of 14-year-old and 18-year-old girls. Cohen illustrated an effect size of 0.8 as highly visible and large and compared it to the discrepancy between the heights of 13-year-old and 18-year-old girls. (Cohen, 1988; Coe, 2002).

Summary:

The effect size is used to measure the difference between two means. If the effect size between 0 and 0.2, it is described as a small effect, and if it is between 0.2 and 0.5, then it is a medium effect, and it would be considered as a significant effect if its value is greater than 0.5.

Alternative Measures of Effect-Size

Effect size can also be determined using the value of the Pearson correlation coefficient (r). The following cases were suggested by Cohen (1992) and Chuan (2006) to demonstrate the cases of the large, medium and small effect based on the value of the Pearson correlation coefficient (r) cited in (Kim, 2015; Draper, 2018).

i) If r = 0.10 – 0.3 the effect is considered a small effect

ii) If r = 0.30 – 0.5 the effect is considered medium, 0.3 is the threshold of the medium effect.

iii) If r = 0.50 or larger, the effect is considered large, 0.5 is the threshold of the large effect.

iv) If r = 0 then it means that there is no relationship between the variables or no effect.

v) If r = 1 then there is a perfect relationship or perfect effect.

The t-test

A t-test was used in this study to compare the means of data from two related samples (the means of observed and predicted impact factors in students' attainment).

In general, the use of a t-test helps researchers to decide if there is a significant difference between two means of data. "The t-test enables us to decide whether the mean of one condition is really different from the mean of another condition" (University of Sussex, 2009, p. 1). Kothari (2004) stated that the t-test is considered an appropriate method for assessing the significance of the difference between the means of two samples.

Types of a t-test

The following summary of the two types of the t-test is based on both research projects of Kim (2015) and the University of Arizona (2009).

The dependent samples t-test can also be called the repeated measures t-test or a paired-samples t-test. In this test, the participants in the first group are related to the participants in the second group, i.e. if the participants at the pre-test are the same participants at the post-test, then this test is called a paired-samples t-test since the scores between pre and post-test are meaningfully related or dependent on each other.

The independent samples t-tests: if the participants at the pre-test are not the same participants at the post-test, then this test is called an Independent or unpaired-samples t-test since the participants in each group have no relationship to particular members of the other group.

APPENDIX TWO

Consents

APPENDIX 2 - CONSENTS

School of Education
Clifton Lane, Nottingham NG11 8NS. Tel. +44 (0)115 941 8418 www.ntu.ac.uk/education

TO WHOM IT MAY CONCERN

29 September 2015

Dear Sir/Madam

Research at the Institute of Applied Technology

We write to ask permission for our PhD student Mo'ath Kasem Hasan Farah to be allowed to complete his research at your institution. We assure you that his work has received ethical clearance through the Nottingham Trent University vetting process and that the work forms part of a larger study for which Mr Farah is registered as a PhD student.

Yours faithfully

Professor Gren Ireson, Director of Studies

Dr Ruth Richards, Co-supervisor

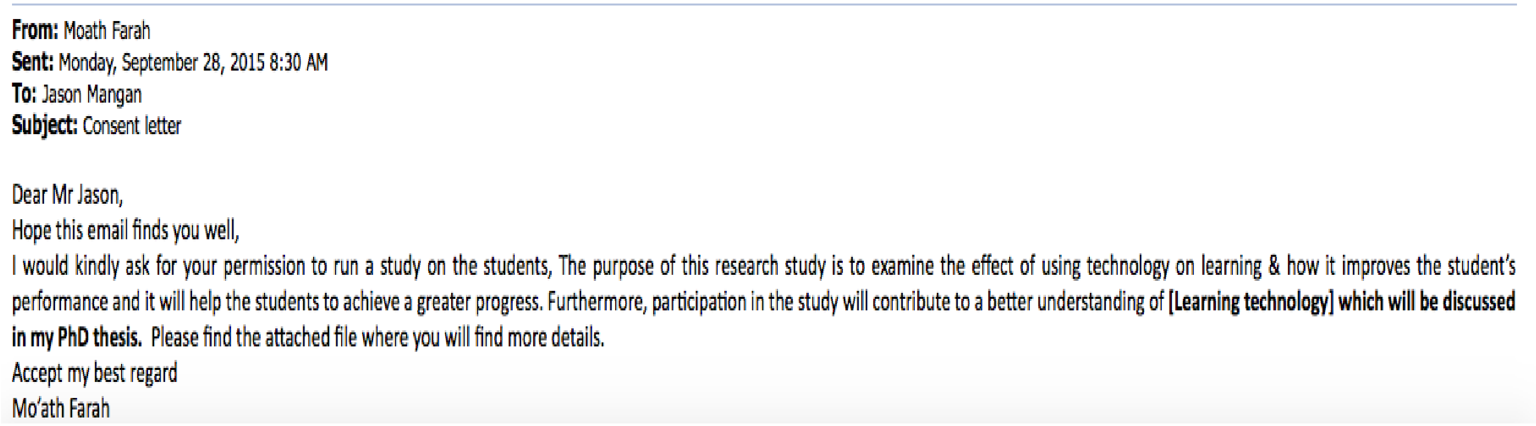
John Carroll.

Dr John Carroll, Co-supervisor

Nottingham Trent University

School of Education

NOTTINGHAM
TRENT UNIVERSITY



From: Moath Farah
Sent: Monday, September 28, 2015 8:30 AM
To: Jason Mangan
Subject: Consent letter

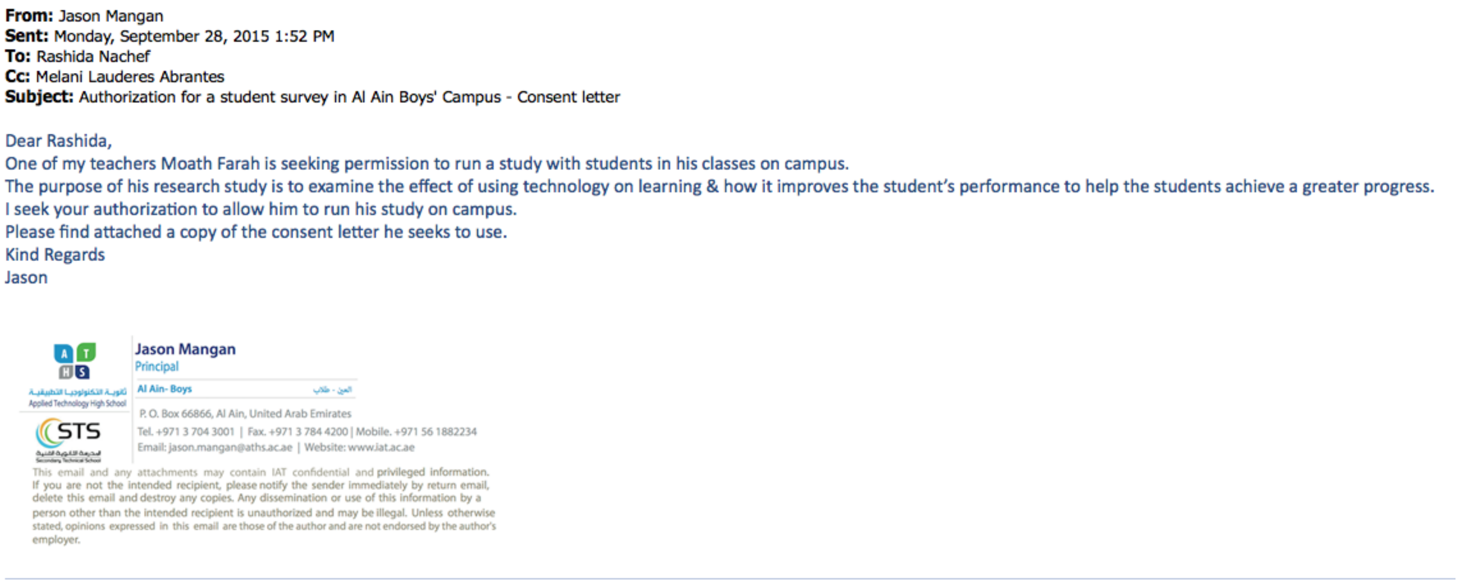
Dear Mr Jason,

Hope this email finds you well,

I would kindly ask for your permission to run a study on the students, The purpose of this research study is to examine the effect of using technology on learning & how it improves the student's performance and it will help the students to achieve a greater progress. Furthermore, participation in the study will contribute to a better understanding of **[Learning technology] which will be discussed in my PhD thesis.** Please find the attached file where you will find more details.

Accept my best regard

Mo'ath Farah

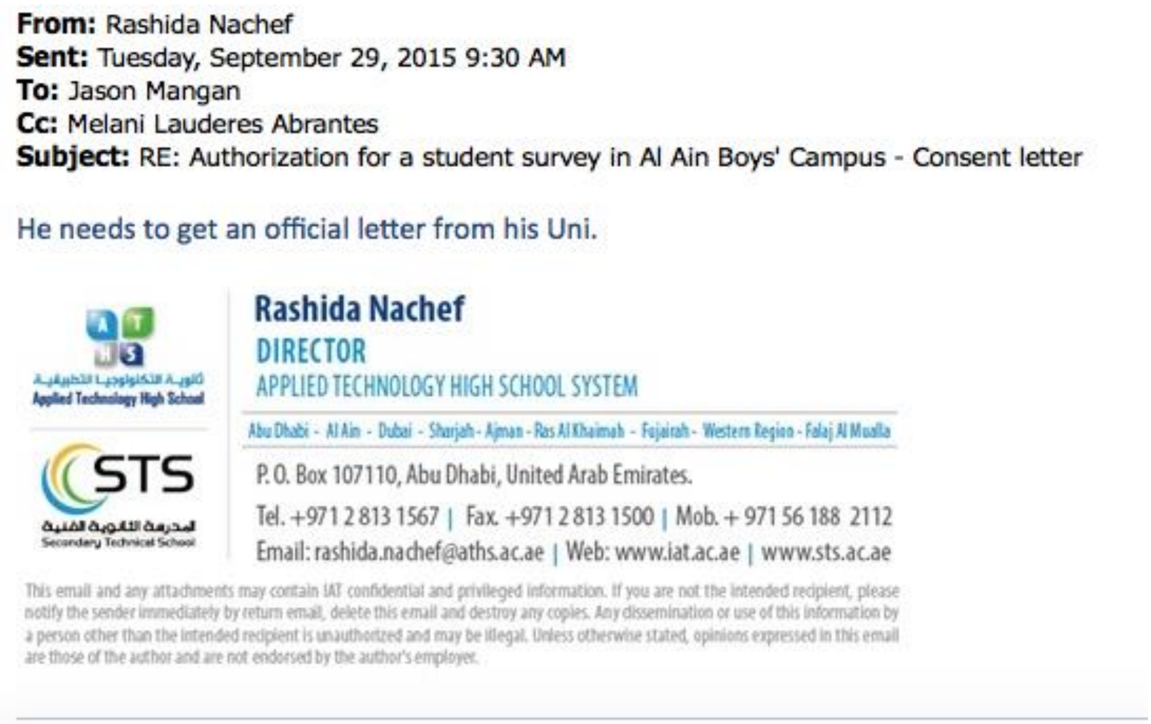


From: Jason Mangan
Sent: Monday, September 28, 2015 1:52 PM
To: Rashida Nachef
Cc: Melani Lauderes Abrantes
Subject: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

Dear Rashida,
One of my teachers Moath Farah is seeking permission to run a study with students in his classes on campus.
The purpose of his research study is to examine the effect of using technology on learning & how it improves the student's performance to help the students achieve a greater progress.
I seek your authorization to allow him to run his study on campus.
Please find attached a copy of the consent letter he seeks to use.
Kind Regards
Jason

ثانوية التكنولوجيا التطبيقية
Applied Technology High School
المدرسة الثانوية الفنية
Secondary Technical School

Jason Mangan
Principal
Al Ain- Boys العين - طلاب
P. O. Box 66866, Al Ain, United Arab Emirates
Tel. +971 3 704 3001 | Fax. +971 3 784 4200 | Mobile. +971 56 1882234
Email: jason.mangan@aths.ac.ae | Website: www.iat.ac.ae



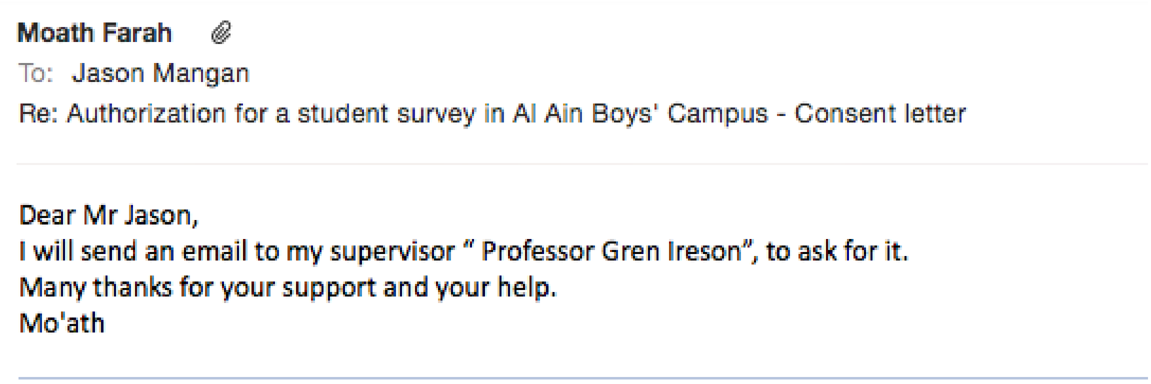
From: Rashida Nachef
Sent: Tuesday, September 29, 2015 9:30 AM
To: Jason Mangan
Cc: Melani Lauderes Abrantes
Subject: RE: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

He needs to get an official letter from his Uni.

Rashida Nachef
DIRECTOR
APPLIED TECHNOLOGY HIGH SCHOOL SYSTEM
Abu Dhabi - Al Ain - Dubai - Sharjah - Ajman - Ras Al Khaimah - Fujairah - Western Region - Falaj Al Moalla
P. O. Box 107110, Abu Dhabi, United Arab Emirates.
Tel. +971 2 813 1567 | Fax. +971 2 813 1500 | Mob. + 971 56 188 2112
Email: rashida.nachef@aths.ac.ae | Web: www.iat.ac.ae | www.sts.ac.ae

Dear Moath,
Can you please provide me with an official letter from you University.
Thank you
Regards
Jason

Jason Mangan
Principal
Al Ain- Boys العين - طلاب
P. O. Box 66866, Al Ain, United Arab Emirates
Tel. +971 3 704 3001 | Fax. +971 3 784 4200 | Mobile. +971 56 1882234
Email: jason.mangan@aths.ac.ae | Website: www.iat.ac.ae

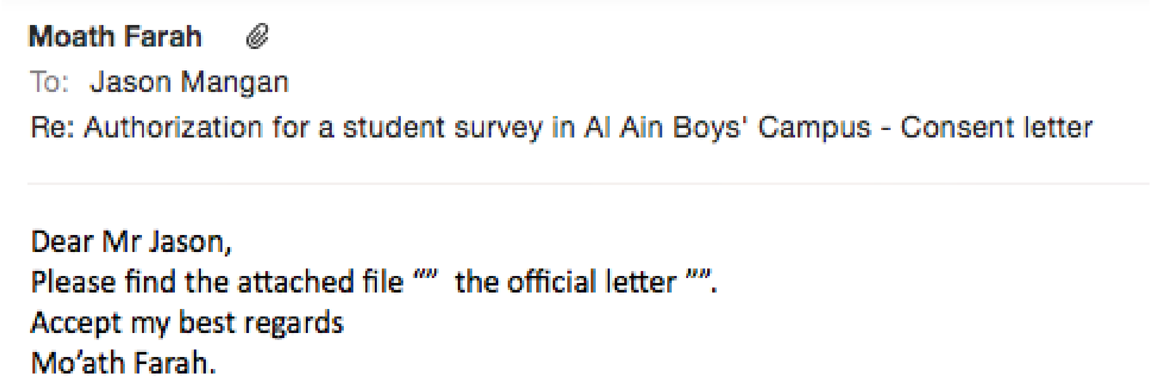


Moath Farah

To: Jason Mangan

Re: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

Dear Mr Jason,
I will send an email to my supervisor “ Professor Gren Ireson”, to ask for it.
Many thanks for your support and your help.
Mo'ath

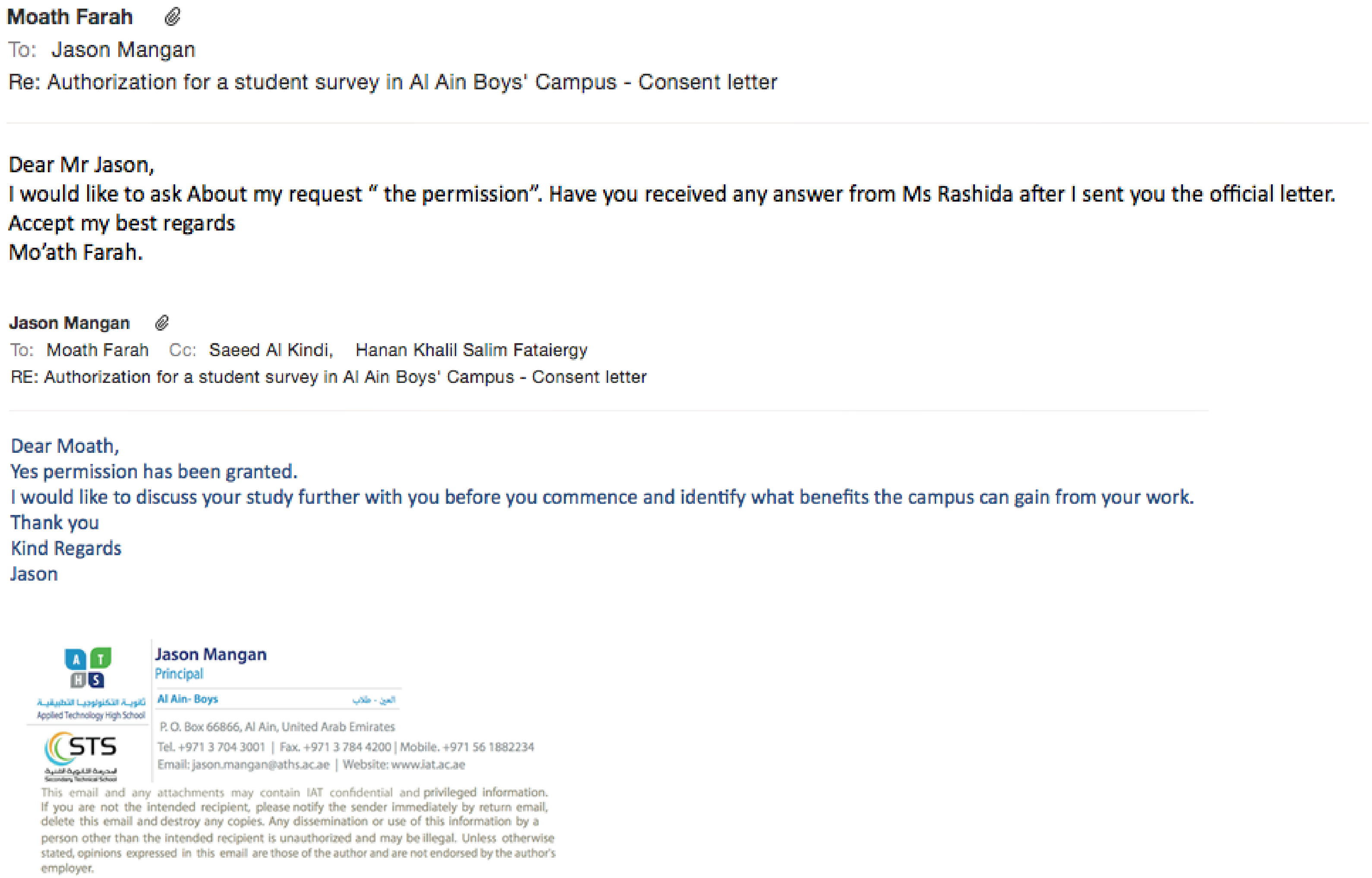


Moath Farah

To: Jason Mangan

Re: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

Dear Mr Jason,
Please find the attached file “” the official letter “”.
Accept my best regards
Mo’ath Farah.



Moath Farah

To: Jason Mangan

Re: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

Dear Mr Jason,
I would like to ask About my request " the permission". Have you received any answer from Ms Rashida after I sent you the official letter.
Accept my best regards
Mo'ath Farah.

Jason Mangan

To: Moath Farah Cc: Saeed Al Kindi, Hanan Khalil Salim Fataiergy

RE: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

Dear Moath,
Yes permission has been granted.
I would like to discuss your study further with you before you commence and identify what benefits the campus can gain from your work.
Thank you
Kind Regards
Jason

ثانوية التكنولوجيا التطبيقية
Applied Technology High School

Jason Mangan
Principal

Al Ain- Boys العين - طلاب

P. O. Box 66866, Al Ain, United Arab Emirates
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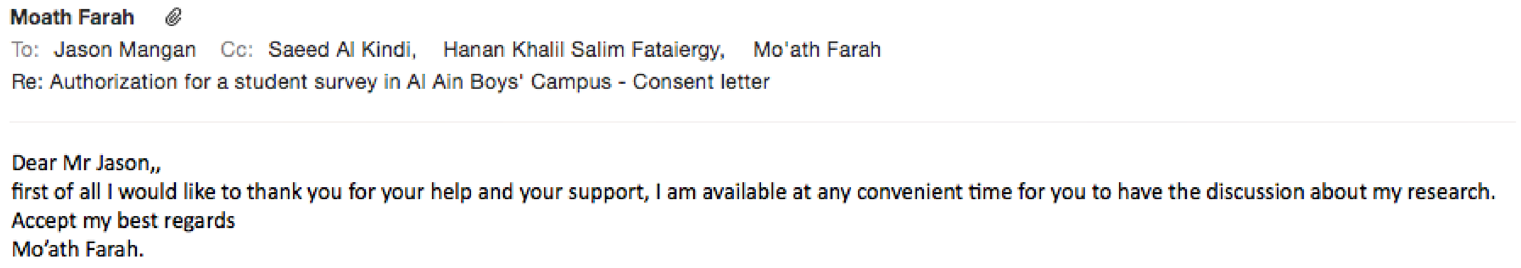
Email: jason.mangan@aths.ac.ae | Website: www.iat.ac.ae



Moath Farah

To: Jason Mangan Cc: Saeed Al Kindi, Hanan Khalil Salim Fataiergy, Mo'ath Farah

Re: Authorization for a student survey in Al Ain Boys' Campus - Consent letter

Dear Mr Jason,,
first of all I would like to thank you for your help and your support, I am available at any convenient time for you to have the discussion about my research.
Accept my best regards
Mo'ath Farah.

APPENDIX THREE

Teacher's Consent Letter

APPENDIX 3 – TEACHER'S CONSENT LETTER

Consent to Participate in Research

Identification of Investigator and Purpose of Study

You are invited to participate in a research study, entitled "Learning Technology using mobile technologies and computer software". The study is being conducted by **Mo'ath Farah -** Nottingham Trent University – England-UK.

The purpose of this research study is to examine **the effect of using technology on learning**. Your participation in the study will contribute to a better understanding of **Learning technology.**

If you agree to participate then:

[Please tick box as appropriate]

1. I confirm that I have read and understood the information sheet for this study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐
3. The procedures regarding confidentiality have been clearly explained (e.g. use of names, pseudonyms, anonymisation of data, etc.) to me. ☐
4. I understand that other researchers will have access to this data only if they ☐

   Agree to preserve the confidentiality of the data and if they agree to the terms, I have specified in this form.

5. Select only **one** of the following:

- I would like my name to be used in this project. ☐
- I do not want my name to be used in this project. ☐

6. I agree to take part in the above study. ☐

Risks/Benefits/Confidentiality of Data

There are **no known.** There will be no costs for participating, nor will you benefit from participating.

Participation or Withdrawal

Your participation in this study is voluntary. You may decline to answer any question, and you have the right to withdraw from participation at any time.

Contacts

If you have any questions about the study, contact the researcher **Mo'ath Farah** by email to **mo39athfarah@yahoo.co.uk.** This study has been reviewed by Nottingham Trent University Review Board**.**

Thank you.

M.Farah

APPENDIX FOUR

Teacher's Questionnaire

APPENDIX 4 – TEACHER’S QUESTIONNAIRE

Dear valued colleagues,

I would kindly ask you to fill in this survey, which will be used in my PhD thesis. The research is exploring the implication of technology in the learning process. Your answers are very significant, as I am conducting a qualitative survey in order to understand teachers’ attitudes towards the use of technology in learning.

The study was approved by Nottingham Trent University. All the information collected in this survey will be kept strictly confidential and used only for this research without any individual identification of participants.

Should you need any clarifications, for the survey questions, I will be happy to assist.

Thank you for your time and cooperation
Mo'ath Farah
PhD student,
Nottingham Trent University

The Questionnaire

1. Approximately how long have you been teaching in years?

   ____

2. How many courses are you teaching this semester?

   ____

3. What devices do you use to prepare your lessons? (Select all that apply)
    a) Desktop Computer
    b) Laptop Computer
    c) iPad
    d) iPod/MP3 player
    e) another (please indicate it) ___________________________________

4. What devices do you use to deliver your lessons?
    a) Desktop Computer
    b) Laptop Computer
    c) iPad
    d) iPod/MP3 player
    e) Another (please indicate it) ___________________________________

5. How are new technologies important to your job as a teacher?
    a) Completely unimportant
    b) Unimportant
    c) Neither important or unimportant
    d) Important
    e) Very important

6. How do your students communicate with you most frequently?
    a) Face-to-face either before or after class
    b) Face-to-face using office hours
    c) Phone
    d) Personal/individual email
    e) Course website/WebCT
    f) Instant messaging
    g) State other…………………

7. There are four levels in the pedagogy dimension: ***direct teaching, cognitively active learning, constructive learning, and social learning***. On each of the four pedagogy dimensions listed below, how do you rate yourself in terms of use?

   a) **Direct (traditional) teaching:** teaching methodology, which relies primarily on lectures, note-taking, chapter reviews and the regurgitation of facts on tests. The teaching style is strongly teacher-directed.

      i. Never use
      ii. Sometimes use
      iii. Use about half of the time
      iv. Mostly use
      v. Always use

   b) **Cognitively active learning:** at this level, the teacher believes that students should be active participants in learning rather than passive recipients of information. He or she *emphasises understanding and application rather than memorisation and repetition*. Students are encouraged to actively organise information items by themselves with the teacher-provided clues,

      i. Never use
      ii. Sometimes use
      iii. Use about half of the time
      iv. Mostly use
      v. Always use

   c) **Constructive learning:** students construct their own knowledge on the basis of interaction with their environment.

      i. Never use
      ii. Sometimes use
      iii. Use about half of the time
      iv. Mostly use
      v. Always use

d) **Social learning:** at this level, the focus is extended to address collaborative and social dimensions of education. A teacher believes that meaningful learning occurs when individuals are engaged in social activities.

    i. Never use
    ii. Sometimes use
    iii. Use about half of the time
    iv. Mostly use
    v. Always use

8. Based on your thoughts and the class observation report's (the use of technology section), what is your level as a user of educational technology (computer, laptop, audio/video display devices, iPads or other tablets, etc.) in the classroom?

    a. Never used it,
    b. A basic user,
    c. An adequate user,
    d. Good user.
    e. Advanced user

9. Have you tried to integrate the use of IT with the curriculum in your classroom?
    a. Yes,
    b. No, If no please, refer to Q 16

10. How often do you use the Internet as a facility to deliver the lesson?
    a. Every lesson
    b. Most lessons
    c. Some lessons
    d. Occasional lessons
    e. Never

11. How do you view the progress of your students when using integrated IT into lessons?
    a. Excellent
    b. Very good
    c. Good
    d. Satisfactory
    e. Not satisfactory

12. In your point of view, how is the effect of using mobile technology on your students' performance?

    a. Positive
    b. Partially positive
    c. Neither positive or negative
    d. Somewhat negative
    e. Negative

13. In your opinion, what is the effect of mobile technology on students' learning?

Mobile technology is the technology used for cellular communication.

    a. Positive
    b. Partially positive
    c. Neither positive nor negative
    d. Somewhat negative
    e. Negative

14. How would you rate the progress achieved by your students when you use the following methods:
    a. *Direct teaching,*
    b. *Cognitively active learning*
    c. *Constructive learning*
    d. *Social learning?*

Complete the table below. Refer to question 10 for the definitions of each teaching method.

	Excellent	Very Good	Good	Satisfactory	Not Satisfactory
Direct teaching					
Cognitively active learning					
Constructive learning					
Social learning					

15. In the case of using mobile technology devices, how many apps, software codes do you use in your teaching process (per Chapter)?

Mobile technology is the technology used for cellular communication.

a. One.
b. Two.
c. Three.
d. More than 4.

16. Have you constructed your own webpage for teaching?

a. Yes
b. No

17. Do you use the learning management system at the institution?

a. Yes
b. No

18. How often do you use mobile technology devices in your classes? *Mobile technology is the technology used for cellular communication.*

a. Per lesson
b. Per day
c. Per week,
d. Per month
e. Never

19. Which of those listed below, you do during the teaching and HOW helpful are they *TO YOUR students*?

	Not Applicable (never experienced)	Completely Unhelpful	Somewhere in the middle	Helpful	Very Helpful
Lecture notes projected via PowerPoint slides; Projection of Internet sites					
Individual or small-group work using computer workstations in a computer lab or computer classroom					
Audio, video or images display					
Simulation/ interactive animations/ applets					

20. How would you rate your ability to assist students with technical problems with their mobile learning devices

    a) I can help with the majority of occurring problems
    b) Small issues I can manage, but bigger ones I cannot
    c) I do not bother myself with it; I send student direct to the IT department

<u>End of survey</u>

Thank you for your time and cooperation.

APPENDIX FIVE

Teachers' Responses / Raw Data

APPENDIX 5 – TEACHERS' RESPONSES/ RAW DATA

	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
Q1 - years of teaching	6	13	25	23	12	7	9	18	18	23	23	15	10	11	8	14	8	5	8	5

	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
Q2 - courses per semester	3	2	4	3	3	3	5	3	3	5	2	4	3	2	2	3	3	2	2	3

Q3 - devices used to prepare lessons	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Desktop computer	/		/																	
b. Laptop computer	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
c. iPad	/			/		/	/	/	/	/		/	/	/	/	/	/	/	/	/
d. iPod/ MP3 player																				
e. Another (indicate)				/										/						

Q4 - devices used to deliver lessons	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Desktop computer																				
b. Laptop computer	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
c. iPad	/		/	/	/	/	/	/	/	/		/	/	/	/	/	/		/	/
d. iPod/ MP3 player	/																			
e. Another (indicate)				/										/						

Q5 - How important is technology for teaching job	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Completely unimportant																				
b. Unimportant																				
c. Neither important or unimportant		/		/														/		/
d. Important	/				/	/			/				/		/		/		/	
e. Very important			/				/	/		/	/	/		/		/				

Q6 - students communicating with you most frequently	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Face-to-face before or after class	/		/	/			/		/	/			/	/		/	/	/	/	/
b. Face-to-face using office hours								/	/								/		/	/
c. Phone																				
d. Personal /individual email		/			/	/			/				/	/		/	/			
e. Course website/ WebCT								/				/			/					
f. Instant messaging																				
g. Other (indicate)											/									

Q7a - direct/traditional teaching	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1. Never use																				
2.Sometimes use		/	/	/	/						/			/						
3. Use about half of the time						/	/	/	/	/		/			/	/	/			
4. Mostly use													/					/	/	/
5. Always use	/																			

Q7b - cognitively active teaching	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1. Never use																				
2.Sometimes use						/		/	/	/			/							
3. Use about half of the time			/				/				/	/			/		/			
4. Mostly use	/	/			/									/		/		/	/	/
5. Always use				/																

Q7c - constructive learning	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1. Never use					/															
2.Sometimes use			/			/	/	/		/	/	/	/				/	/	/	/
3. Use about half of the time	/			/											/					
4. Mostly use		/							/					/		/				
5. Always use																				

Q7d - social learning	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1. Never use							/					/								
2.Sometimes use					/	/		/	/	/	/		/		/		/	/	/	/
3. Use about half of the time	/															/				
4. Mostly use		/	/	/										/						
5. Always use																				

Q8 - user level of technology in class	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Never used it																				
b. Basic user																	/			
c. An adequate user						/			/									/		
d. Good user	/	/	/	/	/		/			/	/		/	/	/	/				
e. Advanced user								/				/							/	/

Q9 - did you integrate IT with curriculum	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Yes	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
b. No (go to Q13)																				

Q10 - how often uses Internet to deliver lesson	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Every lesson								/												
b. Most lessons	/				/	/			/	/				/			/			
c. Some lessons		/	/	/			/				/	/	/		/	/				
d. Occasional lessons																		/	/	/
e. Never																				

Q11 – students' progress while integrating IT in lessons	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Excellent																				
b. Very good					/	/	/		/	/				/					/	
c. Good	/		/					/			/	/	/		/	/		/		/
d Satisfactory		/		/													/			
e. Not satisfactory																				

Q12 - effect of mobile technology on students' performance	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Positive			/			/	/	/						/			/	/		
b. Partially positive	/	/			/				/	/	/	/	/			/				
c. Neither positive or negative				/											/					
d. Partially negative																			/	/
e. Negative																				

Q13 - effect of mobile technology on students' learning	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Positive						/	/	/						/						
b. Partially positive	/	/	/						/	/	/	/				/			/	/
c. Neither positive or negative				/	/								/		/		/	/		
d. Partially negative																				
e. Negative																				

Q14a - students' progress using *direct teaching*	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1.excellent	/												/		/	/				
2. Very good					/						/			/				/		/
3. Good						/	/	/		/							/		/	
4 Satisfactory		/	/	/					/			/								
5. Not satisfactory																				

Q14b - students' progress using *cognitively active learning*	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
1.excellent				/	/						/									
2. Very good	/	/				/	/	/		/		/		/	/	/		/		/
3. Good			/						/				/						/	
4Satisfactory																	/			
5. Not satisfactory																				

Q14c - students' progress using *constructive learning*	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
1.excellent																				
2. Very good	/	/	/	/		/		/	/	/						/			/	
3. Good							/				/	/	/	/			/	/		/
4Satisfactory															/					
5. Not satisfactory																				

Q14d - students' progress using *social learning*	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1.excellent																/				
2. Very good			/	/		/		/	/											
3. Good		/								/	/		/	/				/	/	
4.Satisfactory	/				/										/		/			/
5. Not satisfactory							/					/								

Q15 - how many apps/software codes are used to teach a chapter	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. One		/													/	/				/
b. Two				/							/			/			/	/	/	
c. Three	/							/		/		/	/							
d. More then 4			/		/		/		/											

Q16 - constructed own webpage for teaching	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Yes	/		/									/								
b. No		/		/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/

Q17 - using LMS in the institution	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
a. Yes	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/			/
b. No																		/	/	

Q18 - how often is used mobile technology in classes	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
a. Per lesson	/	/		/	/	/	/		/	/		/	/	/			/			
b. Per day											/							/		
c. Per week			/					/							/				/	/
d. Per month																/				
e. Never																				

Q19a - used for teaching and how helpful *notes via PPT*	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
1. Not applicable (never used)																				
2. Completely unhelpful			/	/																
3. Somewhere helpful									/											
4. Helpful		/			/	/		/		/	/	/	/	/	/				/	/
5. Very helpful	/						/									/	/	/		

Q19b - used for teaching and how helpful *Internet projection*	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
1. Not applicable (never used)																				
2. Completely unhelpful																				
3. Somewhere helpful			/	/			/		/		/							/		/
4. Helpful	/	/			/			/		/			/	/	/	/				
5. Very helpful						/						/					/		/	

Q19c - used for teaching and how helpful *individual/small groups with computer station*	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1. Not applicable (never used)				/																
2. Completely unhelpful																				
3. Somewhere helpful	/																	/	/	
4. Helpful		/	/		/				/	/	/	/	/		/		/			
5. Very helpful						/	/	/						/		/				/

Q19d - used for teaching and how helpful *audio, video or image display*	SMT1	SMT2	SMT3	HMT4	SFT5	SMT6	SMT7	SMT8	SMT9	HMT10	HMT11	HMT12	SFT13	SMT14	SMT15	SMT16	SMT17	HFT18	HMT19	HFT20
1. Not applicable (never used)																				
2. Completely unhelpful																				
3. Somewhere helpful											/	/							/	/
4. Helpful	/	/	/						/	/			/		/	/				
5. Very helpful				/	/	/	/	/						/			/	/		

Q19e - used for teaching and how helpful ***simulation/ interactive animations/ applets***	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
1. not applicable (never used)																				
2. Completely unhelpful																				
3. Somewhere helpful												/	/			/		/		
4. Helpful		/									/				/					/
5. Very helpful	/		/	/	/	/	/	/	/	/				/			/		/	

Q20 - ability to assist technical problems with learning devices	**SMT1**	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT10**	**HMT11**	**HMT12**	**SFT13**	**SMT14**	**SMT15**	**SMT16**	**SMT17**	**HFT18**	**HMT19**	**HFT20**
a. Can help with majority problems		/				/		/					/	/				/	/	/
b. Small issues can, bigger problems no	/		/	/	/		/		/	/	/	/			/	/	/			
c. I don't solve it, send a student to IT department.																				

	SMT1	**SMT2**	**SMT3**	**HMT4**	**SFT5**	**SMT6**	**SMT7**	**SMT8**	**SMT9**	**HMT 10**	**HMT 11**	**HMT 12**	**SFT 13**	**SMT 14**	**SMT 15**	**SMT 16**	**SMT 17**	**HFT 18**	**HMT 19**	**HFT 20**
Q1	6	13	25	23	12	7	9	18	18	23	23	15	10	11	8	14	8	5	8	5
Q2	3	2	4	3	3	3	5	3	3	5	2	4	3	2	2	3	3	2	2	5
Q3	a,b,c	b	a	b,c,e	b	b,c,	b,c,	b,c	b,c	b,c	b	b,c	b,c	b,c,e	b,c	b,c	b,c	b,c	b,c	b,c
Q4	b,c,d	b	b,c	b,c,e	b,c	b,c,	b,c,	b,c	b,c	b,c	a	b,c	b,c	b,c,e	b,c	b,c	b,c	b	b,c	b,c
Q5	d	c	e	c	d	d	e	e	d	e	e	e	d	e	d	e	d	c	d	c
Q6	a	d	a	a	d	d	a	b,e	a,b,d	a	g	e	a,d	a,d	e	a,d	a,b,d	a	a,b	a,b
Q7 a	5	2	2	2	2	3	3	3	3	3	2	3	4	2	3	3	3	4	4	4
Q7 b	4	4	3	5	4	2	3	2	2	2	3	3	2	4	3	4	3	4	4	4
Q7 c	3	4	2	3	1	2	2	2	4	2	2	2	2	4	3	4	2	2	2	2
Q7 d	3	4	4	4	2	2	1	2	2	2	2	1	2	4	2	3	2	2	2	2
Q8	d	d	d	d	d	c	d	e	c	d	d	e	d	d	d	d	b	c	e	e
Q9	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Q10	b	c	c	c	b	b	c	a	b	b	c	c	c	b	c	c	b	c	c	c
Q11	c	d	c	d	b	b	b	c	b	b	c	c	c	b	c	c	d	c	b	c
Q12	b	b	a	c	b	a	a	a	b	b	b	b	b	a	c	b	a	a	d	d
Q13	b	b	b	c	c	a	a	a	b	b	b	b	c	a	c	b	c	c	b	b

Q14 a	1	4	4	4	2	3	3	3	4	3	2	4	1	2	1	1	3	2	3	2
Q14 b	2	2	3	1	1	2	2	2	3	2	1	2	3	2	2	2	4	2	3	2
Q14 c	2	2	2	2		2	3	2	2	2	3	3	3	3	4	2	3	3	2	3
Q14 d	4	3	2	2	4	2	5	2	2	3	3	5	3	3	4	1	4	3	3	4
Q15	c	a	d	b	d		d	c	d	c	b	c	c	b	a	a	b	b	b	a
Q16	a	b	a	b	b	b	b	b	b	b	b	a	b	b	b	b	b	b	b	b
Q17	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	b	b	a
Q18	a	a	c	a	a	a	a	c	a	a	b	a	a	a	c	d	a	b	c	c
Q19 a	5	4	2	2	4	4	5	4	3	4	4	4	4	4	4	5	5	5	4	4
Q19 b	4		3	3	4	5	4	4	3	4	3	5	4	4	4	4	5	3	5	3
Q19 c	3	4	4	1	4	5	5	5	4	5	3	4	4	5	4	5	4	3	3	5
Q19 d	5	4	4	5	5	5	5	5	4	5	3	3	4	5	4	4	5	5	3	3
Q19 e	5	4	5	5	5	5	5	5	5	5	4	3	3	5	4	3	5	3	5	4
Q20	b	a	b	b	b	a	b	a	b	b	b	b	a	a	b	b	b	a	a	a

APPENDIX SIX

Examples of Lesson Plans/ The Implementation of the CPT Lessons

APPENDIX 6 – EXAMPLES OF LESSON PLANS/ THE IMPLEMENTATION OF THE CPT LESSONS

EXAMPLE ONE: PHYSICS - C3, P3, T4 AND C3, P3, T0

This example shows two physics lessons (two different contents) that were implemented in this study to verify the impact factor of C3, P3, T4. The first lesson, simple harmonic motion, was delivered using digital technology-based learning (C3, P3, T4). The second lesson, Newton's second law (Newton's first and third laws were revised with the students as well), was delivered without using digital technology, i.e. nondigital technology-based learning (C3, P3, T0). The timeline for implementing each lesson was three weeks (three teaching hours a week). Students were examined in week number four. The purpose of this example is to allow the reader to:

I. Know how lessons were constructed and implemented.
II. Know how learning objectives were integrated with digital technology.
III. Know how learning objectives were implemented without digital technology.
IV. To see how different pedagogies and kinds of the curriculum were applied to the teaching-learning process.
V. Compare the level of complexities between these two lessons by comparing the learning objectives for each lesson and comparing the assessments conducted after the teaching-learning process.

To measure the impact of digital technology on students' attainment, students were examined after completing each lesson (the conducted exams are shown in Appendix 8 – Samples of the Exams Conducted During this Study). To ensure as identical as possible level of complexities, the conducted exams in both cases were constructed according to Bloom's taxonomy.

Several digital technology tools were used to implement the digital technology-based learning, such as smartboard, PowerPoint presentation, Internet connection, simulations, shared links, learning management system, iBook, iPad and laptop, as well as Matlab and Vernier software, used during laboratory experiments.

To ensure that the difference between the implementation of these two lessons is related to the use of digital technology only and to eliminate or minimise other aspects of possible influence on students' attainment, such as teacher's attitudes or preferences of specific pedagogy or kind of curriculum, the following procedures were considered in all the CPT strategies implemented, all subjects (Physics, Biology, Mathematics, English language and Social studies) investigated during this study:

I. The same teacher should implement the two lessons (two different topics) for the same group of students. This implies that the same teacher implemented two situations: digital and nondigital technology-based learning.
II. A positive learning environment should be offered to students in both situations. This includes the physical environment as safe, clean and well-equipped classrooms, digital or nondigital technology tools, as well as the positive, encouraging and friendly relationship between the teacher and students.
III. The same pedagogical dimensions should be applied in both teaching scenarios.
IV. The same kinds of the curriculum (theoretical, interactive or practical) should be applied in both situations.
V. The same level of complexities should be applied for both contents and conducted exams.

Two different approaches were discussed and shared with the involved teachers to review the content's cognitive complexity: i) Florida's original depth of knowledge (DOK) Levels and ii) Webb's four-level DOK, refer to section 3.17.5. It was agreed with the involved teachers to use these approaches to judge the content complexity and ensure that both contents delivered, through digital technology or without, have the same level of complexity.

I confirm that these procedures were applied to all CPT strategies investigated in this study, including the three examples explained in this appendix (example one: physics, example two: biology, example three: social studies).

Table 90 shows a summary of the learning objectives of the two physics lessons.

Lesson's title / **Learning objectives**	**Depth of Knowledge (DOK)**	**Simple harmonic motion**	**Newton's second law**
Learning objective number one	Level 1: Recall / low cognitive complexity.	Define periodic motion, period (T), amplitude (A), and frequency (f) of periodic motion.	Define force, inertia, acceleration and equilibrium.
Learning objective number two	Level 1: Recall / low cognitive complexity.	State and apply Hooke's law and verify that a restoring force always pulls the object toward the equilibrium position. Examples given, the spring-mass system and simple pendulum.	State and apply Newton's second law: $\Sigma F = ma$, where F stands for the force, m is the mass, and a is the acceleration. Newton's first and third laws to be revised with the students.
Learning objective number three	Level 2: Basic application of skills and concepts / moderate cognitive complexity.	For a spring, plot a graph of force applied against extension produced and relate the slope of the line to the spring constant (K) and the area under the graph to the energy stored in the spring (elastic potential energy (P.E)).	For an object, plot the graph of the force applied against acceleration produced and relate the slope of the line to the mass of the object (m). Draw a free body diagram of objects at equilibrium or those accelerating.
Learning objective number four	Level 3: Strategic thinking and complex reasoning / high cognitive complexity.	Create the connection between simple harmonic motion, the simple pendulum, and real-life application, such as the pendulum clock. The main formula of the simple pendulum $T = 2\pi \sqrt{l/g}$, where T is the periodic time, L is the length of the rope and g is the gravitational acceleration ($g = 9.8\ m/s^2$).	Create the connection (relationship) between Newton's second law and another concept in physics, which is the linear momentum and to include some real-life applications related to these concepts (Newton's second law and linear momentum), such as the seat belts and airbags in the car.
Learning objective number five	Level 4: Extended thinking and complex reasoning / high cognitive complexity.	Solve problems related to Hooke's law, simple pendulum and the elastic potential energy. Problems related to the conservation of mechanical energy were included as well.	Solve problems related to Newton's laws, which includes drawing the free body diagram, calculating the net force and acceleration.

Table 90. Summary of the learning objectives of the included lessons

The First Lesson: Simple Harmonic Motion (C3, P3, T4)

This lesson was implemented using digital technology-based learning. The C3, P3, T4 strategy was applied to implement its learning objectives. As shown below, this means that three kinds of the curriculum (C3) were used: theoretical, practical and interactive. Eighty per cent of the content was integrated with digital technology (T4), which means that four out of five learning objectives were integrated with digital technology. Three pedagogical dimensions (P3) were used to deliver the content: direct teaching, social (collaborative) learning and cognitive learning. Following is the detail discussion of the implementation of each of the learning objectives, including the interpretation of the suggested terminologies (C3, P3, T4).

Learning objective number one

Define simple harmonic motion, periodic motion, period (T), amplitude (A), and frequency (f) of periodic motion.

To implement this learning objective, three pedagogical dimensions (P3) were used as follows:

Firstly, direct teaching; the teacher explained these terms simple harmonic motion, periodic motion, period (T), amplitude (A), and frequency (f) of periodic motion. The following points were discussed with the students (summary of the lecture notes).

I. The periodic motion is a movement, which repeats itself in a regular cycle.
II. Period, T, is the time that it takes an object to complete one complete cycle of motion from x = A to x = - A, and back to x = A (the wavelength) as shown in Figure 125.

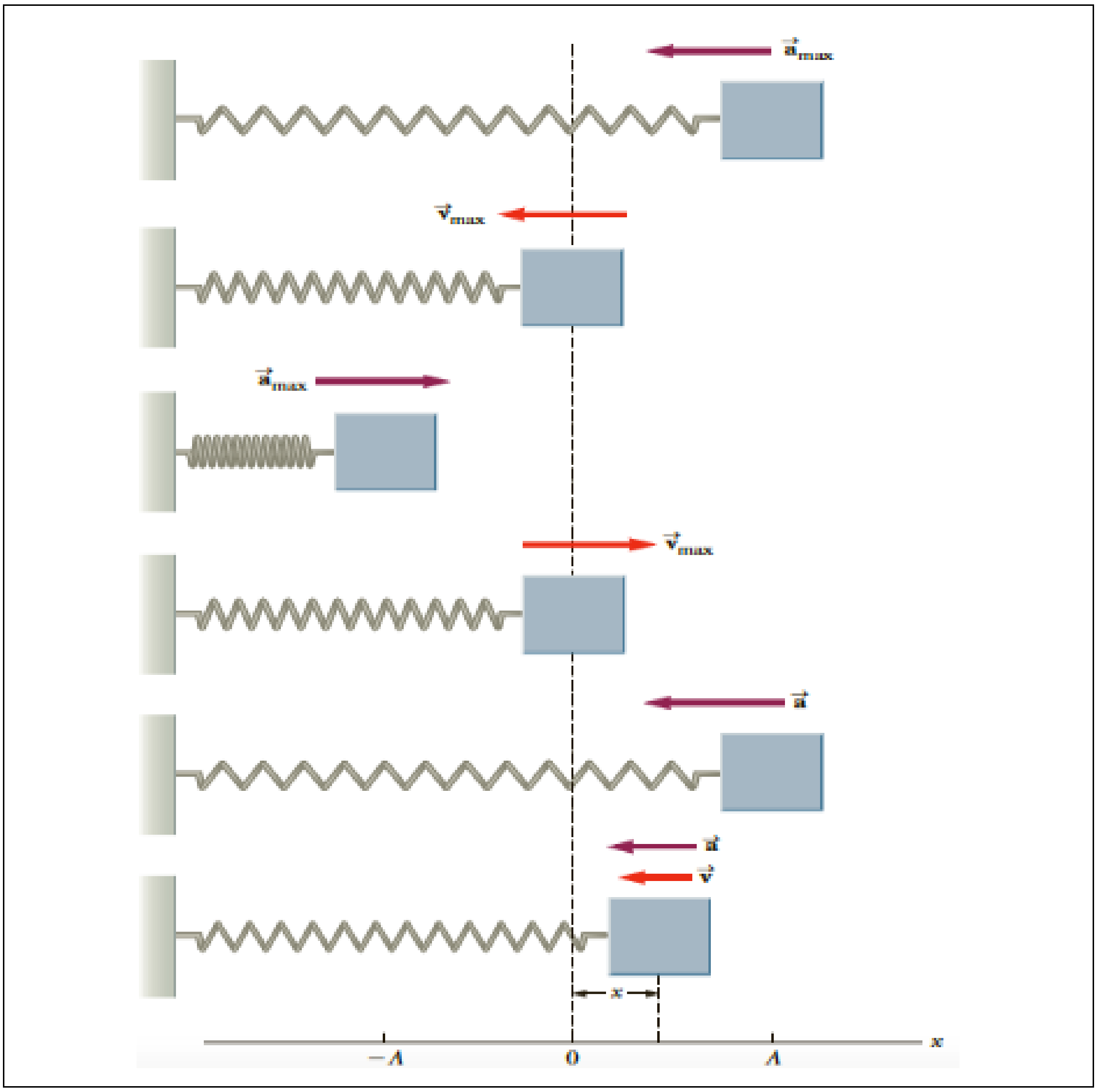


Figure 125. Simple harmonic motion for an object – spring-mass system (Serway & Vuille, 2013, p. 461)

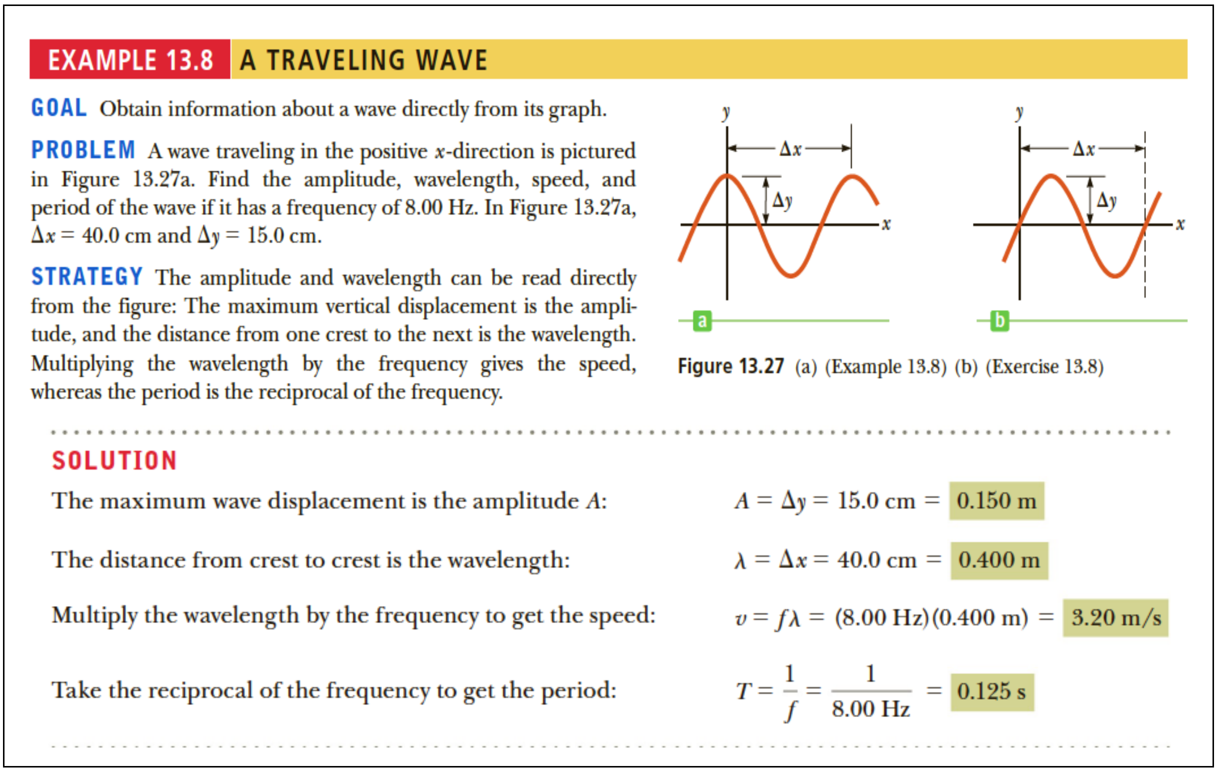
III. Simple Harmonic Motion: Motion that occurs when the net force along the direction of motion obeys Hooke's Law (see learning objective two), which means that the force is proportional to the displacement and always directed toward the equilibrium position. The motion of a spring-mass system is an example of simple harmonic motion.

IV. The frequency, f, is the number of complete cycles or vibrations per unit time.

V. Frequency is the reciprocal of the period $f = 1 / T$.

VI. The amplitude is the maximum position of the object from its equilibrium position.

Secondly, collaborative learning; students were divided into groups of five and asked to write down the definitions of these terms based on their understanding, i.e., in their own words. Students were asked to share and discuss their own definitions with each other. After which, students were asked to work together to complete the task, which is shown in Figure 126. The answer key was given to students after they completed the task.



EXAMPLE 13.8 **A TRAVELING WAVE**

GOAL Obtain information about a wave directly from its graph.

PROBLEM A wave traveling in the positive x-direction is pictured in Figure 13.27a. Find the amplitude, wavelength, speed, and period of the wave if it has a frequency of 8.00 Hz. In Figure 13.27a, $\Delta x = 40.0$ cm and $\Delta y = 15.0$ cm.

STRATEGY The amplitude and wavelength can be read directly from the figure: The maximum vertical displacement is the amplitude, and the distance from one crest to the next is the wavelength. Multiplying the wavelength by the frequency gives the speed, whereas the period is the reciprocal of the frequency.

Figure 13.27 (a) (Example 13.8) (b) (Exercise 13.8)

SOLUTION

The maximum wave displacement is the amplitude A: $A = \Delta y = 15.0 \text{ cm} = \boxed{0.150 \text{ m}}$

The distance from crest to crest is the wavelength: $\lambda = \Delta x = 40.0 \text{ cm} = \boxed{0.400 \text{ m}}$

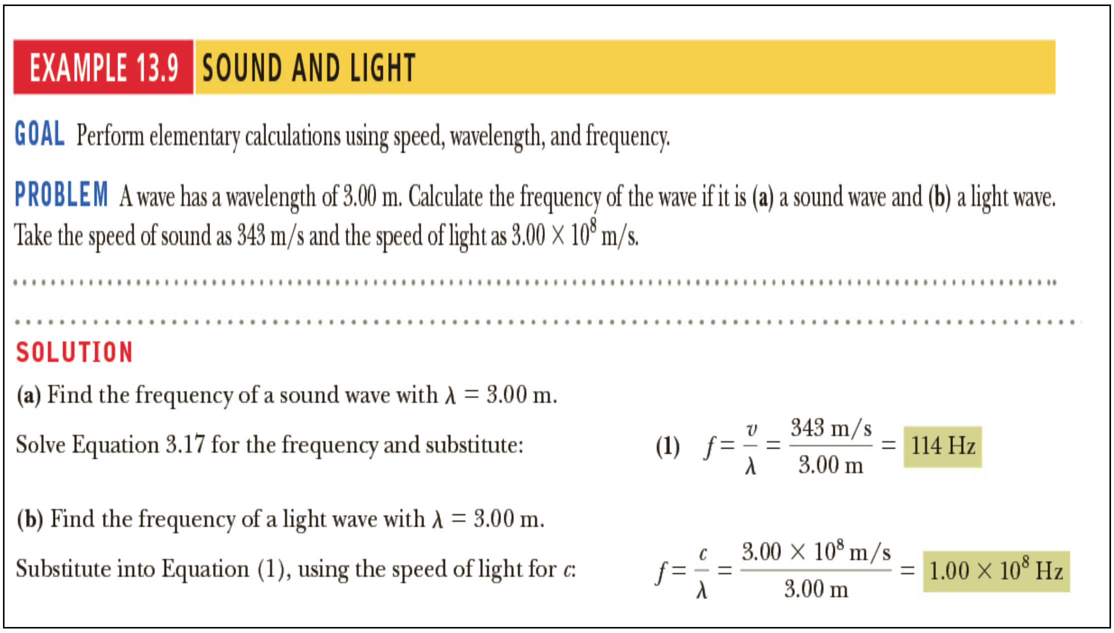
Multiply the wavelength by the frequency to get the speed: $v = f\lambda = (8.00 \text{ Hz})(0.400 \text{ m}) = \boxed{3.20 \text{ m/s}}$

Take the reciprocal of the frequency to get the period: $T = \frac{1}{f} = \frac{1}{8.00 \text{ Hz}} = \boxed{0.125 \text{ s}}$

Figure 126. Travelling wave practice (Serway & Vuille, 2013, p. 467)

Finally, cognitive learning; students were encouraged to think of new examples related to simple harmonic motion. Students' previous knowledge about the wave equation $v = f\lambda$ was refreshed. Students were asked to use the lecture notes and the hard copy book to perform elementary calculations using speed, wavelength, and frequency in order to complete the task, which is shown in Figure 127. The answer key was given to students after they completed the task.

Note: All figures that are taken from the College Physics book, by Chris Vuille and Raymond A Serway, 10th edition, 2014, are reproduced with the permission of the publisher Cengage Learning; permission conveyed through Copyright Clearance Center, Inc.



EXAMPLE 13.9 SOUND AND LIGHT

GOAL Perform elementary calculations using speed, wavelength, and frequency.

PROBLEM A wave has a wavelength of 3.00 m. Calculate the frequency of the wave if it is **(a)** a sound wave and **(b)** a light wave. Take the speed of sound as 343 m/s and the speed of light as 3.00×10^8 m/s.

SOLUTION

(a) Find the frequency of a sound wave with $\lambda = 3.00$ m.

Solve Equation 3.17 for the frequency and substitute:

$$\textbf{(1)} \quad f = \frac{v}{\lambda} = \frac{343\text{ m/s}}{3.00\text{ m}} = 114\text{ Hz}$$

(b) Find the frequency of a light wave with $\lambda = 3.00$ m.

Substitute into Equation (1), using the speed of light for c:

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8\text{ m/s}}{3.00\text{ m}} = 1.00 \times 10^8\text{ Hz}$$

Figure 127. The wave equation practice (Serway & Vuille, 2013, p. 468)

This learning objective was implemented without using digital technology since four out of five learning objectives, eighty per cent of the learning objectives, were integrated with digital technology (T4).

All three kinds of the curriculum (C3) were used to implement this learning objective.

Firstly, theoretical curriculum; the hard copy book (Serway & Vuille, 2013) was used; lecture notes were explained and written on the board (please see the discussed points with the students during the direct teaching).

Secondly, interactive curriculum; physical tools were used. The teacher displayed hardcopy posters related to periodic motion, such as a simple pendulum and spring-mass system (see Figure 125 and Figure 128).

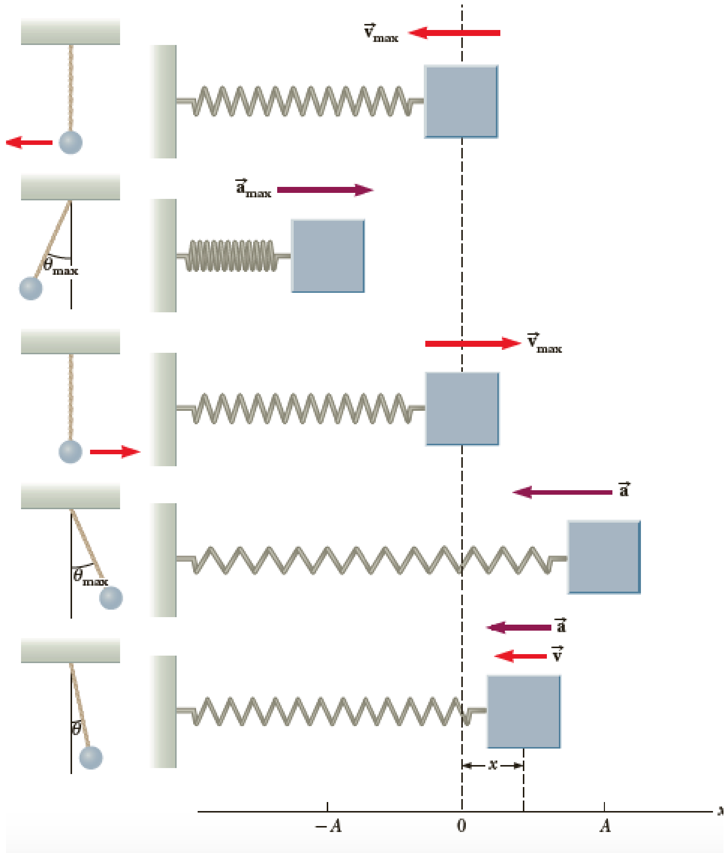


Figure 128. Simple pendulum and the spring-mass system as examples of simple harmonic motion. (Serway & Vuille, 2013, p. 461)

Finally, practical curriculum; physical models of a simple pendulum and spring-mass system with several masses (50 grams, 100 grams and 150 grams) were provided. Thus, students could experience a simple harmonic motion. Students could measure the periodic time of both systems, simple pendulum and spring-mass, using a stopwatch. Please refer to the experiments conducted in the learning objectives number four and five.

Learning objective number two

State and apply Hooke's law and verify that a restoring force always pulls the object toward the equilibrium position, as shown in Figure 129, where the blue arrow shows the direction of the restoring force.

Two examples were provided to explain this learning objective: the spring-mass system and simple pendulum, see Figure 129 and Figure 130.

The following formula represents Hooke’s law:

$$F = -K\Delta X$$

Where:

F is the restoring force (measured by Newton or N)

K is the spring constant (measured by Newton/meter or N/ m)

ΔX is the displacement or the extension (measured by meter or m)

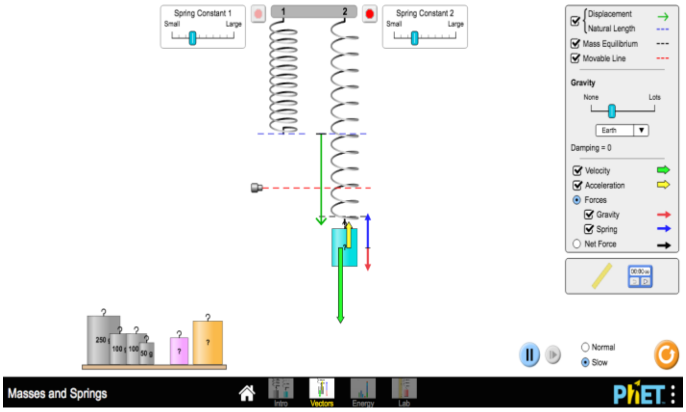


Figure 129. Hooke’s law simulation (spring-mass system), shows the direction of the velocity, acceleration, gravitational and spring force. ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_en.html

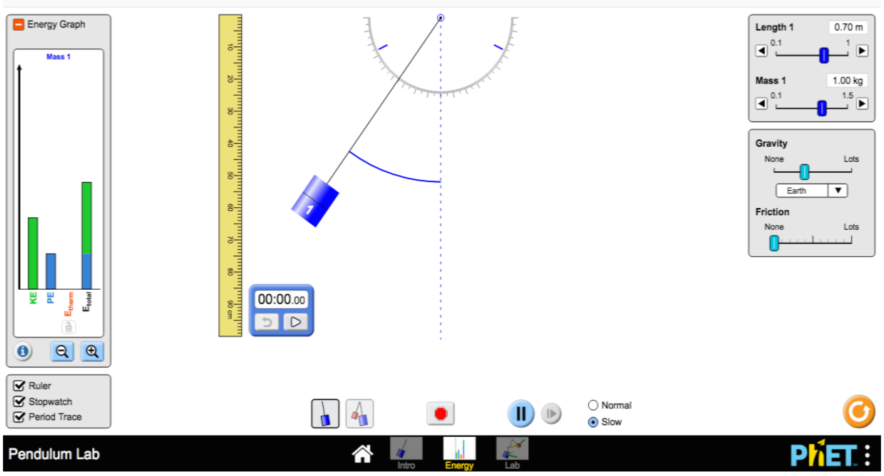


Figure 130. Simulation of the simple pendulum and its mechanical energy. ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html.

The online links for the simulations shown in Figure 129 and Figure 130 were shared with students via LMS or email. Thus, students could open these links and navigate through these simulations using their iPads. For instance, they could change the value of the spring constant, the mass of the object, which is connected with the spring and the length of the rope in the case of a simple pendulum, see Figure 129 and Figure 130. Therefore, students could monitor the impact of changing these parameters on the period (T) using the stopwatch, which is provided by the simulation itself.

This learning objective was implemented using three pedagogical dimensions (P3) supported by digital technology as follows:

Firstly, direct teaching; the teacher offered a full explanation for the content, which is related to this learning objective. The following points were discussed with the students:

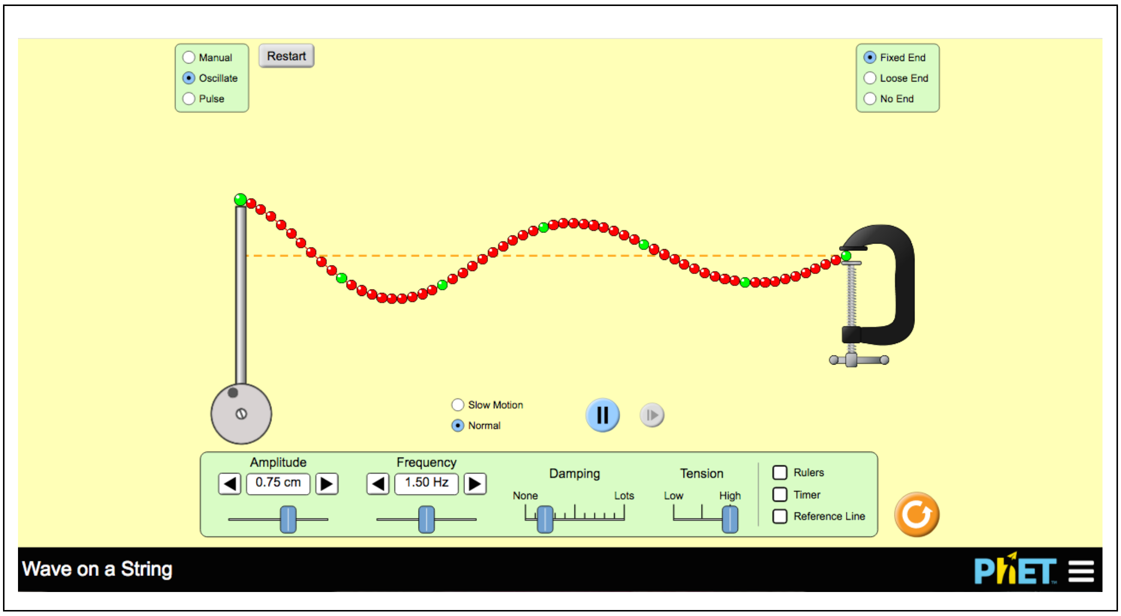
I. The mathematical formula of Hooke’s law is given by $F = -K\Delta X$
  - F is the spring force.
  - K is the spring constant. It is a measure of the stiffness of the spring.
  - A large k indicates a stiff spring and a small k indicates a soft spring.
  - ΔX is the displacement of the object from its equilibrium position (the extension).

II. X = 0 at the equilibrium position

III. The negative sign in Hook’s law indicates that the spring force is always directed opposite to the displacement.

IV. The spring force acts toward the equilibrium position. Thus, it is called the restoring force

Secondly, collaborative learning; students were assigned to work in groups, exchange the notes they collected from the shared simulations shown in Figure 129, Figure 130 and Figure 131.



○ Manual
● Oscillate
○ Pulse

● Fixed End
○ Loose End
○ No End

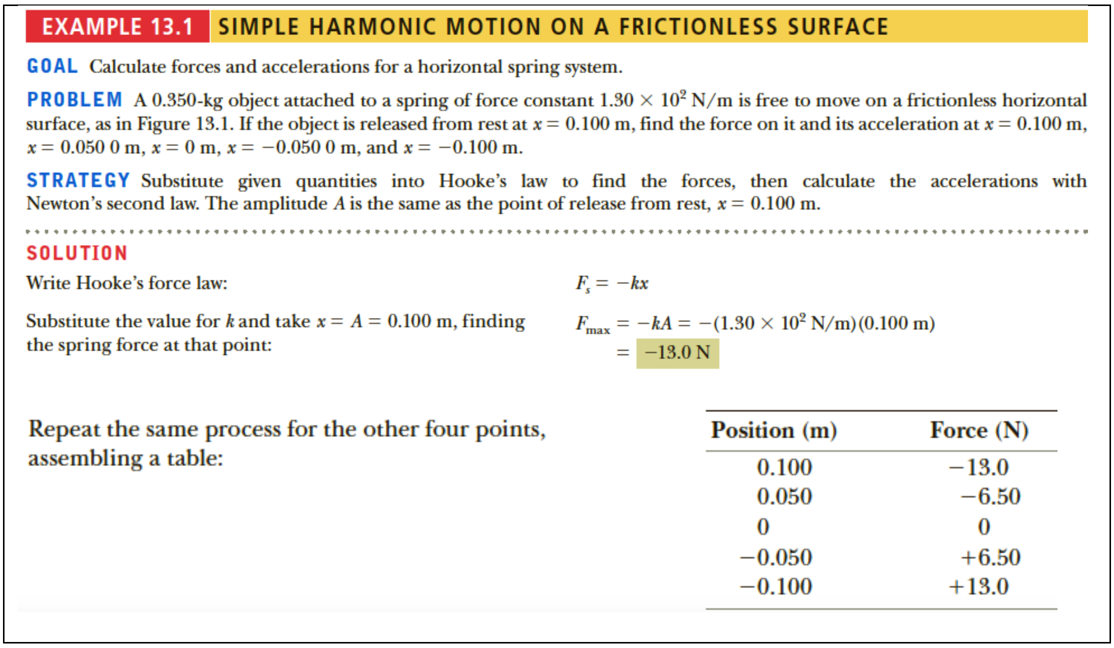
○ Slow Motion
● Normal

Amplitude 0.75 cm

Frequency 1.50 Hz

Figure 131. Simulation shows an example of the periodic motion. ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html

Students were divided into groups and asked to work together to complete the task, which is shown in Figure 132. The answer key was shared with them later on.



EXAMPLE 13.1 SIMPLE HARMONIC MOTION ON A FRICTIONLESS SURFACE

GOAL Calculate forces and accelerations for a horizontal spring system.

PROBLEM A 0.350-kg object attached to a spring of force constant 1.30×10^2 N/m is free to move on a frictionless horizontal surface, as in Figure 13.1. If the object is released from rest at $x = 0.100$ m, find the force on it and its acceleration at $x = 0.100$ m, $x = 0.050\,0$ m, $x = 0$ m, $x = -0.050\,0$ m, and $x = -0.100$ m.

STRATEGY Substitute given quantities into Hooke's law to find the forces, then calculate the accelerations with Newton's second law. The amplitude A is the same as the point of release from rest, $x = 0.100$ m.

SOLUTION

Write Hooke's force law:

$$F_s = -kx$$

Substitute the value for k and take $x = A = 0.100$ m, finding the spring force at that point:

$$F_{\text{max}} = -kA = -(1.30 \times 10^2 \text{ N/m})(0.100 \text{ m})$$
$$= \boxed{-13.0 \text{ N}}$$

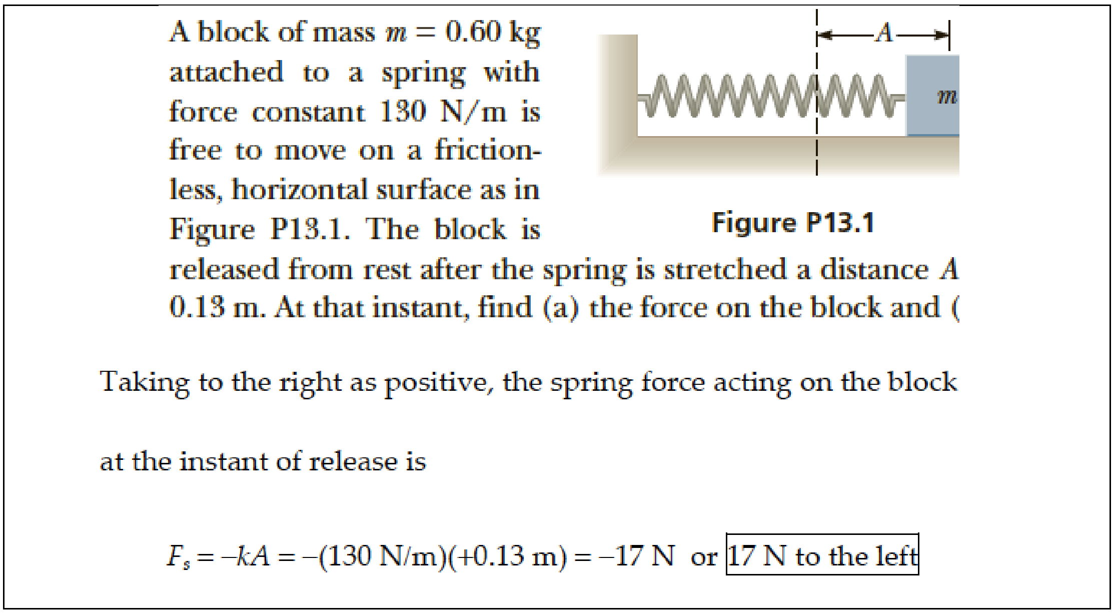
Repeat the same process for the other four points, assembling a table:

Position (m)	Force (N)
0.100	−13.0
0.050	−6.50
0	0
−0.050	+6.50
−0.100	+13.0

Figure 132. Simple harmonic motion on a frictionless surface (Serway & Vuille, 2013, p. 447)

Finally, cognitive learning; students were encouraged to make a further investigation about simple harmonic motion in general, and Hooke’s law in particular, by checking external resources online. For instance, using the shared simulations, such as the links shown in Figure 129, Figure 130 and Figure 131, students could discover that the mass has no impact on the periodic time of simple pendulum, and the vice versa in the case of the spring-mass system. Also, students could discover that the mechanical energy of simple harmonic motion, in the absence of friction, is conserved, see Figure 130.

Students were asked to work in groups to complete the tasks shown in Figure 133 and Figure 134; they were allowed to use their lecture notes, textbook (iBook) and their own collected notes from the shared links, and any other resources for learning, including online resources. Students were allowed to use the search engines, such as Google, Bing, and Yahoo, to assist them in completing these tasks. After which, students were asked to share their work and to discuss it with the teacher as well. Answer Keys for these practices were shared with the students later on.



A block of mass $m = 0.60$ kg attached to a spring with force constant 130 N/m is free to move on a frictionless, horizontal surface as in Figure P13.1. The block is released from rest after the spring is stretched a distance A 0.13 m. At that instant, find (a) the force on the block and (

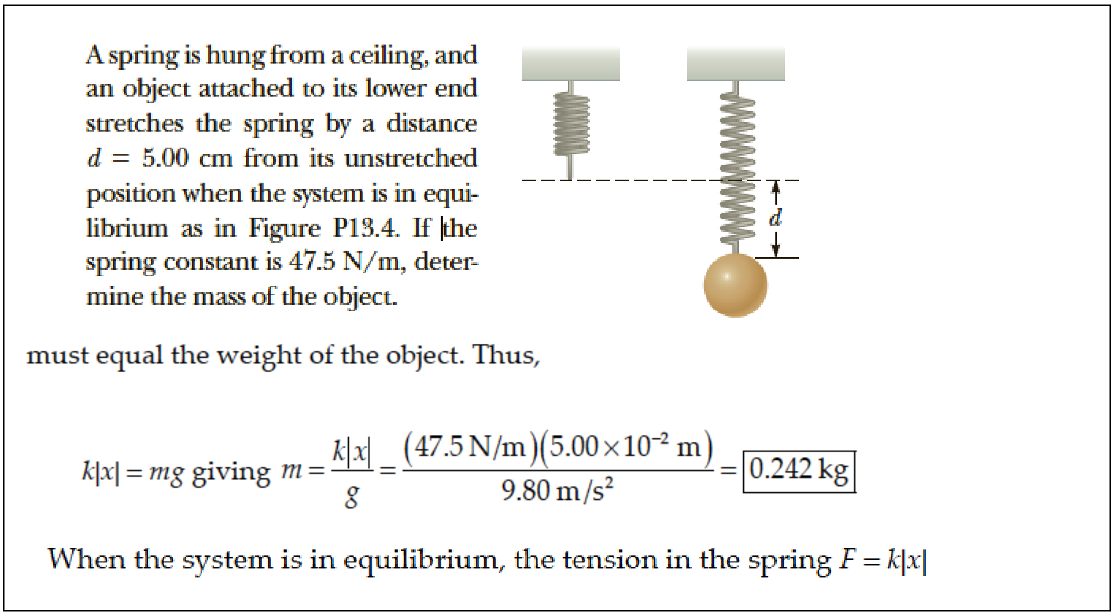
Figure P13.1

Taking to the right as positive, the spring force acting on the block

at the instant of release is

$$F_s = -kA = -(130\text{ N/m})(+0.13\text{ m}) = -17\text{ N} \text{ or } \boxed{17\text{ N to the left}}$$

Figure 133. Practice related to Hooke’s law and its answer key (Serway & Vuille, 2013, p. 475)



A spring is hung from a ceiling, and an object attached to its lower end stretches the spring by a distance d = 5.00 cm from its unstretched position when the system is in equilibrium as in Figure P13.4. If the spring constant is 47.5 N/m, determine the mass of the object.

must equal the weight of the object. Thus,

$$k|x| = mg \text{ giving } m = \frac{k|x|}{g} = \frac{(47.5\text{ N/m})(5.00\times10^{-2}\text{ m})}{9.80\text{ m/s}^2} = \boxed{0.242\text{ kg}}$$

When the system is in equilibrium, the tension in the spring $F = k|x|$

Figure 134. Practice related to Hooke’s law and its answer key (Serway & Vuille, 2013, p. 475)

Three kinds of the curriculum (C3) supported by digital technology were used to implement this learning objective.

Firstly, the theoretical curriculum represented by lecture notes and textbook (soft copy), see Figure 139 and Figure 140. Please refer to the points covered during the direct teaching of this learning objective, and the screenshots of the covered tasks.

Secondly, interactive curriculum represented by simulations that allowed students to navigate through it, see Figure 129, Figure 130 and Figure 131. Videos and online virtual laboratories related to the simple harmonic motion were shared with students as well; see Figure 135 and Figure 136.

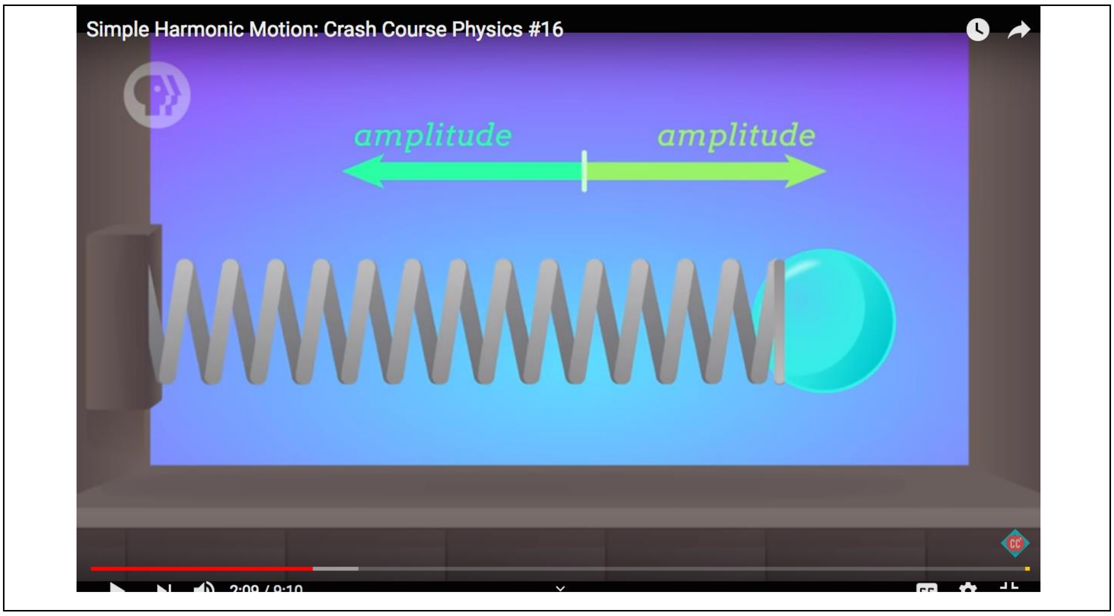


Figure 135. Video related to simple harmonic motion. © 2016 CrashCourse https://www.youtube.com/watch?v=jxstE6A_CYQ

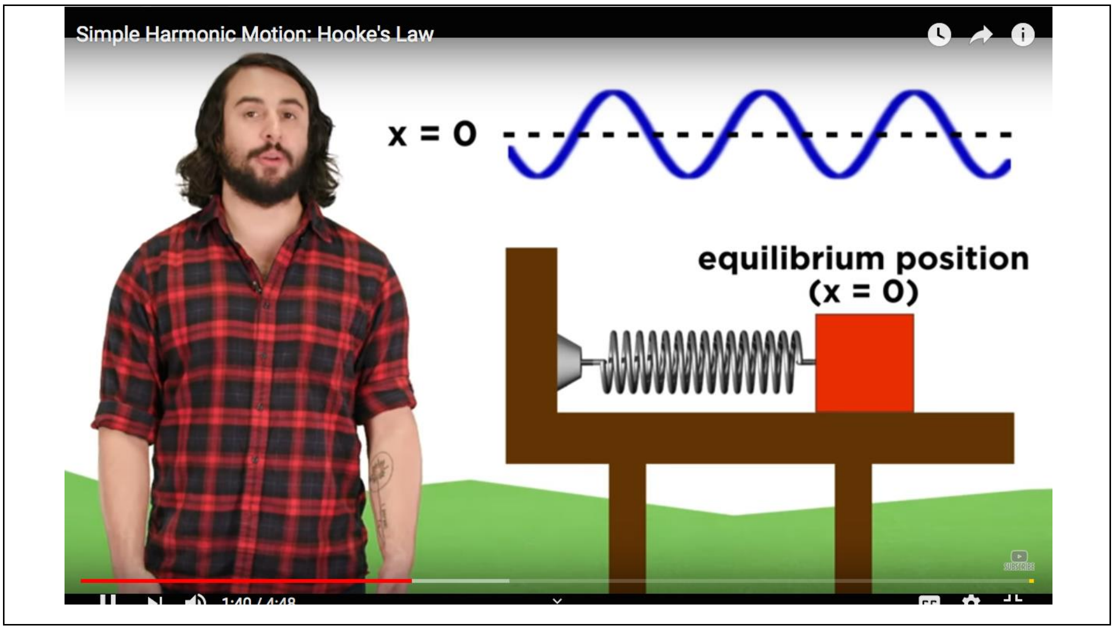


Figure 136. Video related to Hooke’s law. https://www.youtube.com/watch?v=gZ_KnZHCn4M

Finally, practical curriculum; a hands-on experiment was conducted using a spring-mass system (Hooke’s law). Therefore, students could verify experimentally that a restoring force always pulls the object toward the equilibrium position. Please refer to the conducted experiment in this lesson.

The content was uploaded onto the learning management system – desire to learn (D2L-LMS) where students could download it to their iPads or laptops so that they could work on it, see Figure 137 to Figure 148. Extra resources and links were shared with students to enable them to do online research and build new knowledge; students could exchange their gained knowledge using their iPads or laptops.

Figure 137 to Figure 148 show how the learning management system (D2L-LMS) was used during this study. These figures show the content, which was uploaded, to the LMS and the resources that can be found in the LMS, being aware that this LMS is used by all schools that belong to the Institute of Applied Technology (IAT) where the study took place.

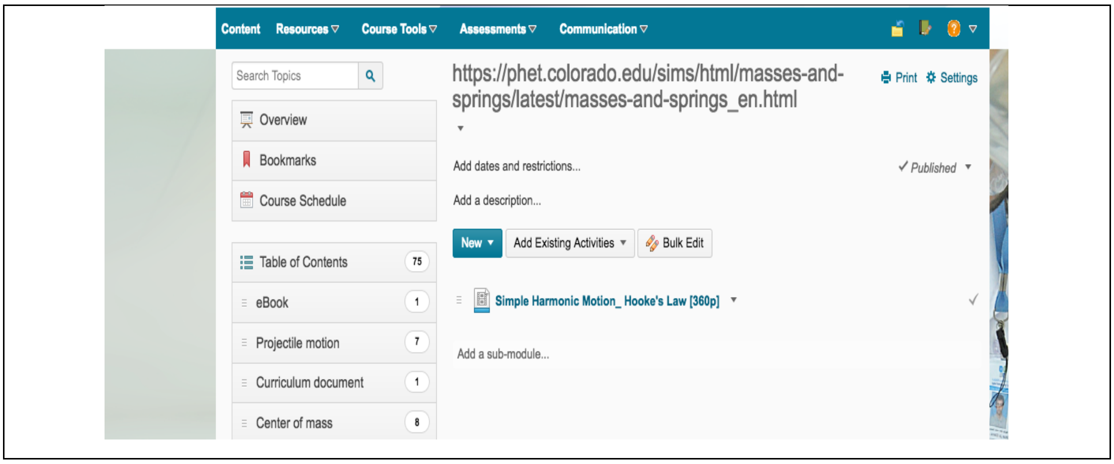
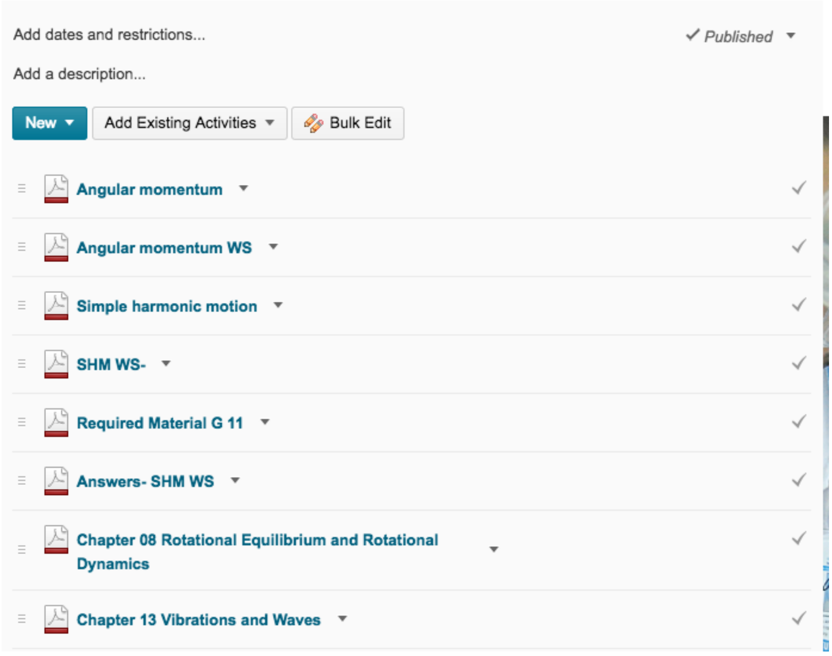
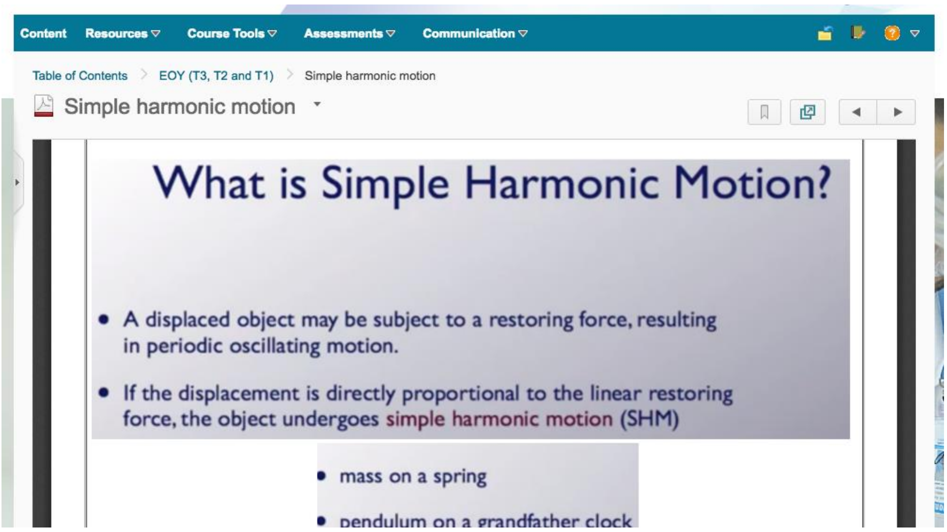


Figure 137. Screenshot of my homepage at the D2L-LMS shows a link and video related to the simple harmonic motion were shared with students.



- Angular momentum ✓
- Angular momentum WS ✓
- Simple harmonic motion ✓
- SHM WS- ✓
- Required Material G 11 ✓
- Answers- SHM WS ✓
- Chapter 08 Rotational Equilibrium and Rotational Dynamics ✓
- Chapter 13 Vibrations and Waves ✓

Figure 138. Screenshot of the D2L-LMS shows the content of the simple harmonic motion lesson, including the lecture notes, textbook (chapter 13) and a worksheet.



Simple harmonic motion

What is Simple Harmonic Motion?

- A displaced object may be subject to a restoring force, resulting in periodic oscillating motion.
- If the displacement is directly proportional to the linear restoring force, the object undergoes simple harmonic motion (SHM)
  - mass on a spring
  - pendulum on a grandfather clock

Figure 139. Screenshot of the D2L-LMS shows the simple harmonic motion lesson (the lecture notes)

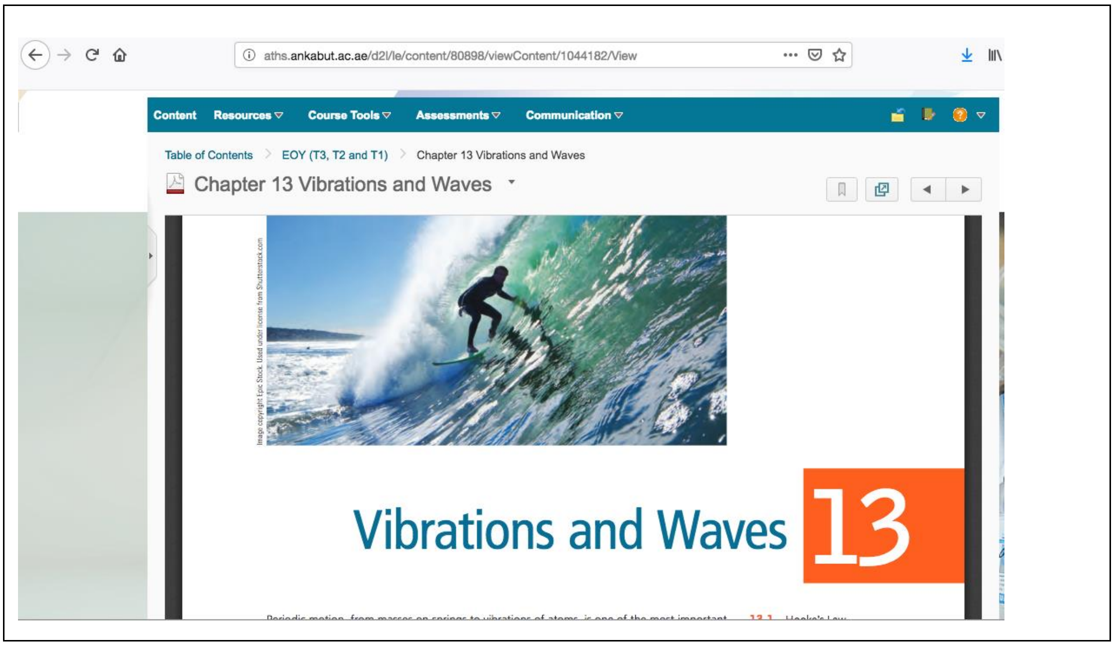

aths.ankabut.ac.ae/d2l/le/content/80898/viewContent/1044182/View

Figure 140. Screenshot of the D2L-LMS shows part of the iBook, chapter 13 of the textbook, Vibrations and waves.

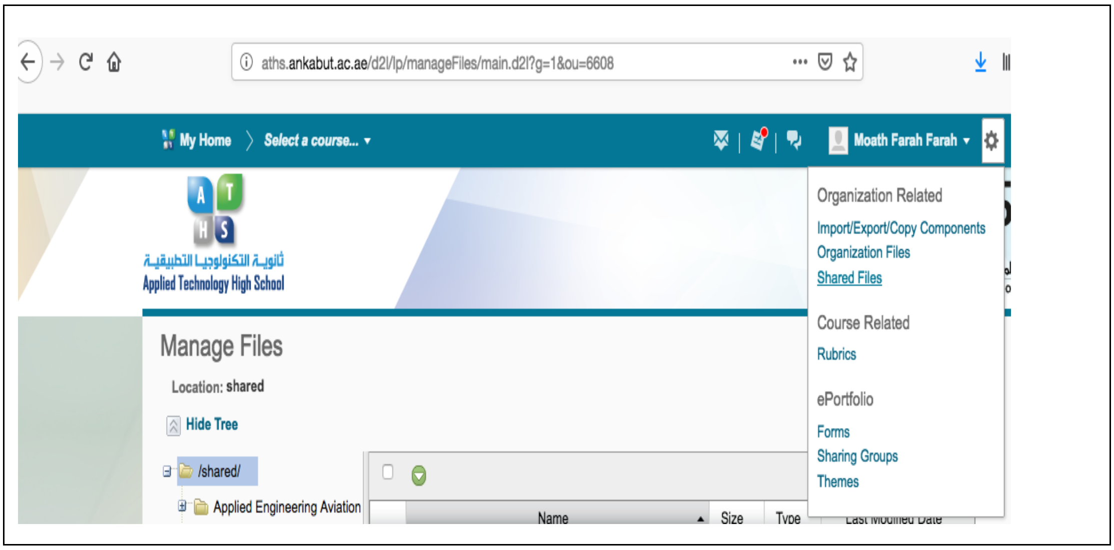
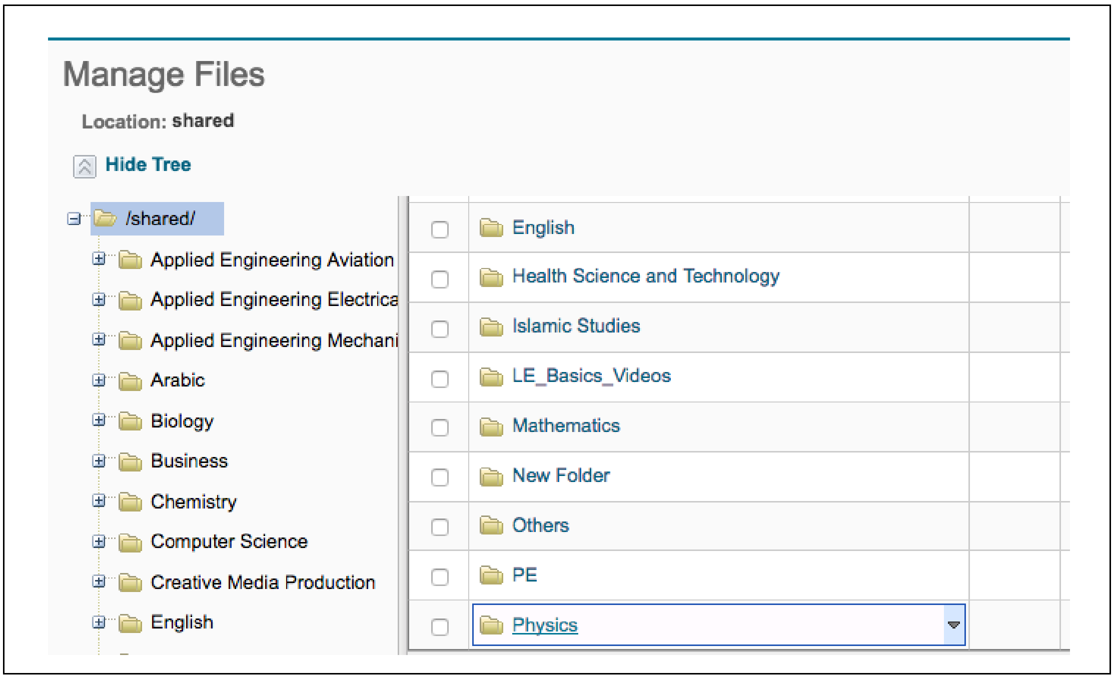

aths.ankabut.ac.ae/d2l/lp/manageFiles/main.d2l?g=1&ou=6608

Figure 141. Screenshot of the D2L-LMS shows different learning resources that can be found on the LMS (the shared files).



Manage Files

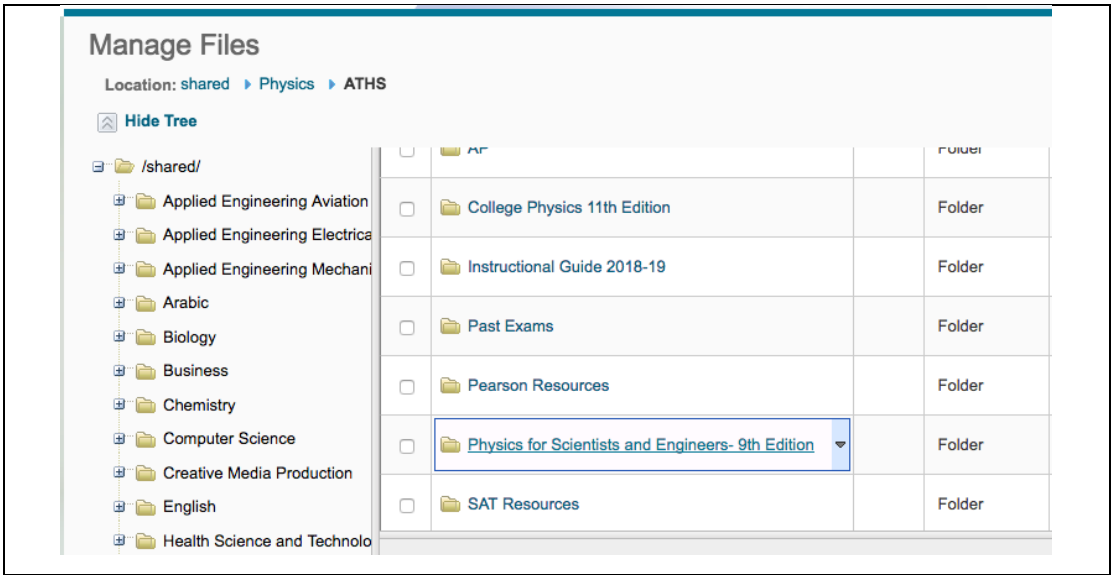
Location: **shared**

Hide Tree

/shared/
Applied Engineering Aviation
Applied Engineering Electrica
Applied Engineering Mechani
Arabic
Biology
Business
Chemistry
Computer Science
Creative Media Production
English

☐ English
☐ Health Science and Technology
☐ Islamic Studies
☐ LE_Basics_Videos
☐ Mathematics
☐ New Folder
☐ Others
☐ PE
☐ Physics

Figure 142. Different subjects are supported by the D2L-LMS.



Manage Files

Location: shared ▸ Physics ▸ **ATHS**

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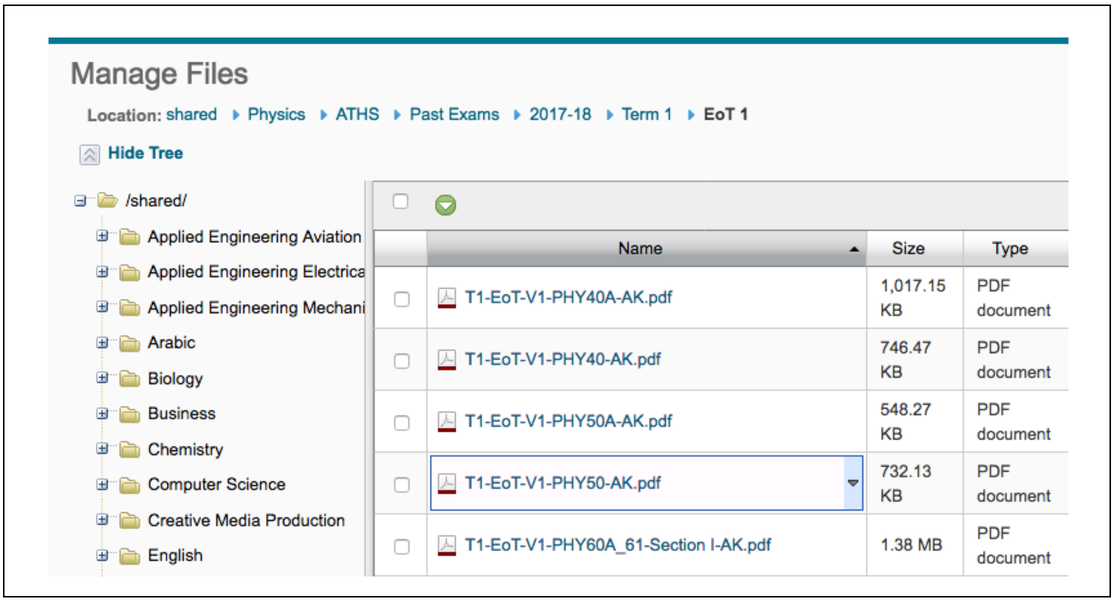
Applied Engineering Aviation
Applied Engineering Electrica
Applied Engineering Mechani
Arabic
Biology
Business
Chemistry
Computer Science
Creative Media Production
English
Health Science and Technolo

☐	College Physics 11th Edition	Folder
☐	Instructional Guide 2018-19	Folder
☐	Past Exams	Folder
☐	Pearson Resources	Folder
☐	Physics for Scientists and Engineers- 9th Edition	Folder
☐	SAT Resources	Folder

Figure 143. Different learning resources related to physics can be found on the D2L-LMS.


Manage Files

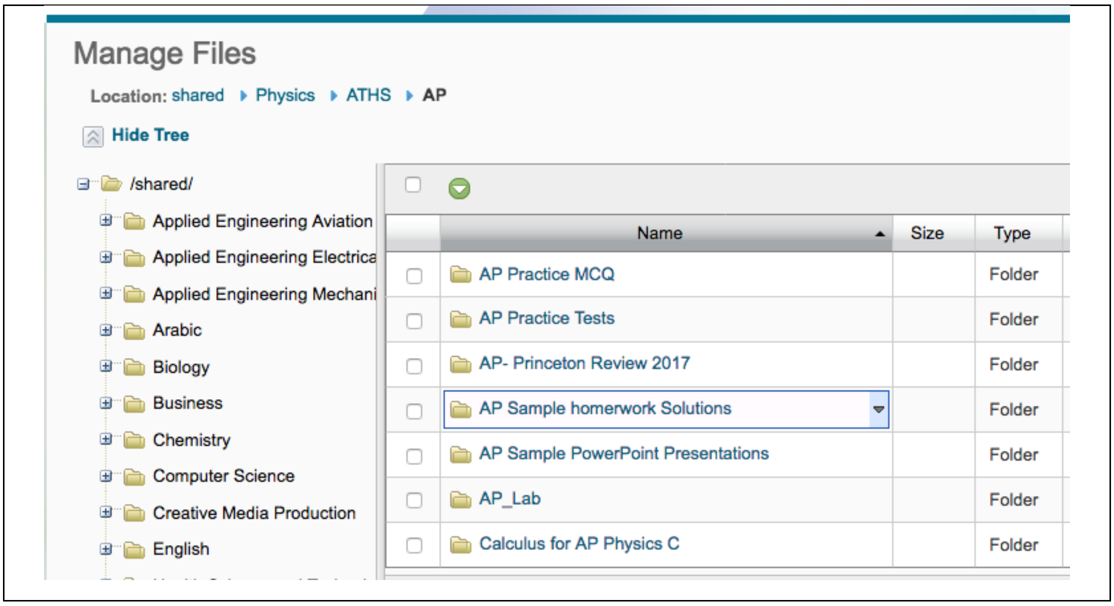
Location: shared ▸ Physics ▸ ATHS ▸ Past Exams ▸ 2017-18 ▸ Term 1 ▸ **EoT 1**

Hide Tree

- /shared/
  - Applied Engineering Aviation
  - Applied Engineering Electrica
  - Applied Engineering Mechani
  - Arabic
  - Biology
  - Business
  - Chemistry
  - Computer Science
  - Creative Media Production
  - English

☐	Name	Size	Type
☐	T1-EoT-V1-PHY40A-AK.pdf	1,017.15 KB	PDF document
☐	T1-EoT-V1-PHY40-AK.pdf	746.47 KB	PDF document
☐	T1-EoT-V1-PHY50A-AK.pdf	548.27 KB	PDF document
☐	T1-EoT-V1-PHY50-AK.pdf	732.13 KB	PDF document
☐	T1-EoT-V1-PHY60A_61-Section I-AK.pdf	1.38 MB	PDF document

Figure 144. Past paper exams are uploaded to the D2L-LMS.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Location: shared ▸ Physics ▸ ATHS ▸ **AP**

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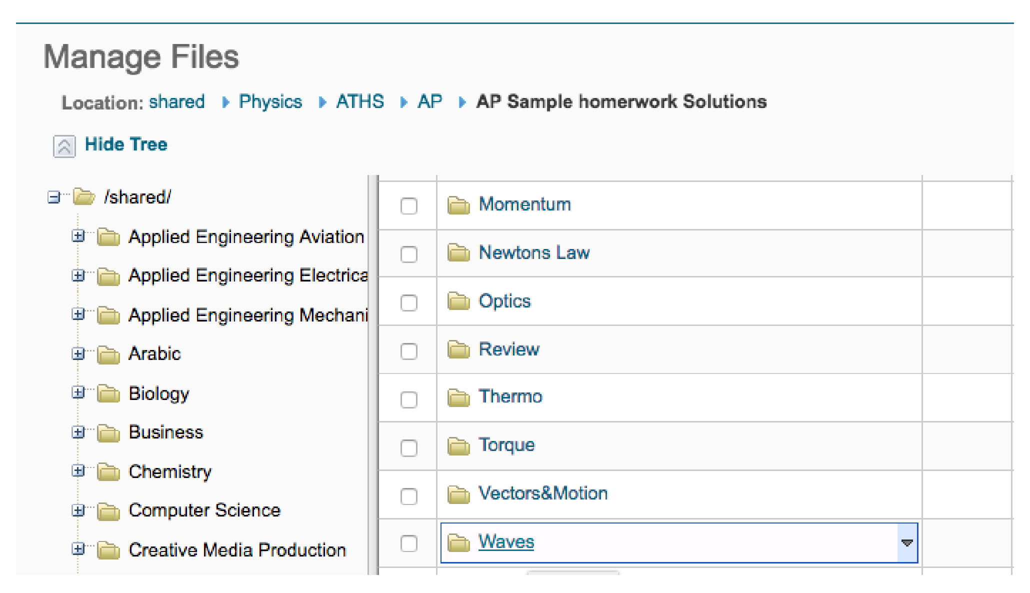
  - Applied Engineering Electrica
  - Applied Engineering Mechani
  - Arabic
  - Biology
  - Business
  - Chemistry
  - Computer Science
  - Creative Media Production
  - English

☐	Name	Size	Type
☐	AP Practice MCQ		Folder
☐	AP Practice Tests		Folder
☐	AP- Princeton Review 2017		Folder
☐	AP Sample homerwork Solutions		Folder
☐	AP Sample PowerPoint Presentations		Folder
☐	AP_Lab		Folder
☐	Calculus for AP Physics C		Folder

Figure 145. Advanced Placement (AP) exams, past paper exams, are uploaded to the D2L-LMS.



Manage Files

Location: shared ▸ Physics ▸ ATHS ▸ AP ▸ AP Sample homerwork Solutions

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- Applied Engineering Aviation
- Applied Engineering Electrica
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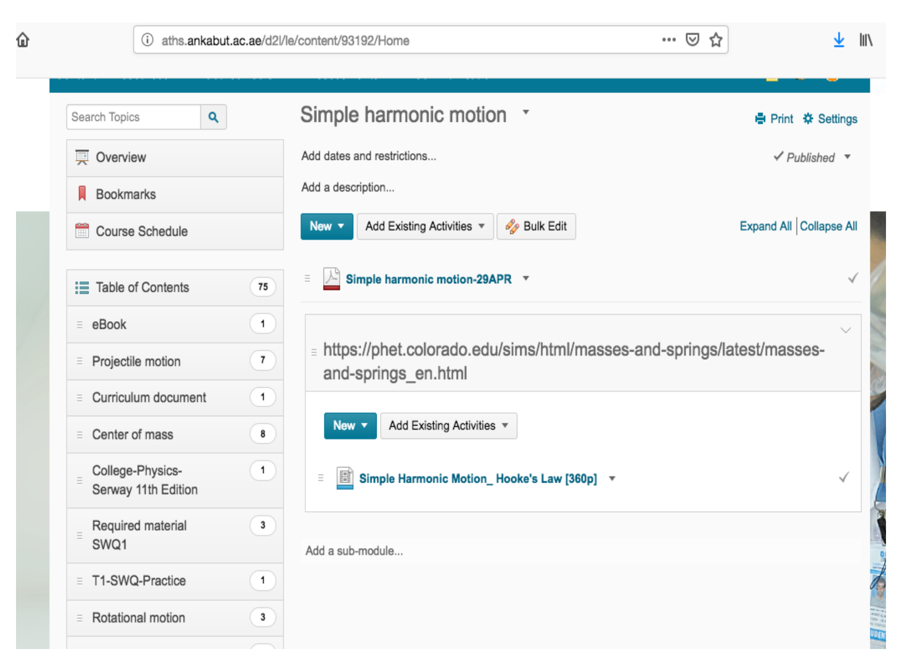
- Business
- Chemistry
- Computer Science
- Creative Media Production

☐ Momentum
☐ Newtons Law
☐ Optics
☐ Review
☐ Thermo
☐ Torque
☐ Vectors&Motion
☐ Waves

Figure 146. The D2L-LMS offers many folders, including worksheets, answer keys, and various learning resources.



aths.ankabut.ac.ae/d2l/le/content/93192/Home

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Projectile motion	7
Curriculum document	1
Center of mass	8
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T1-SWQ-Practice	1
Rotational motion	3

Simple harmonic motion

Add dates and restrictions...

✓ Published

Add a description...

Simple harmonic motion-29APR ✓

https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_en.html

Simple Harmonic Motion_ Hooke's Law [360p] ✓

Add a sub-module...

Figure 147. Video (the second file) related to simple harmonic motion uploaded to the D2L-LMS

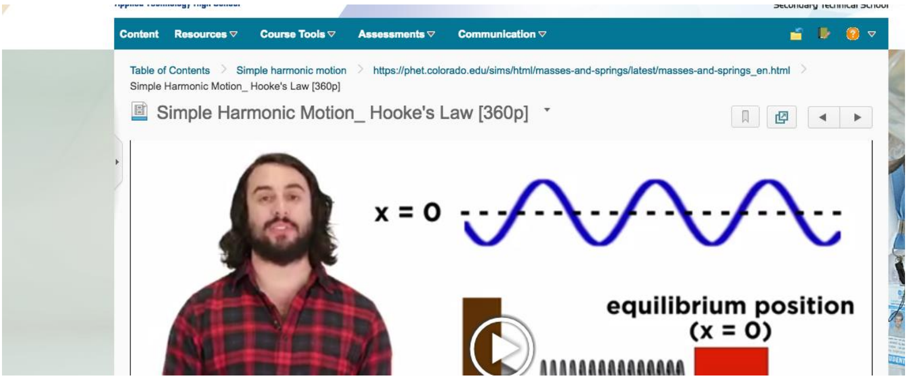


Figure 148. Video related to simple harmonic motion uploaded to the D2L-LMS

Learning objective number three

For a spring, plot a graph of force applied against extension produced and relate the slope of the line to the spring constant (K) and the area under the graph to the energy stored in the spring (elastic potential energy (P.E)).

Three pedagogical dimensions (P3) supported by digital technology were used to implement this learning objective:

Firstly, direct teaching; the teacher explained the relationship between the applied force and the extension in Hooke's law. The elastic potential energy was discussed with the students as well.

Summary of the discussed points:

I. The spring force F acts toward the equilibrium position and directly proportional to the displacement produced ΔX. See Figure 149, which shows a screenshot of an online laboratory experiment that was shared with the students.

II. The energy stored in a stretched or compressed spring or other elastic material is called elastic potential energy and given by $PE_s = \frac{1}{2}kx^2$, see Figure 150 and Figure 151, which show screenshots of related online videos that were shared with the students.

III. The energy is stored only when the spring is stretched or compressed.

IV. Elastic potential energy can be added to the statements of Conservation of Mechanical Energy and Work-Energy theorem. Which can be expressed by the following mathematical formula.

$$ME_i = ME_f$$

$$KE_i + PE_i = KE_f + PE_f$$

$$(\frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2)_i = (\frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2)_f$$

Where

- ME: the mechanical energy (Joule)
- KE: the kinetic energy (Joule)
- PE: the potential energy (Joule)
- m: the mass of the object (kg)
- v: the speed of the object (m/s)
- g: the gravitational acceleration (9.8 m/s^2).
- h: the height (m)
- K: the spring constant (N/m)
- x: the extension (m)

The following figures and links were shared with students via LMS.

This figure has been removed due to Copyright restrictions.

However, it can be viewed via the link shown in the caption below.

Figure 149. Online laboratory experiment shows the procedures for finding the spring constant (K). https://www.youtube.com/watch?v=s0YMDXf-2SI

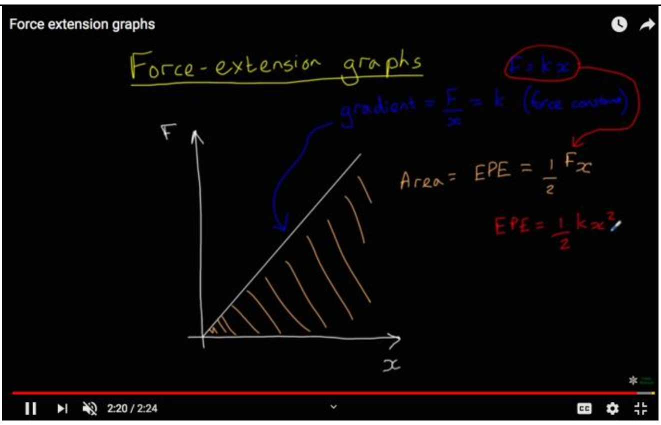


Figure 150. The force-extension graph and elastic potential energy https://www.youtube.com/watch?v=BUrRv9U1-bY

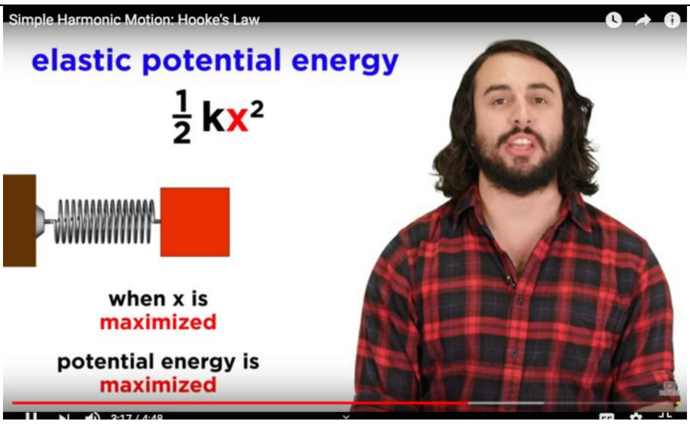
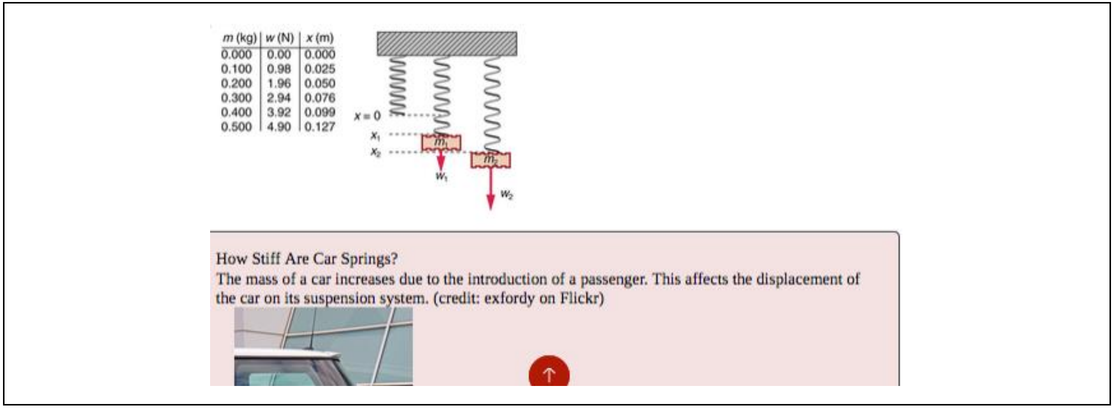


Figure 151. Video related to the elastic potential energy https://www.youtube.com/watch?v=gZ_KnZHCn4M

Secondly, collaborative learning; students were divided into groups to exchange their knowledge and the notes they collected from the shared links, see Figure 149, Figure 150, Figure 151 and Figure 152. The shared link is related to the force-extension graph and the elastic potential energy. Using the link, students were asked to work together to plot the graph between the restoring force (F) and the extension or displacement (X), calculate the slope of the line, which is equal to the spring constant, and also to calculate the stored elastic potential energy, which is equal to the area under the graph. Students were asked to share and discuss their work and findings.

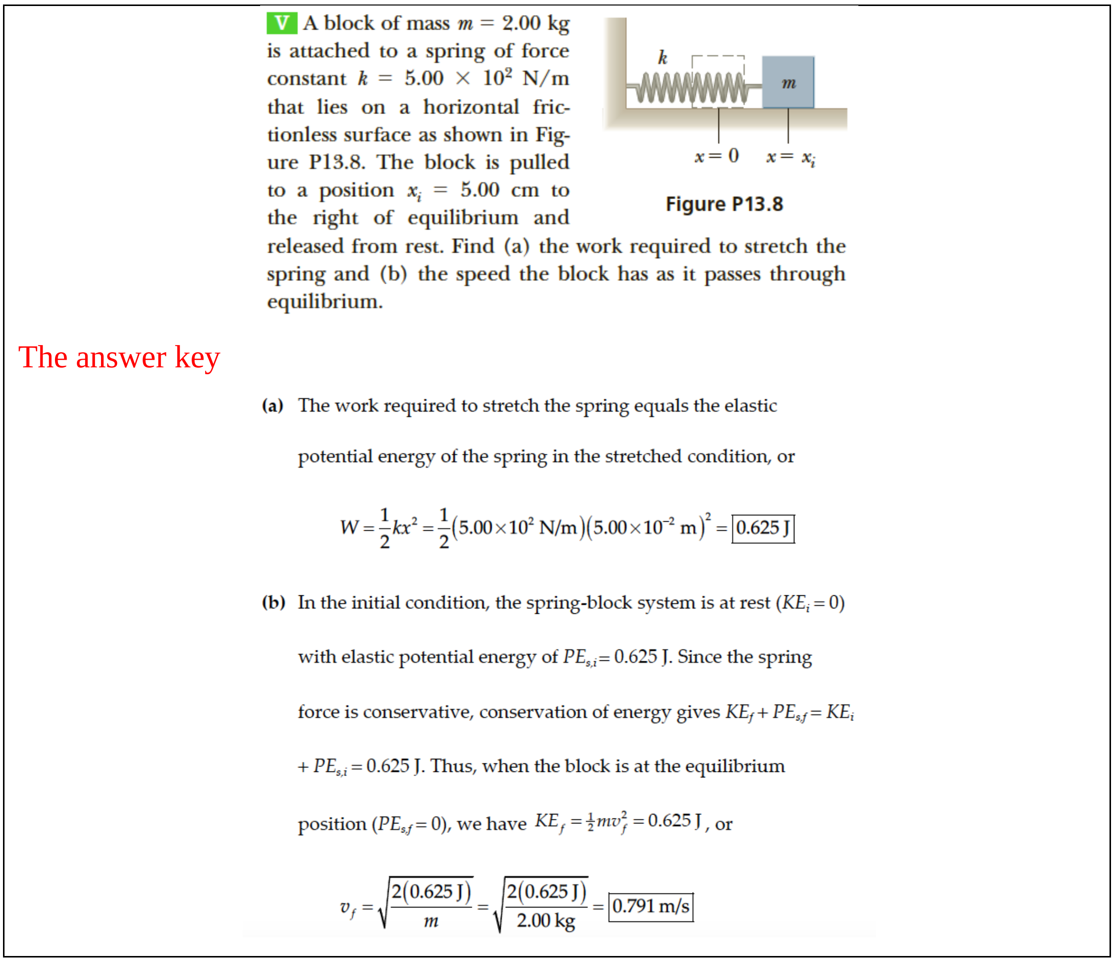


m (kg)	w (N)	x (m)
0.000	0.00	0.000
0.100	0.98	0.025
0.200	1.96	0.050
0.300	2.94	0.076
0.400	3.92	0.099
0.500	4.90	0.127

How Stiff Are Car Springs?
The mass of a car increases due to the introduction of a passenger. This affects the displacement of the car on its suspension system. (credit: exfordy on Flickr)

Figure 152. Force extension graph and elastic potential energy. © OpenStaxCollege CC by 4.0 https://opentextbc.ca/physicstestbook2/chapter/hookes-law-stress-and-strain-revisited/

Students were asked to work together within the same groups to solve the task, which is shown in Figure 153 and share their responses with other groups.



V A block of mass $m = 2.00$ kg is attached to a spring of force constant $k = 5.00 \times 10^2$ N/m that lies on a horizontal frictionless surface as shown in Figure P13.8. The block is pulled to a position $x_i = 5.00$ cm to the right of equilibrium and released from rest. Find (a) the work required to stretch the spring and (b) the speed the block has as it passes through equilibrium.

Figure P13.8

The answer key

(a) The work required to stretch the spring equals the elastic potential energy of the spring in the stretched condition, or

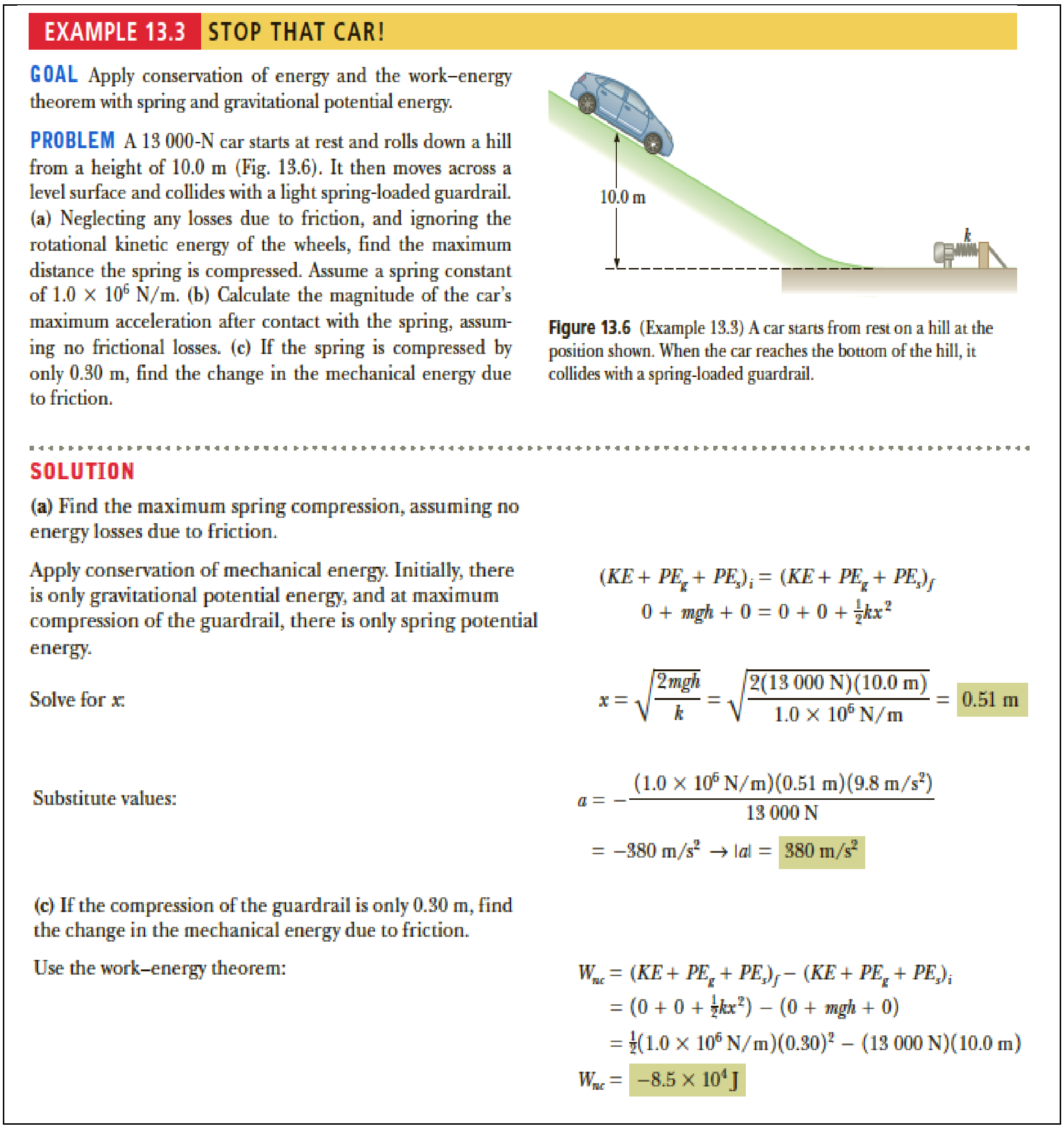
$$W = \frac{1}{2}kx^2 = \frac{1}{2}(5.00\times10^2\text{ N/m})(5.00\times10^{-2}\text{ m})^2 = \boxed{0.625\text{ J}}$$

(b) In the initial condition, the spring-block system is at rest ($KE_i = 0$) with elastic potential energy of $PE_{s,i} = 0.625$ J. Since the spring force is conservative, conservation of energy gives $KE_f + PE_{s,f} = KE_i + PE_{s,i} = 0.625$ J. Thus, when the block is at the equilibrium position ($PE_{s,f} = 0$), we have $KE_f = \frac{1}{2}mv_f^2 = 0.625\text{ J}$, or

$$v_f = \sqrt{\frac{2(0.625\text{ J})}{m}} = \sqrt{\frac{2(0.625\text{ J})}{2.00\text{ kg}}} = \boxed{0.791\text{ m/s}}$$

Figure 153. Practice related to simple harmonic motion in general and mechanical energy (kinetic and elastic potential energy) in particular (Serway & Vuille, 2013, p. 475)

Finally, cognitive learning; students were encouraged to be active members of their groups. They were asked to search online for information related to the conservation of mechanical energy $ME_i = ME_f$, and the elastic potential energy in order to complete the task shown in Figure 154. This task required higher-order thinking skills, such as critical thinking, including the analysis, synthesis and the application of the gained knowledge to a new situation. With the teacher's support, students got the chance to use MatLab software, as shown in Figure 156 and Figure 157, which allowed them to plot the graph of force applied against extension produced.



EXAMPLE 13.3 **STOP THAT CAR!**

GOAL Apply conservation of energy and the work–energy theorem with spring and gravitational potential energy.

PROBLEM A 13 000-N car starts at rest and rolls down a hill from a height of 10.0 m (Fig. 13.6). It then moves across a level surface and collides with a light spring-loaded guardrail. (a) Neglecting any losses due to friction, and ignoring the rotational kinetic energy of the wheels, find the maximum distance the spring is compressed. Assume a spring constant of 1.0×10^6 N/m. (b) Calculate the magnitude of the car's maximum acceleration after contact with the spring, assuming no frictional losses. (c) If the spring is compressed by only 0.30 m, find the change in the mechanical energy due to friction.

Figure 13.6 (Example 13.3) A car starts from rest on a hill at the position shown. When the car reaches the bottom of the hill, it collides with a spring-loaded guardrail.

SOLUTION

(a) Find the maximum spring compression, assuming no energy losses due to friction.

Apply conservation of mechanical energy. Initially, there is only gravitational potential energy, and at maximum compression of the guardrail, there is only spring potential energy.

$$(KE + PE_g + PE_s)_i = (KE + PE_g + PE_s)_f$$
$$0 + mgh + 0 = 0 + 0 + \tfrac{1}{2}kx^2$$

Solve for x:

$$x = \sqrt{\frac{2mgh}{k}} = \sqrt{\frac{2(13\,000\text{ N})(10.0\text{ m})}{1.0 \times 10^6\text{ N/m}}} = 0.51\text{ m}$$

Substitute values:

$$a = -\frac{(1.0 \times 10^6\text{ N/m})(0.51\text{ m})(9.8\text{ m/s}^2)}{13\,000\text{ N}}$$
$$= -380\text{ m/s}^2 \rightarrow |a| = 380\text{ m/s}^2$$

(c) If the compression of the guardrail is only 0.30 m, find the change in the mechanical energy due to friction.

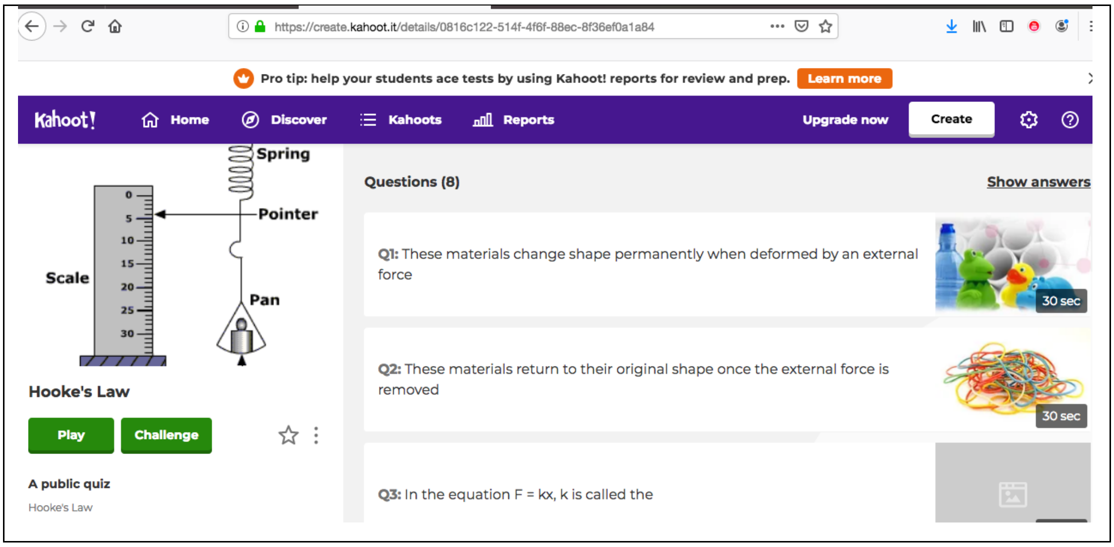
Use the work–energy theorem:

$$W_{nc} = (KE + PE_g + PE_s)_f - (KE + PE_g + PE_s)_i$$
$$= (0 + 0 + \tfrac{1}{2}kx^2) - (0 + mgh + 0)$$
$$= \tfrac{1}{2}(1.0 \times 10^6\text{ N/m})(0.30)^2 - (13\,000\text{ N})(10.0\text{ m})$$
$$W_{nc} = -8.5 \times 10^4\text{ J}$$

Figure 154. Practice related to simple harmonic motion in general and the conservation of mechanical energy (Serway & Vuille, 2013, p. 450)

Various tools of digital technology were used to deliver this learning objective, such as smartboard, PowerPoint presentation, Internet connection, simulations, shared links, learning management system, iBook, MatLab software, students' iPads and laptops.

I conducted an online assessment (virtual platform) using Kahoot website (https://kahoot.com/) and set students to write their responses on the platform. Thus, students could check their understanding, see Figure 155.



https://create.kahoot.it/details/0816c122-514f-4f6f-88ec-8f36ef0a1a84

Pro tip: help your students ace tests by using Kahoot! reports for review and prep.

Questions (8)

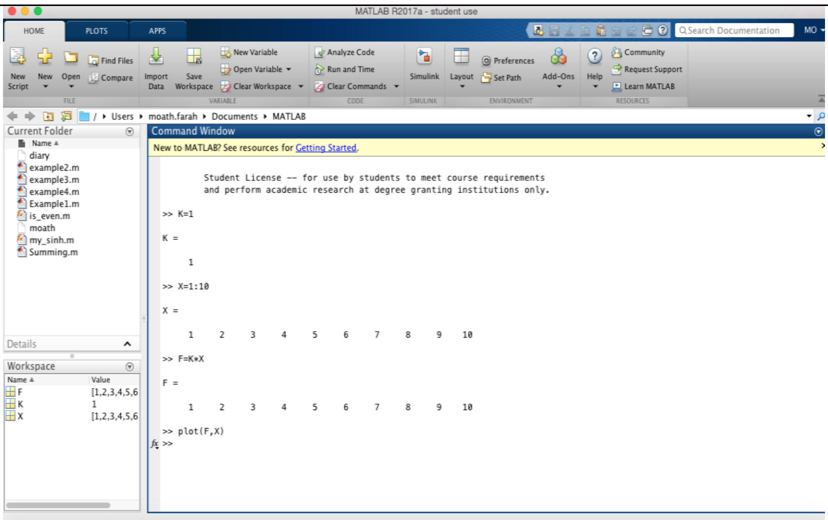
Q1: These materials change shape permanently when deformed by an external force

Q2: These materials return to their original shape once the external force is removed

Q3: In the equation F = kx, k is called the

Figure 155. Online assessment constructed using Kahoot platform. https://create.kahoot.it/details/0816c122-514f-4f6f-88ec-8f36ef0a1a84

Matlab computer software was used to plot a graph of force applied against extension produced. Students, supported by the teacher, were given a chance to use MatLab and plot the graph by themselves, see Figure 156 and Figure 157.



Name	Value
F	[1,2,3,4,5,6
K	1
X	[1,2,3,4,5,6

```
      Student License -- for use by students to meet course requirements
      and perform academic research at degree granting institutions only.

>> K=1

K =

     1

>> X=1:10

X =

     1     2     3     4     5     6     7     8     9    10

>> F=K*X

F =

     1     2     3     4     5     6     7     8     9    10

>> plot(F,X)
fx >>
```

Figure 156. Matlab software was used to plot a graph of force applied against extension produced

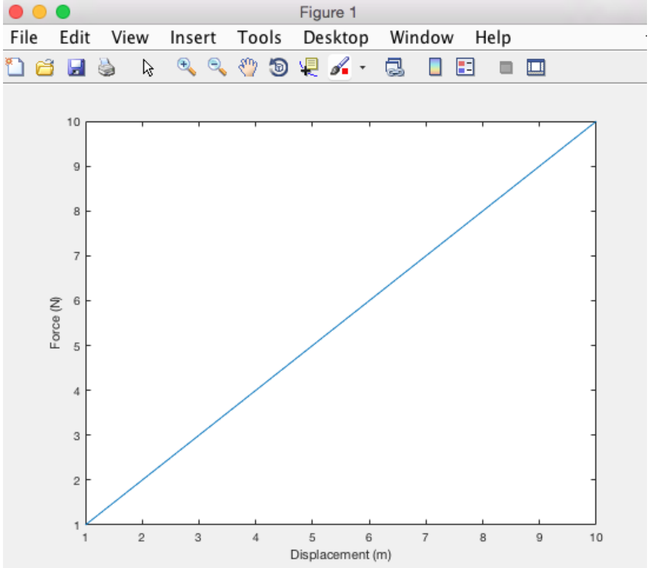


Figure 157. Matlab software was used to plot a graph of force applied against extension produced

Three kinds of the curriculum (C3) supported by digital technology were used:

Firstly, the theoretical curriculum, which includes lecture notes and textbook (iBook), please refer to Figure 139, Figure 140 and the points covered during the direct teaching pedagogy of this learning objective, as well as the screenshots of the covered tasks, such as Figure 153 and Figure 154. External links were shared with students and displayed on the data show (the smart board), see Figure 158. Students were asked to look for new knowledge in the shared links and to share it with their peers and the teacher.

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However, it can be viewed via the link shown in the caption below.

Figure 158. External resource related to the simple harmonic motion. http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/forces/forceselasticityrev2.shtml

Secondly, interactive curriculum represented by simulations, videos and online virtual laboratories related to the simple harmonic motion were shared with students, see Figure 149, Figure 150, Figure 151 and Figure 152.

Finally, practical curriculum; spring-mass system experiment was conducted (Hooke’s law). Thus, students could plot the graph of force applied against extension produced; additionally, they calculated the spring constant and the elastic potential energy. An online laboratory related to calculating the spring constant was shared with students to assist them, see Figure 149 and Figure 159. Please refer to the experiment conducted in this lesson (Hooke’s law).

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Copyright restrictions.

However, it can be viewed via the link shown in the caption below.

Figure 159. External resource related to simple harmonic motion (Hooke’s law). http://www.4physics.com/phy_demo/HookesLaw/HookesLawLab.html

Hooke’s law experiment

Students were provided with several setups that consist of springs, hangers and slotted weights. Students were asked to measure the extension in the spring each time they hang a mass on it. Students were asked to:

I. Complete Table 91
II. Plot a graph of weight (N) and extension of spring (m). See Figure 160

Force (F); weight (N)	Extension, X (m)

Table 91. Force applied (F) and the produced extension (X)

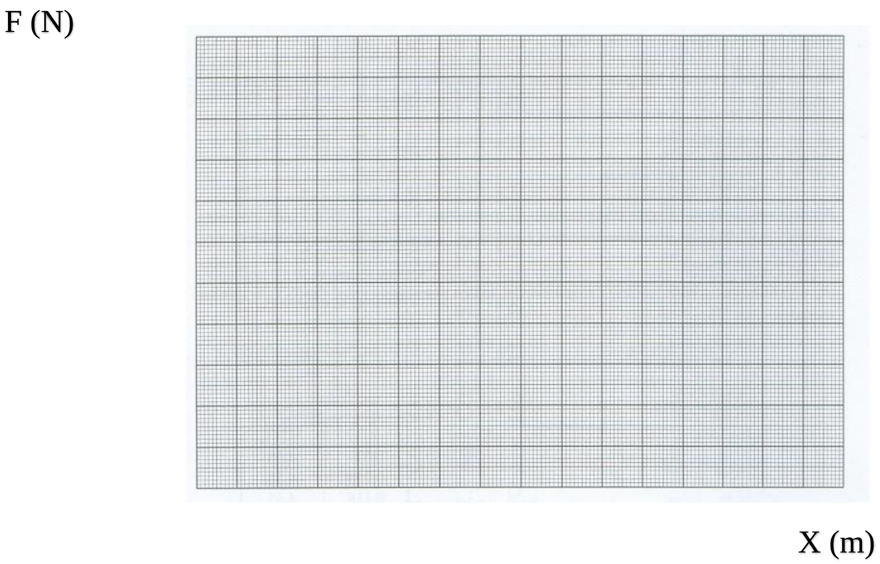


Figure 160. Force applied (F) against the produced extension (X)

Learning objective number four

Create the connection between simple harmonic motion, the simple pendulum and spring-mass system, and real-life applications, such as the pendulum clock, see Figure 161.

This learning objective requires students to explore and compare the periodic time of a simple pendulum with the periodic time of a spring-mass system.

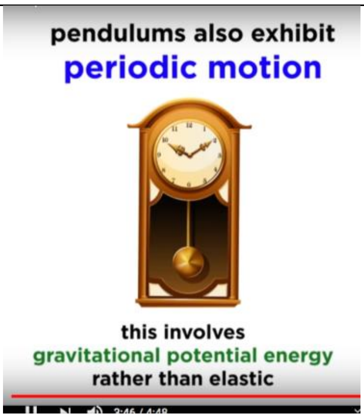


Figure 161. Video related to the pendulum clock https://www.youtube.com/watch?v=gZ_KnZHCn4M

Three pedagogical dimensions (P3) supported by digital technology were used to implement this learning objective.

Firstly, direct teaching; the teacher explained the concept of the simple pendulum. The following points were discussed with the students:

I. The simple pendulum is another example of a system that exhibits simple harmonic motion (the first example is the spring-mass system).

II. The restoring force is the component of the weight tangent to the path of motion F = - mg sin θ, see Figure 162

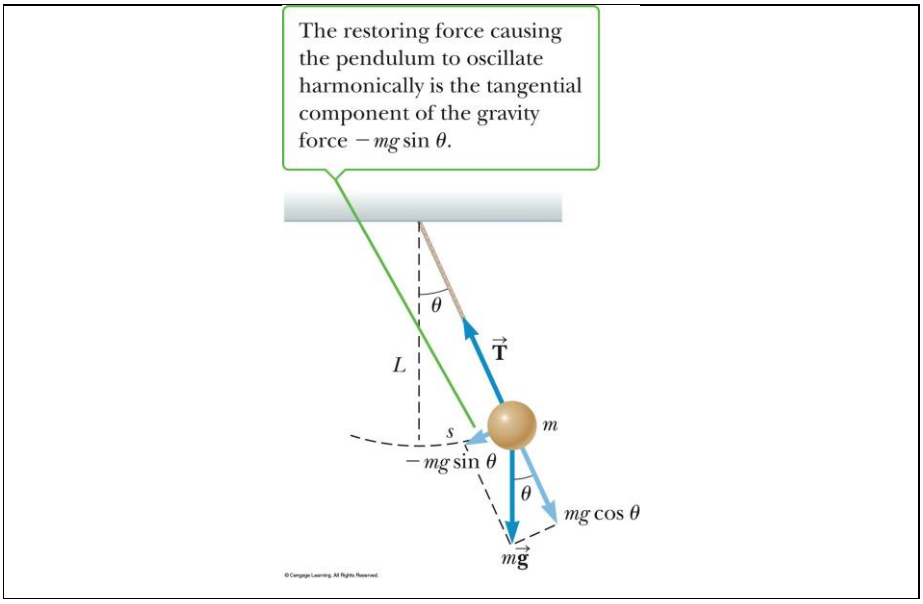


Figure 162. Simple pendulum (Serway & Vuille, 2013, p. 460)

III. The periodic time of a simple pendulum is given by the following formula

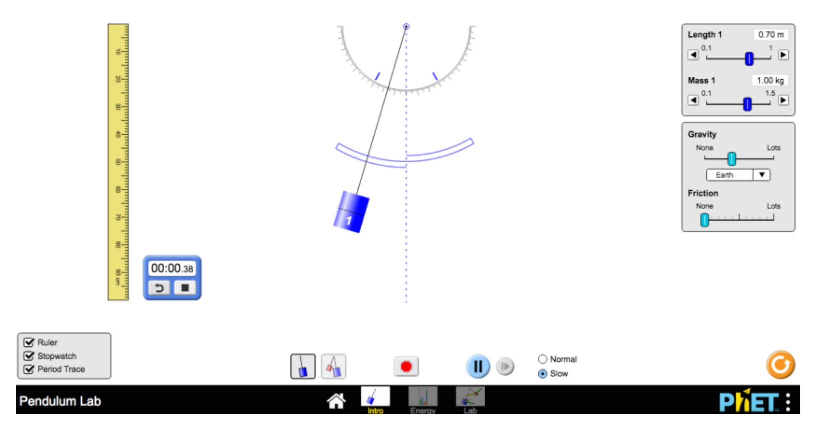
$$T = 2\pi\sqrt{l/g}$$

Where T is the periodic time, l is the length of the rope and g is the gravitational acceleration (g = 9.8 m/s^2). Using this formula, students should be able to calculate the periodic time of a simple pendulum, the length of the rope. Students should go more in-depth to investigate the periodic time of simple pendulum in different planets, which should be different from its value in the earth as the value of g is different from one planet to another.

IV. The periodic time of a simple pendulum equation shows that the period is independent of the amplitude and the mass

V. The period (T) depends on the length of the pendulum and the gravitational acceleration at the location of the pendulum.

Secondly, collaborative learning; students were divided into groups of five and were asked to work together and exchange their gained knowledge about the simple pendulum. Groups were asked to investigate the shared links and discuss it with each other and the teacher. Figure 163, Figure 164 and Figure 165 represent the links that were shared with students.



00:00.38

Length 1 0.70 m

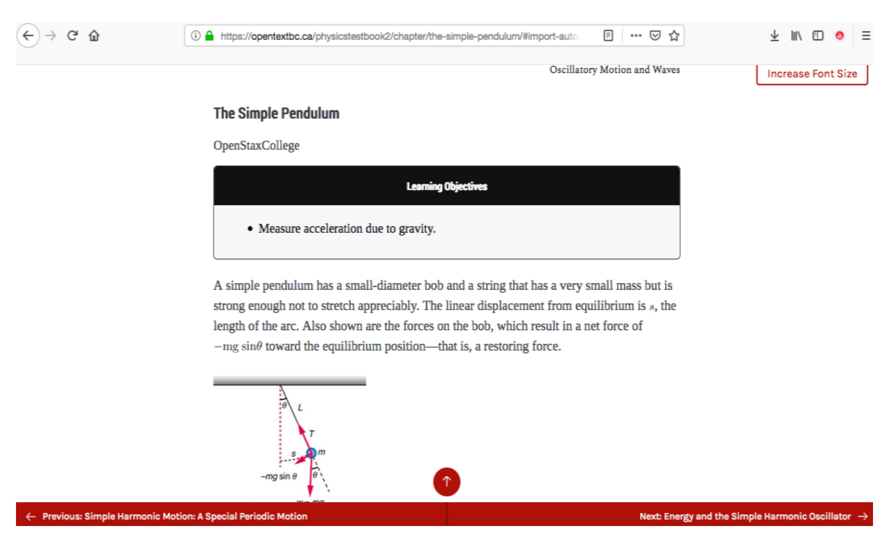
Mass 1 1.00 kg

Gravity Earth

☑ Ruler
☑ Stopwatch
☑ Period Trace

○ Normal
● Slow

Figure 163. Simulation of the simple pendulum. ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html



https://opentextbc.ca/physicstestbook2/chapter/the-simple-pendulum/#import-auto

Oscillatory Motion and Waves

The Simple Pendulum

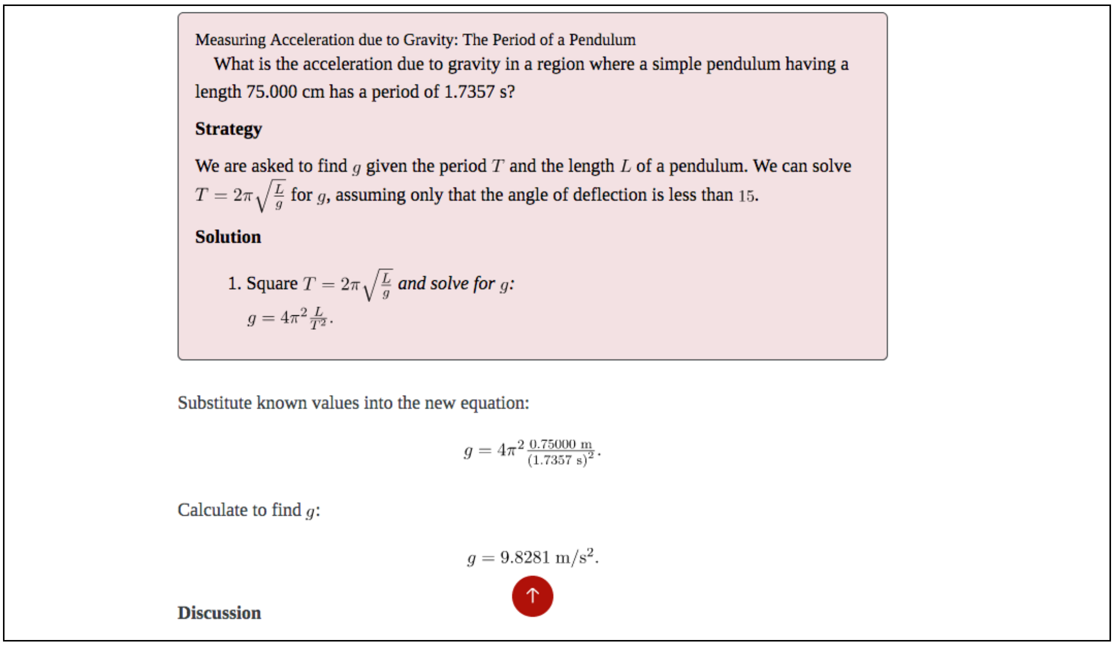
OpenStaxCollege

Learning Objectives

- Measure acceleration due to gravity.

A simple pendulum has a small-diameter bob and a string that has a very small mass but is strong enough not to stretch appreciably. The linear displacement from equilibrium is s, the length of the arc. Also shown are the forces on the bob, which result in a net force of $-\mathrm{mg}\ \sin\theta$ toward the equilibrium position—that is, a restoring force.

Figure 164. External resource related to the simple pendulum ©OpenStaxCollege CC by 4.0 https://opentextbc.ca/physicstestbook2/chapter/the-simple-pendulum/#import-auto-id3178394



Measuring Acceleration due to Gravity: The Period of a Pendulum

What is the acceleration due to gravity in a region where a simple pendulum having a length 75.000 cm has a period of 1.7357 s?

Strategy

We are asked to find g given the period T and the length L of a pendulum. We can solve $T=2\pi\sqrt{\frac{L}{g}}$ for g, assuming only that the angle of deflection is less than 15.

Solution

1. Square $T=2\pi\sqrt{\frac{L}{g}}$ *and solve for* g*:*
   $g=4\pi^2\frac{L}{T^2}$.

Substitute known values into the new equation:

$$g=4\pi^2\frac{0.75000\ \text{m}}{(1.7357\ \text{s})^2}.$$

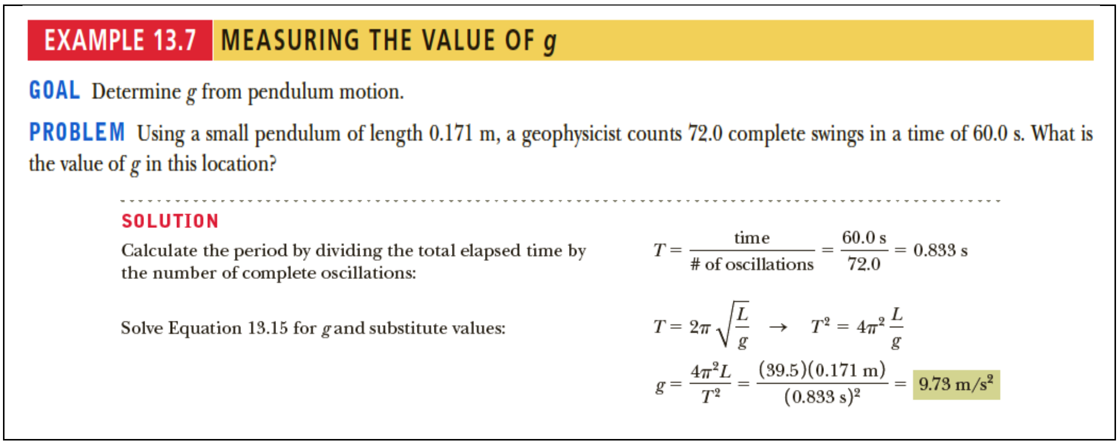
Calculate to find g:

$$g=9.8281\ \text{m/s}^2.$$

Discussion

Figure 165. External resource related to the simple pendulum ©OpenStaxCollege CC by 4.0 https://opentextbc.ca/physicstestbook2/chapter/the-simple-pendulum/#import-auto-id3178394

Students were asked to work in groups to complete a mathematical task related to the simple pendulum, see Figure 166. The answer key was given to the students after they completed it.



EXAMPLE 13.7 **MEASURING THE VALUE OF *g***

GOAL Determine *g* from pendulum motion.

PROBLEM Using a small pendulum of length 0.171 m, a geophysicist counts 72.0 complete swings in a time of 60.0 s. What is the value of *g* in this location?

SOLUTION

Calculate the period by dividing the total elapsed time by the number of complete oscillations:

$$T=\frac{\text{time}}{\#\text{ of oscillations}}=\frac{60.0\ \text{s}}{72.0}=0.833\ \text{s}$$

Solve Equation 13.15 for *g* and substitute values:

$$T=2\pi\sqrt{\frac{L}{g}}\quad\rightarrow\quad T^2=4\pi^2\frac{L}{g}$$

$$g=\frac{4\pi^2L}{T^2}=\frac{(39.5)(0.171\ \text{m})}{(0.833\ \text{s})^2}=\boxed{9.73\ \text{m/s}^2}$$

Figure 166. Measuring the gravitational acceleration using the simple pendulum equation (Serway & Vuille, 2013, p. 462)

Finally, cognitive pedagogical dimension was used as well; students were active members in their groups. The teacher refreshed students' previous knowledge about periodic time. A simulation related to simple pendulum was shared with the students, as shown in Figure 167. Thus, students could build their knowledge. For instance, students could discover new knowledge, such as discovering that the values of the periodic time are different from one planet to another, and discovering that there is no relationship between the periodic time and the connected mass (m). Students were asked to justify their discoveries using the mathematical formula, the periodic time of a simple pendulum $T = 2\pi\sqrt{l/g}$.

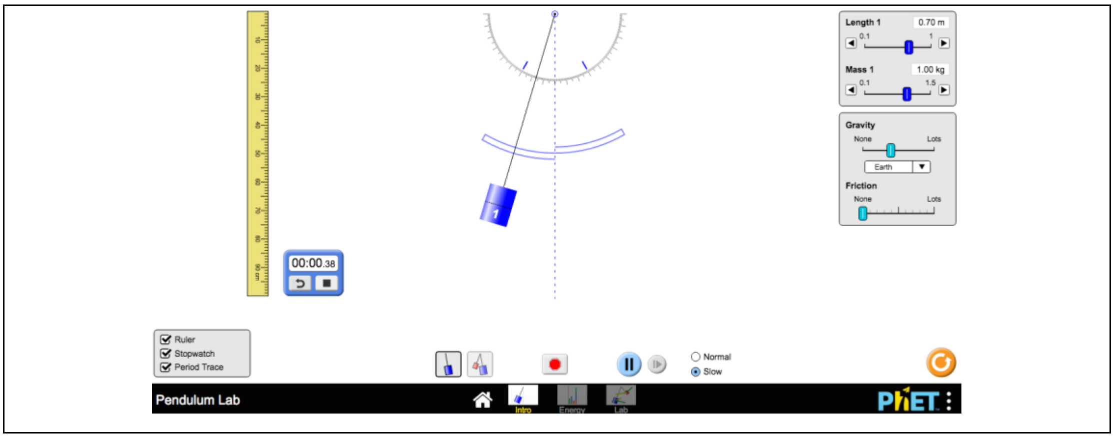
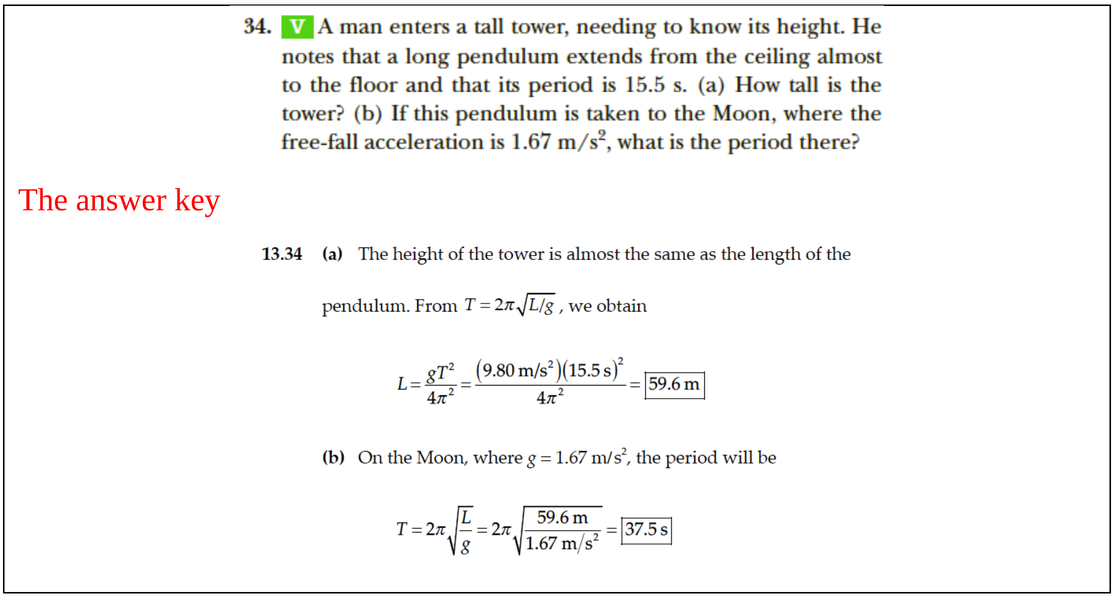


Figure 167. Simulation of the simple pendulum. ©PhETInteractiveSimulations, CC by 4.0 https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html

In groups, students had to complete three different tasks that required higher-order thinking skills, such as critical thinking, analysis and synthesis, see Figure 168, Figure 169 and Figure 170. Students were asked to share their work and discuss it with the teacher. Answer keys were given to the students after they completed the tasks.



34. V A man enters a tall tower, needing to know its height. He notes that a long pendulum extends from the ceiling almost to the floor and that its period is 15.5 s. (a) How tall is the tower? (b) If this pendulum is taken to the Moon, where the free-fall acceleration is 1.67 m/s^2, what is the period there?

The answer key

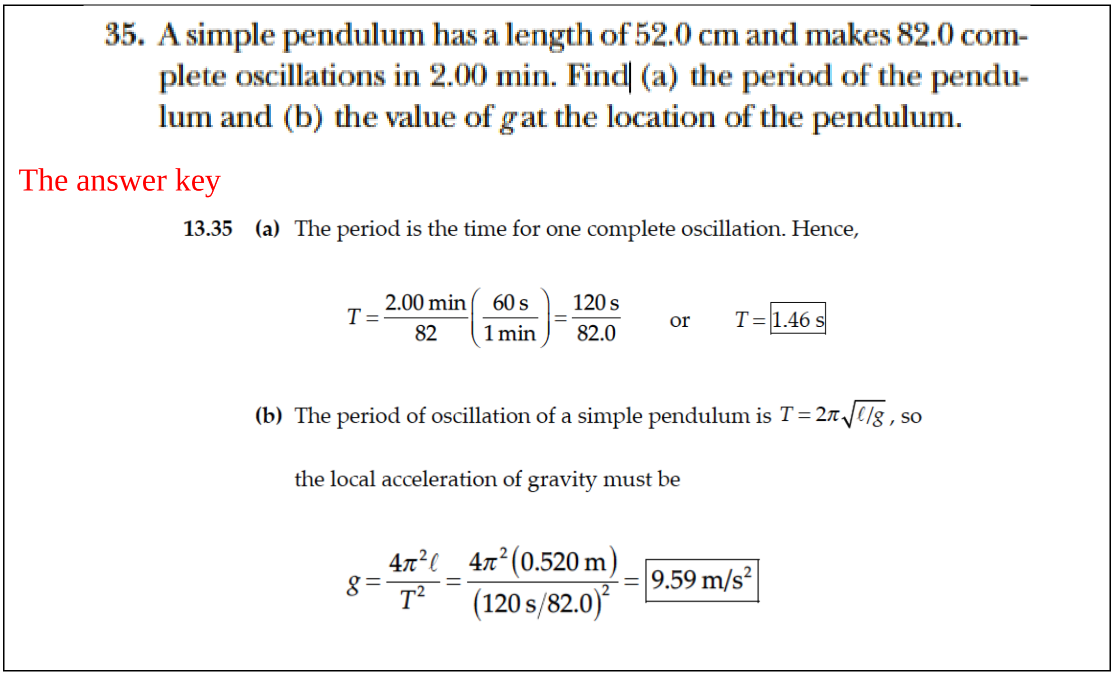
13.34 **(a)** The height of the tower is almost the same as the length of the pendulum. From $T = 2\pi\sqrt{L/g}$, we obtain

$$L = \frac{gT^2}{4\pi^2} = \frac{(9.80\ \text{m/s}^2)(15.5\ \text{s})^2}{4\pi^2} = \boxed{59.6\ \text{m}}$$

(b) On the Moon, where $g = 1.67$ m/s^2, the period will be

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{59.6\ \text{m}}{1.67\ \text{m/s}^2}} = \boxed{37.5\ \text{s}}$$

Figure 168. Practice related to the simple pendulum (Serway & Vuille, 2013, p. 477)



35. A simple pendulum has a length of 52.0 cm and makes 82.0 complete oscillations in 2.00 min. Find (a) the period of the pendulum and (b) the value of g at the location of the pendulum.

The answer key

13.35 **(a)** The period is the time for one complete oscillation. Hence,

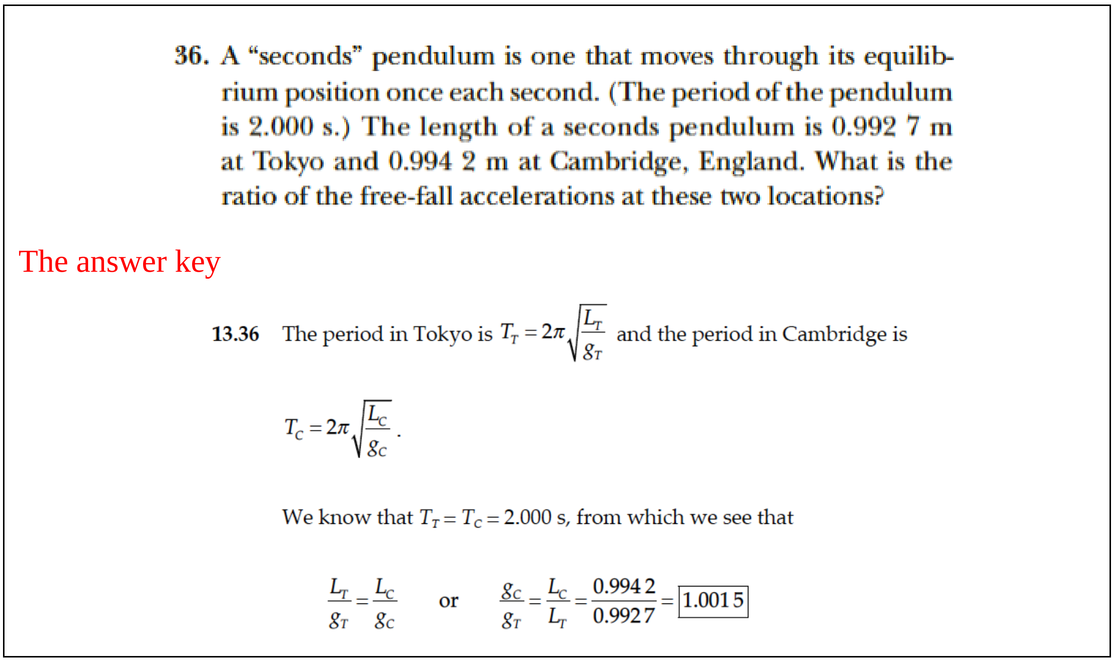
$$T=\frac{2.00\text{ min}}{82}\left(\frac{60\text{ s}}{1\text{ min}}\right)=\frac{120\text{ s}}{82.0}\qquad\text{or}\qquad T=\boxed{1.46\text{ s}}$$

(b) The period of oscillation of a simple pendulum is $T=2\pi\sqrt{\ell/g}$, so

the local acceleration of gravity must be

$$g=\frac{4\pi^2\ell}{T^2}=\frac{4\pi^2(0.520\text{ m})}{(120\text{ s}/82.0)^2}=\boxed{9.59\text{ m/s}^2}$$

Figure 169. Practice related to the simple pendulum (Serway & Vuille, 2013, p. 477)



36. A "seconds" pendulum is one that moves through its equilibrium position once each second. (The period of the pendulum is 2.000 s.) The length of a seconds pendulum is 0.992 7 m at Tokyo and 0.994 2 m at Cambridge, England. What is the ratio of the free-fall accelerations at these two locations?

The answer key

13.36 The period in Tokyo is $T_T=2\pi\sqrt{\frac{L_T}{g_T}}$ and the period in Cambridge is

$$T_C=2\pi\sqrt{\frac{L_C}{g_C}}.$$

We know that $T_T=T_C=2.000$ s, from which we see that

$$\frac{L_T}{g_T}=\frac{L_C}{g_C}\qquad\text{or}\qquad\frac{g_C}{g_T}=\frac{L_C}{L_T}=\frac{0.9942}{0.9927}=\boxed{1.0015}$$

Figure 170. Practice related to the simple pendulum (Serway & Vuille, 2013, p. 477)

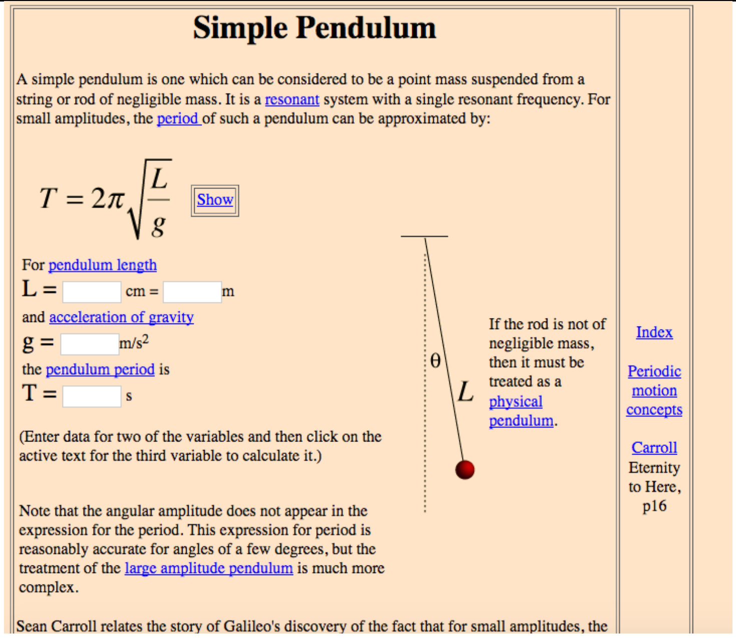
Various digital technology tools were used to deliver this learning objective, such as smartboard, Internet connection, simulations, iPads and laptops. The shared links allowed students to navigate through the calculations of the periodic time of simple pendulum, see Figure 167 and Figure 171. Students could calculate the value of the gravitational acceleration (g) using the main formula of the simple pendulum $T = 2\pi\sqrt{l/g}$.

Using the shared simulation, which is shown in Figure 167, students could calculate the periodic time of simple pendulum and the gravitational acceleration in different planets, such as Jupiter, Mars and Mercury.

Three kinds of the curriculum (C3), supported by digital technology, were used to implement this learning objective.

Firstly, theoretical curriculum, which includes lecture notes, please refer to the points covered during the direct teaching of this learning objective, soft copy textbook (Serway & Vuille, 2013) was used as well, see Figure 139 and Figure 140.

Secondly, interactive curriculum represented by simulations and videos related to simple pendulum were shared with students, as shown in Figure 161, Figure 167 and Figure 171.



Simple Pendulum

A simple pendulum is one which can be considered to be a point mass suspended from a string or rod of negligible mass. It is a resonant system with a single resonant frequency. For small amplitudes, the period of such a pendulum can be approximated by:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

For pendulum length

L = cm = m

and acceleration of gravity

g = m/s²

the pendulum period is

T = s

(Enter data for two of the variables and then click on the active text for the third variable to calculate it.)

If the rod is not of negligible mass, then it must be treated as a physical pendulum.

Note that the angular amplitude does not appear in the expression for the period. This expression for period is reasonably accurate for angles of a few degrees, but the treatment of the large amplitude pendulum is much more complex.

Sean Carroll relates the story of Galileo's discovery of the fact that for small amplitudes, the

Figure 171. Simulation of the simple pendulum http://hyperphysics.phy-astr.gsu.edu/hbase/pend.html

Finally, practical curriculum; simple pendulum experiment was conducted.

Thus, students could measure the periodic time and the length of the pendulum, as shown in Figure 172. The value of the gravitational acceleration was considered 9.8 m/s^2. The link, which is shown in Figure 172, was used to assist students while implementing this experiment. Please refer to the conducted experiment in this learning objective, *period of a simple pendulum*.

This figure has been removed due to Copyright restrictions.
However, it can be viewed via the link shown in the caption below.

Figure 172. Simple pendulum experiment
https://www.youtube.com/watch?v=02w9lSii_Hs

As part of the practical curriculum, students were directed to several websites to apply the idea of the simple pendulum and its equation to the concept of the pendulum clock, as shown in Figure 173, Figure 174 and Figure 175.

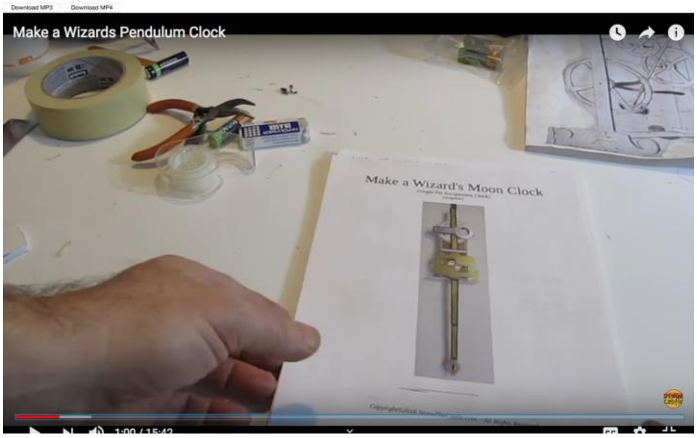


Figure 173. Video shows how to make a pendulum clock https://www.youtube.com/watch?v=vSwzeqeo4l8

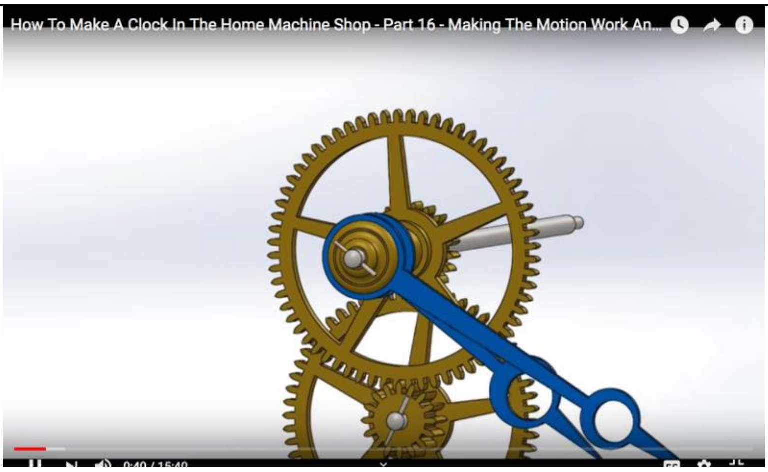


Figure 174. Video shows how to make a pendulum clock https://www.youtube.com/watch?v=8OViP9AR2HE

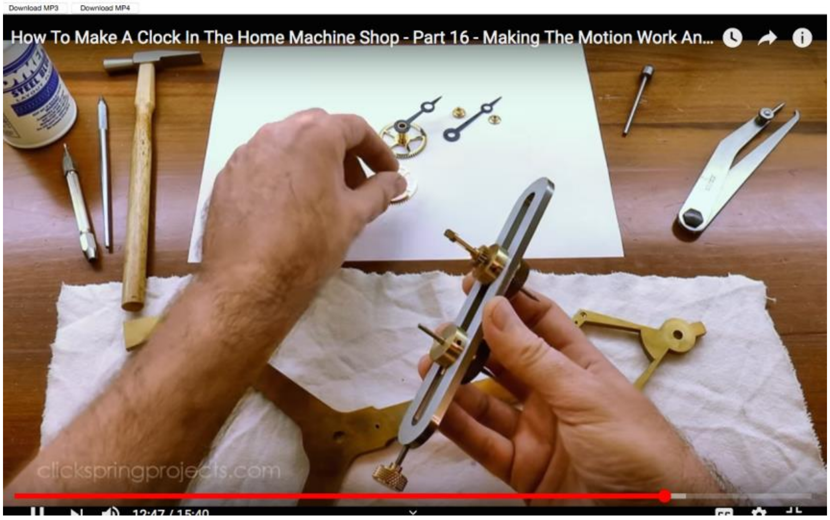


Figure 175. Video related to pendulum clock https://www.youtube.com/watch?v=8OViP9AR2HE

The simple pendulum and spring-mass system

Students were asked to compare the periodic time of a simple pendulum, which is given by the formula $T = 2\pi\sqrt{l/g}$ with the periodic time of a spring-mass system, which is given by the formula $T = 2\pi\sqrt{{}^{m}/_{k}}$, where m is the connected mass, k is the spring constant. The link, which is shown in Figure 176, was shared with the students via LMS.

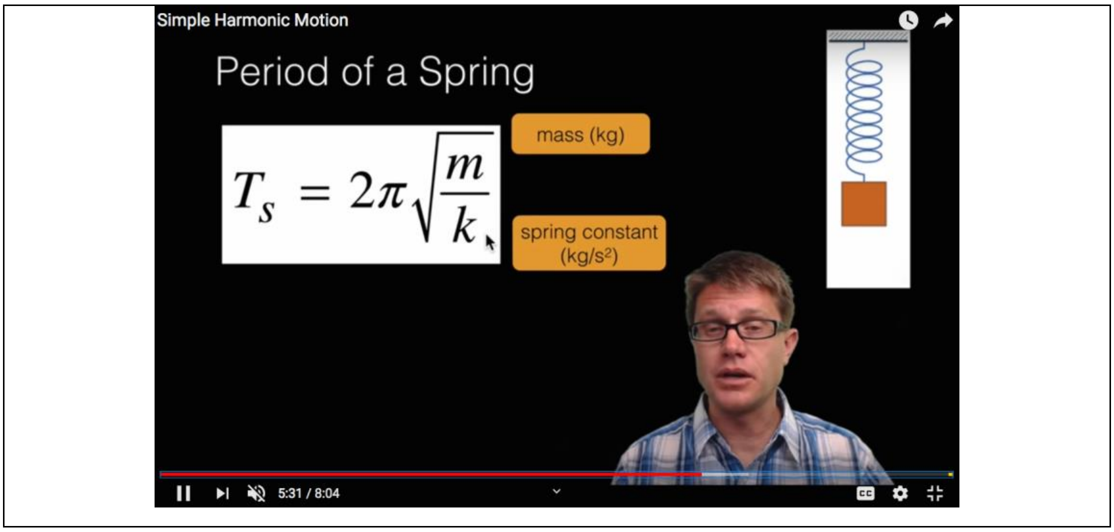


Figure 176. Video related to the periodic time of a spring-mass system https://www.youtube.com/watch?v=tudxily5Qu0

The teacher supported students by discussing the following points with them:

I. The Period T of a spring-mass system is given by the following formula:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

This formula gives the time required for an object of mass (m) attached to a spring of constant k to complete one cycle of its motion

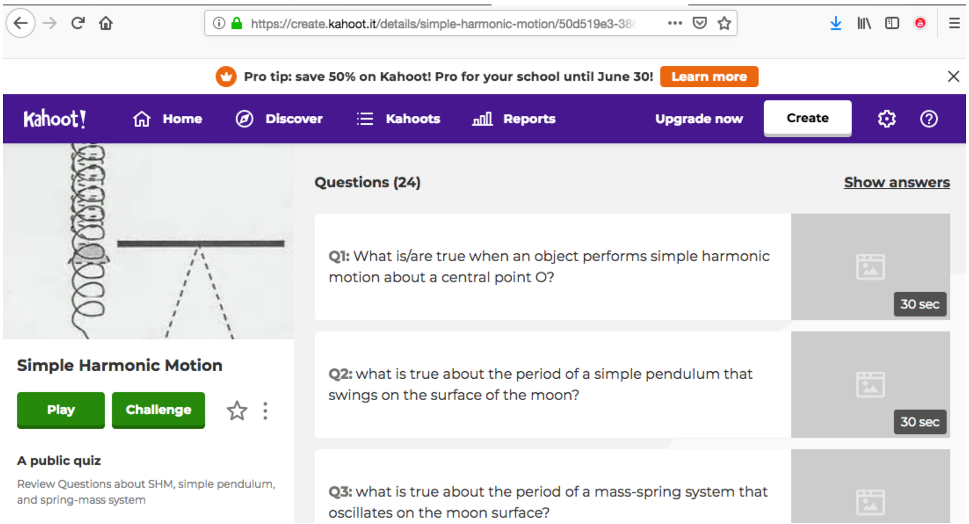
II. The frequency, f, is the number of complete cycles or vibrations per unit time

III. Frequency is the reciprocal of the period $f = 1 / T$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Units used to measure the frequency are cycles/second, Hertz and Hz

As part of formative assessment to check students' understanding of these two concepts, the periodic time of a simple pendulum and spring-mass system, the teacher used two online assessments using Kahoot virtual platform (https://kahoot.com), as shown in Figure 177 and Figure 178.



https://create.kahoot.it/details/simple-harmonic-motion/50d519e3-38

Pro tip: save 50% on Kahoot! Pro for your school until June 30!

Simple Harmonic Motion

A public quiz

Review Questions about SHM, simple pendulum, and spring-mass system

Questions (24)

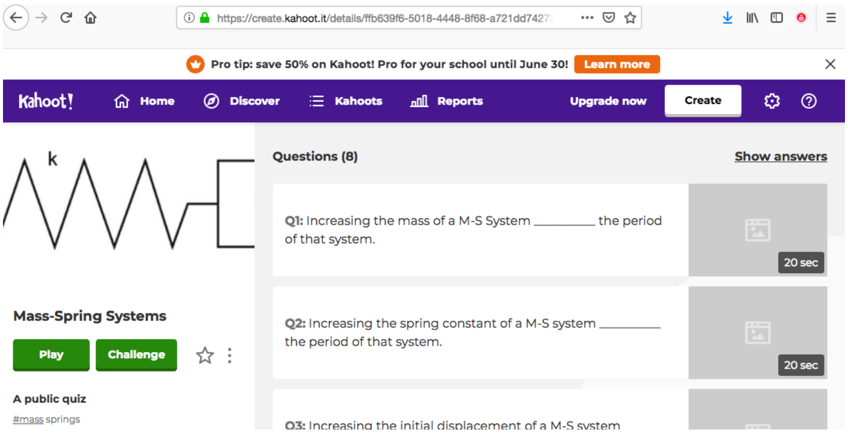
Show answers

Q1: What is/are true when an object performs simple harmonic motion about a central point O?

Q2: what is true about the period of a simple pendulum that swings on the surface of the moon?

Q3: what is true about the period of a mass-spring system that oscillates on the moon surface?

Figure 177. Online assessment of the periodic time of simple pendulum. https://create.kahoot.it/details/simple-harmonic-motion/50d519e3-3866-4b70-b618-0a3f6ebd0ff3



https://create.kahoot.it/details/ffb639f6-5018-4448-8f68-a721dd7427

Pro tip: save 50% on Kahoot! Pro for your school until June 30!

Mass-Spring Systems

A public quiz

#mass springs

Questions (8)

Show answers

Q1: Increasing the mass of a M-S System ________ the period of that system.

Q2: Increasing the spring constant of a M-S system ________ the period of that system.

Q3: Increasing the initial displacement of a M-S system

Figure 178. Online assessment of the periodic time of spring-mass system https://create.kahoot.it/details/ffb639f6-5018-4448-8f68-a721dd74273a

The conducted experiment: Period of a simple pendulum

This experiment was implemented with students. The idea of this experiment was taken from the following link, which was shared with students as well. https://www.youtube.com/watch?v=02w9lSii_Hs&feature=youtu.be, see Figure 172, Figure 179, Figure 180, Figure 181 and Figure 182. The following introduction, procedures and the screenshots (Figure 179 to Figure 182) were shared with students.

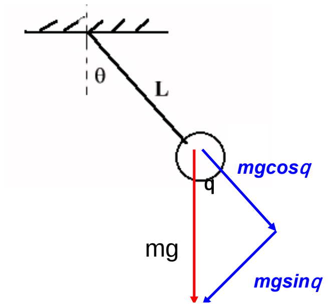
Introduction

- The simple pendulum is another example of a system that exhibits simple harmonic motion.
- A simple pendulum consists of a mass (m) located at the end of a string. The string's length represents the radius of a circle and has negligible mass.
- The restoring force is the component of the weight tangent to the path of motion

$$F_t = - mg \sin \theta$$

If the angle (θ) is small (less than or equal to 10^0), then the radian value of theta and sine theta in degrees are approximately equal. In other words, if $\theta \leq 10^0$, then $\theta^{rad} \approx \sin \theta$.

Using the circular motion equations and supported by the teacher's supervision, students were asked to derive the main formula of the simple pendulum. Since this lesson was implemented using educational technology (digital technology-based learning), students were allowed to search through the Internet resources to complete this task. The teacher has discussed with them their findings to check their understanding. The teacher confirmed that not all students could derive the main formula. Therefore, there was a need for the scaffolding process for the students who could not complete this task. The following derivation was shared and discussed with students after they completed the task.



$$Fr\sin q = t = Ia$$
$$- mg\sin q(L) = (mL^2)a$$
$$- g\sin q = La \quad if\, q <<<, \sin q = q$$
$$a + (\frac{g}{L})q = 0$$
$$w = \sqrt{\frac{g}{L}}, \quad w = \frac{2p}{T}$$
$$T_{pendulum} = 2p\sqrt{\frac{l}{g}}$$

Where $T_{pendulum}$ is the time taken by the pendulum to complete one oscillation.

- **Materials required**

Note: Figure 179, Figure 180, Figure 181 and Figure 182 are screenshots of a virtual experiment that can be accessed via the following link https://www.youtube.com/watch?v=02w9lSii_Hs&feature=youtu.be

To calculate the period for a given pendulum, we need a pendulum and a stopwatch (Figure 179).

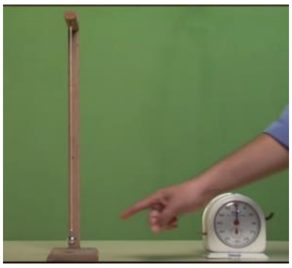


Figure 179. Materials needed

- **Procedures**: Count the time it takes the pendulum to complete ten oscillations. Swing the pendulum to one side and leave it. Start the clock and count ten oscillations (one oscillation is one full way forth and back). Count until ten and stop the clock (Figure 180).

Figure 180. Procedures

- The mean value should give the period T of the simple pendulum. For instance, if it takes twenty seconds to complete ten oscillations, then the period for the simple pendulum is two seconds per oscillation.
- Now reduce the length of the pendulum and see the effect on the period T (Figure 181).

Figure 181. Shorten the simple pendulum

- Swing the pendulum and start the stop clock, count ten oscillations and stop the clock (Figure 182).

Figure 182. Count ten oscillations and stop the clock

  - What have you noticed?

  - Write your conclusions

Learning objective number five

Solve problems related to Hooke’s law, simple pendulum and the elastic potential energy, including the periodic time of simple pendulum and spring-mass system. Problems related to the conservation of mechanical energy were included as well.

Three pedagogical dimensions (P3) supported by digital technology were used to implement this learning objective.

Firstly, direct teaching; the teacher offered the necessary support, such as the required formulas, an extra clarification for some problems. Thus, students could start solving the assigned tasks.

Secondly, collaborative learning, students worked in groups, so that they could exchange their experience, ideas and thoughts.

Finally, cognitive learning, students were active members, as they could participate in the discussions which took place in their groups while solving the assigned tasks. Students could search through online resources looking for hints and making further investigation.

The digital technology used in this learning objective included searching online using the google search engine, iPads and laptops. With the help of shared links, see Figure 183, Figure 184 and Figure 185, students could improve their cognitive skills, such as critical thinking and mathematical skills.

Three kinds of the curriculum (C3) supported by digital technology were implemented:

Firstly, theoretical curriculum, which included worksheets consisting of problems from different levels of complexities according to Bloom’s Taxonomy, such as comprehensive, application and analysis (Teaching Learning Center, 2015; bloomstaxonomy.org, 2018). Please refer to Figure 186 and Figure 187.

Secondly, interactive curriculum; simulations and other links shared with students, see Figure 183, Figure 184 and Figure 185. Finally, practical curriculum, please refer to the experiment Simple harmonic motion conducted in this learning objective.

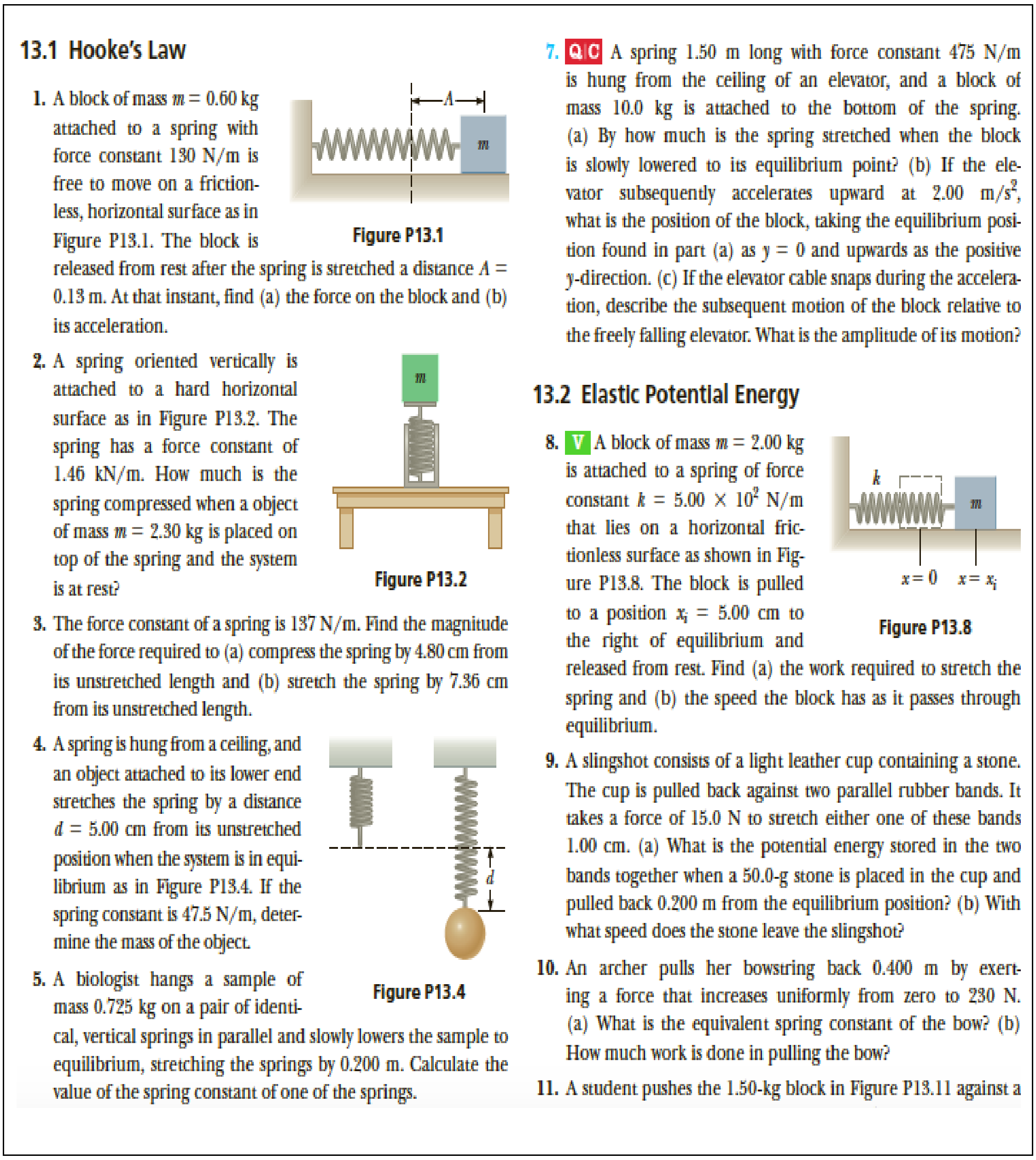
Figure 183. An external resource that shows mathematical problems related to simple harmonic motion and the solving strategies https://sciencenotes.org/hookes-law-example-problem/

Figure 184. An external resource that shows mathematical problems related to simple harmonic motion https://sciencenotes.org/hookes-law-example-problem/

Figure 185. Related video shows mathematical problems related to the solving strategies of simple harmonic motion problems in physics https://www.youtube.com/watch?v=_Gnke2x3vT8

Figure 186 and Figure 187 show screenshots of the worksheet (the problems) that were given to students to implement learning objective number five. The teacher discussed these problems inside the classroom with the students after they had their chance to solve them on their own (in groups) using their gained knowledge. Afterwards, answer keys to these problems were given to the students.

Note, these problems are taken from the textbook (softcopy), which is College physics Serway (Serway & Vuille, 2013).



13.1 Hooke's Law

1. A block of mass $m = 0.60$ kg attached to a spring with force constant 130 N/m is free to move on a frictionless, horizontal surface as in Figure P13.1. The block is released from rest after the spring is stretched a distance $A = 0.13$ m. At that instant, find (a) the force on the block and (b) its acceleration.

Figure P13.1

2. A spring oriented vertically is attached to a hard horizontal surface as in Figure P13.2. The spring has a force constant of 1.46 kN/m. How much is the spring compressed when a object of mass $m = 2.30$ kg is placed on top of the spring and the system is at rest?

Figure P13.2

3. The force constant of a spring is 137 N/m. Find the magnitude of the force required to (a) compress the spring by 4.80 cm from its unstretched length and (b) stretch the spring by 7.36 cm from its unstretched length.

4. A spring is hung from a ceiling, and an object attached to its lower end stretches the spring by a distance $d = 5.00$ cm from its unstretched position when the system is in equilibrium as in Figure P13.4. If the spring constant is 47.5 N/m, determine the mass of the object.

Figure P13.4

5. A biologist hangs a sample of mass 0.725 kg on a pair of identical, vertical springs in parallel and slowly lowers the sample to equilibrium, stretching the springs by 0.200 m. Calculate the value of the spring constant of one of the springs.

7. QC A spring 1.50 m long with force constant 475 N/m is hung from the ceiling of an elevator, and a block of mass 10.0 kg is attached to the bottom of the spring. (a) By how much is the spring stretched when the block is slowly lowered to its equilibrium point? (b) If the elevator subsequently accelerates upward at 2.00 m/s^2, what is the position of the block, taking the equilibrium position found in part (a) as $y = 0$ and upwards as the positive y-direction. (c) If the elevator cable snaps during the acceleration, describe the subsequent motion of the block relative to the freely falling elevator. What is the amplitude of its motion?

13.2 Elastic Potential Energy

8. V A block of mass $m = 2.00$ kg is attached to a spring of force constant $k = 5.00 \times 10^2$ N/m that lies on a horizontal frictionless surface as shown in Figure P13.8. The block is pulled to a position $x_i = 5.00$ cm to the right of equilibrium and released from rest. Find (a) the work required to stretch the spring and (b) the speed the block has as it passes through equilibrium.

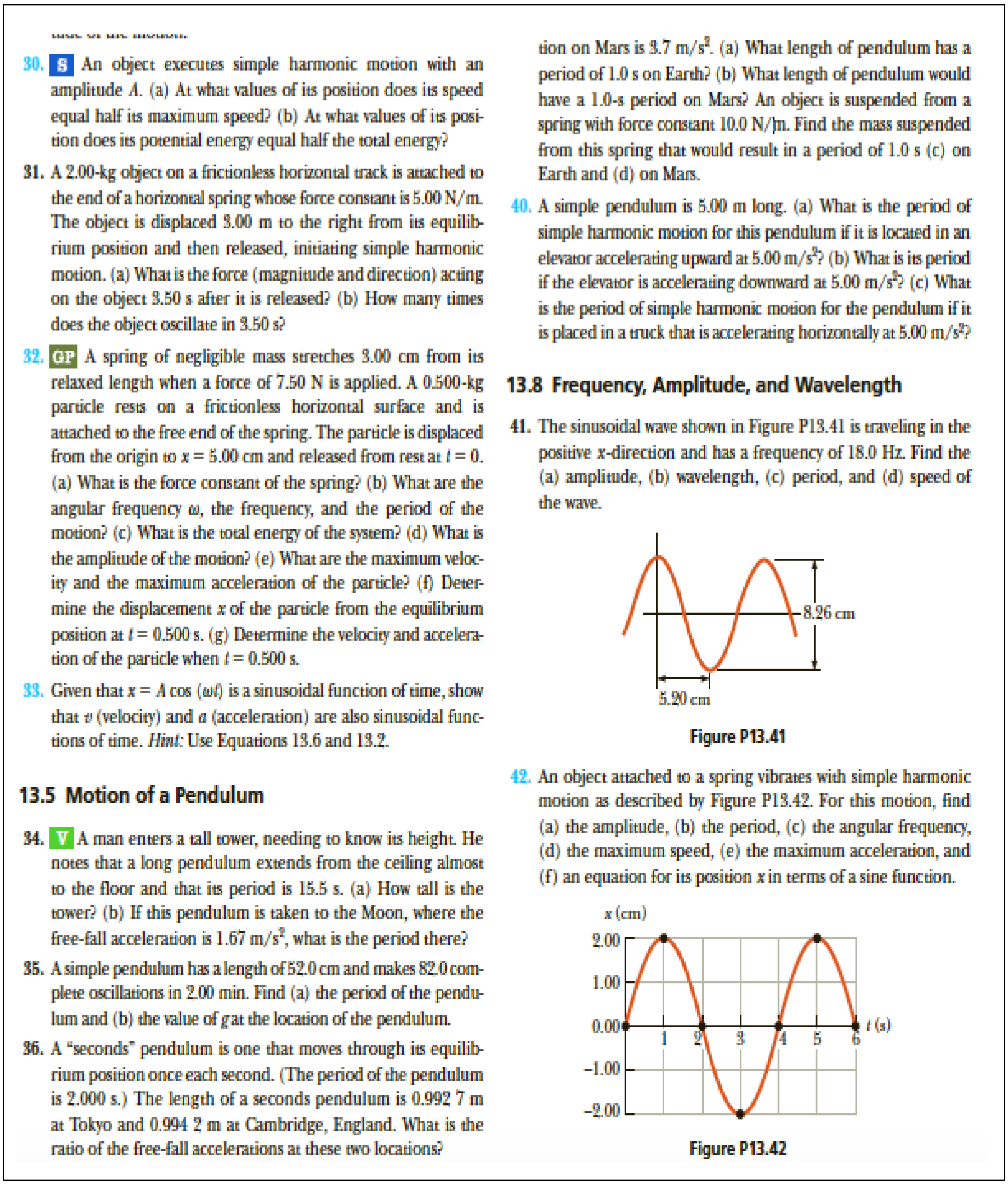
Figure P13.8

9. A slingshot consists of a light leather cup containing a stone. The cup is pulled back against two parallel rubber bands. It takes a force of 15.0 N to stretch either one of these bands 1.00 cm. (a) What is the potential energy stored in the two bands together when a 50.0-g stone is placed in the cup and pulled back 0.200 m from the equilibrium position? (b) With what speed does the stone leave the slingshot?

10. An archer pulls her bowstring back 0.400 m by exerting a force that increases uniformly from zero to 230 N. (a) What is the equivalent spring constant of the bow? (b) How much work is done in pulling the bow?

11. A student pushes the 1.50-kg block in Figure P13.11 against a

Figure 186. Screenshot of the problems that were given to students to implement learning objective number five (Serway & Vuille, 2013, p. 475)



tude of the motion.

30. **S** An object executes simple harmonic motion with an amplitude *A*. (a) At what values of its position does its speed equal half its maximum speed? (b) At what values of its position does its potential energy equal half the total energy?

31. A 2.00-kg object on a frictionless horizontal track is attached to the end of a horizontal spring whose force constant is 5.00 N/m. The object is displaced 3.00 m to the right from its equilibrium position and then released, initiating simple harmonic motion. (a) What is the force (magnitude and direction) acting on the object 3.50 s after it is released? (b) How many times does the object oscillate in 3.50 s?

32. **GP** A spring of negligible mass stretches 3.00 cm from its relaxed length when a force of 7.50 N is applied. A 0.500-kg particle rests on a frictionless horizontal surface and is attached to the free end of the spring. The particle is displaced from the origin to $x = 5.00$ cm and released from rest at $t = 0$. (a) What is the force constant of the spring? (b) What are the angular frequency ω, the frequency, and the period of the motion? (c) What is the total energy of the system? (d) What is the amplitude of the motion? (e) What are the maximum velocity and the maximum acceleration of the particle? (f) Determine the displacement x of the particle from the equilibrium position at $t = 0.500$ s. (g) Determine the velocity and acceleration of the particle when $t = 0.500$ s.

33. Given that $x = A \cos(\omega t)$ is a sinusoidal function of time, show that v (velocity) and a (acceleration) are also sinusoidal functions of time. *Hint:* Use Equations 13.6 and 13.2.

13.5 Motion of a Pendulum

34. **V** A man enters a tall tower, needing to know its height. He notes that a long pendulum extends from the ceiling almost to the floor and that its period is 15.5 s. (a) How tall is the tower? (b) If this pendulum is taken to the Moon, where the free-fall acceleration is 1.67 m/s^2, what is the period there?

35. A simple pendulum has a length of 52.0 cm and makes 82.0 complete oscillations in 2.00 min. Find (a) the period of the pendulum and (b) the value of g at the location of the pendulum.

36. A "seconds" pendulum is one that moves through its equilibrium position once each second. (The period of the pendulum is 2.000 s.) The length of a seconds pendulum is 0.992 7 m at Tokyo and 0.994 2 m at Cambridge, England. What is the ratio of the free-fall accelerations at these two locations?

tion on Mars is 3.7 m/s^2. (a) What length of pendulum has a period of 1.0 s on Earth? (b) What length of pendulum would have a 1.0-s period on Mars? An object is suspended from a spring with force constant 10.0 N/m. Find the mass suspended from this spring that would result in a period of 1.0 s (c) on Earth and (d) on Mars.

40. A simple pendulum is 5.00 m long. (a) What is the period of simple harmonic motion for this pendulum if it is located in an elevator accelerating upward at 5.00 m/s^2? (b) What is its period if the elevator is accelerating downward at 5.00 m/s^2? (c) What is the period of simple harmonic motion for the pendulum if it is placed in a truck that is accelerating horizontally at 5.00 m/s^2?

13.8 Frequency, Amplitude, and Wavelength

41. The sinusoidal wave shown in Figure P13.41 is traveling in the positive x-direction and has a frequency of 18.0 Hz. Find the (a) amplitude, (b) wavelength, (c) period, and (d) speed of the wave.

Figure P13.41

42. An object attached to a spring vibrates with simple harmonic motion as described by Figure P13.42. For this motion, find (a) the amplitude, (b) the period, (c) the angular frequency, (d) the maximum speed, (e) the maximum acceleration, and (f) an equation for its position x in terms of a sine function.

Figure P13.42

Figure 187. Screenshot of the problems that were given to students to implement learning objective number five (Serway & Vuille, 2013, p. 478)

The conducted experiment: Simple harmonic motion

Note: the required tools for this experiment including the digital technology tools, such as logger pro vernier software, lab quest devices and the motion detectors are provided by the Institute of Applied Technology (IAT) to all students and teachers.

Introduction

“One simple system that vibrates is a mass hanging from a spring. The force applied by an ideal spring is proportional to how much it is stretched or compressed. Given this force behaviour, the up and down motion of the mass is called simple harmonic.

Objectives

I. Measure the position and velocity as a function of time for an oscillating mass and spring system.
II. Determine the amplitude and period of the observed simple harmonic motion”. (Vernier.com, 2019)

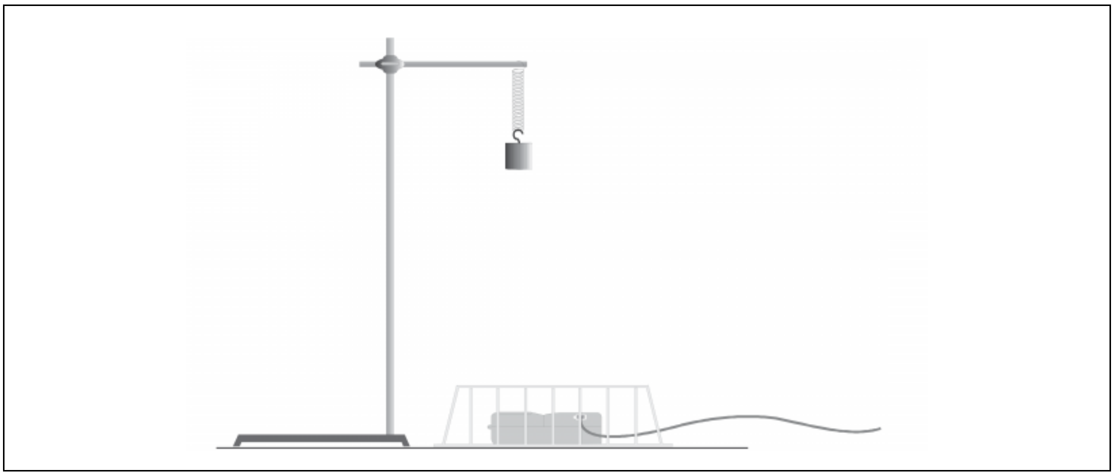


Figure 188. Mass spring system above a motion detector. (Vernier.com, 2019)

Summary of the experiment

As shown in Figure 188, the ring stands supporting the spring, which has a hanging mass on it. Set the spring-mass in motion oscillating above the motion detector, which is shown in Figure 189. A plot of the motion of the oscillating spring will be generated by the motion detector, which is connected to what is called Labquest device, i.e., data analyser, see Figure 190.

Figure 189. Motion detector used in this experiment

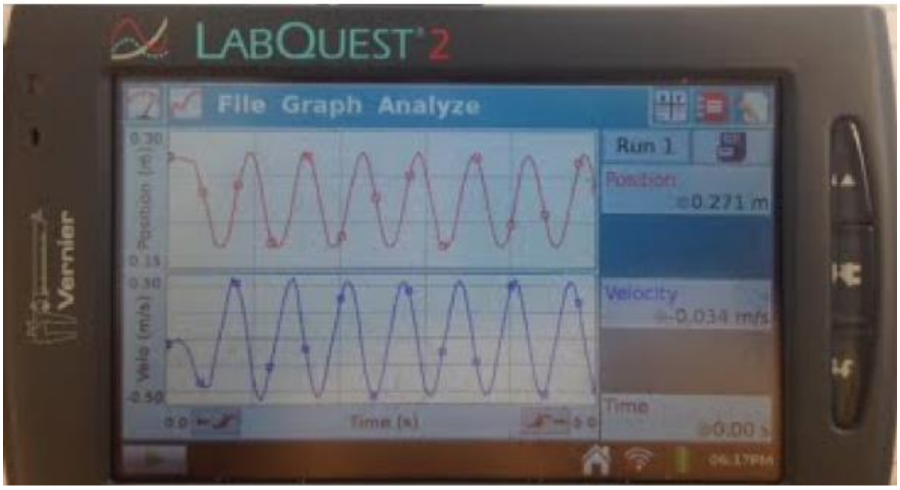
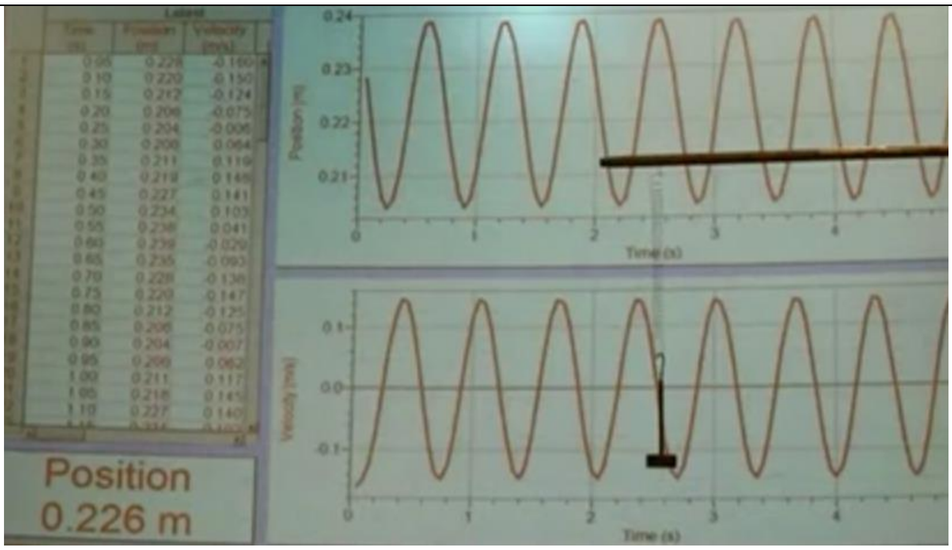


Figure 190. Labquest device graphing the motion of the oscillating spring.

Fifty-grams mass to be used over the motion detector, as shown in Figure 188 and Figure 191. Two different situations were dealt with using the 50-grams mass.

The first situation (Figure 191), smaller oscillation compared to the second one (Figure 192), so after setting the spring-mass system in motion. The motion detector will collect the data, which will be graphed by the lab quest device (Vernier software) as a sinusoidal function, as shown in Figure 191.



	Latest		
	Time (s)	Position (m)	Velocity (m/s)
1	0.05	0.228	-0.160
2	0.10	0.220	-0.150
3	0.15	0.212	-0.124
4	0.20	0.206	-0.075
5	0.25	0.204	-0.006
6	0.30	0.206	0.064
7	0.35	0.211	0.119
8	0.40	0.219	0.145
9	0.45	0.227	0.141
10	0.50	0.234	0.103
11	0.55	0.238	0.041
12	0.60	0.239	-0.029
13	0.65	0.235	-0.093
14	0.70	0.228	-0.136
15	0.75	0.220	-0.147
16	0.80	0.212	-0.125
17	0.85	0.206	-0.075
18	0.90	0.204	-0.007
19	0.95	0.206	0.062
20	1.00	0.211	0.117
21	1.05	0.218	0.145
22	1.10	0.227	0.140

Position
0.226 m

Figure 191. Screenshot of the position and velocity as functions of time for an oscillating spring-mass system in the first situation. Data was collected and graphed by the logger pro Vernier software. https://youtu.be/PjoUTNEvct4

The figure above consists of two graphs (parts). The upper one shows the position, time graph (x-t graph). Using this graph, students could measure the position as a function of time, periodic time, frequency, wavelength and amplitude while the lower one shows the velocity-time graph (v-t graph). It allows students to find the velocity of the connected mass at any moment.

The second situation (Figure 192), the oscillation was larger than the first situation (larger amplitude). Students are going to compare the periods, frequency and amplitude of these two situations (Figure 191 and Figure 192) using the same spring.

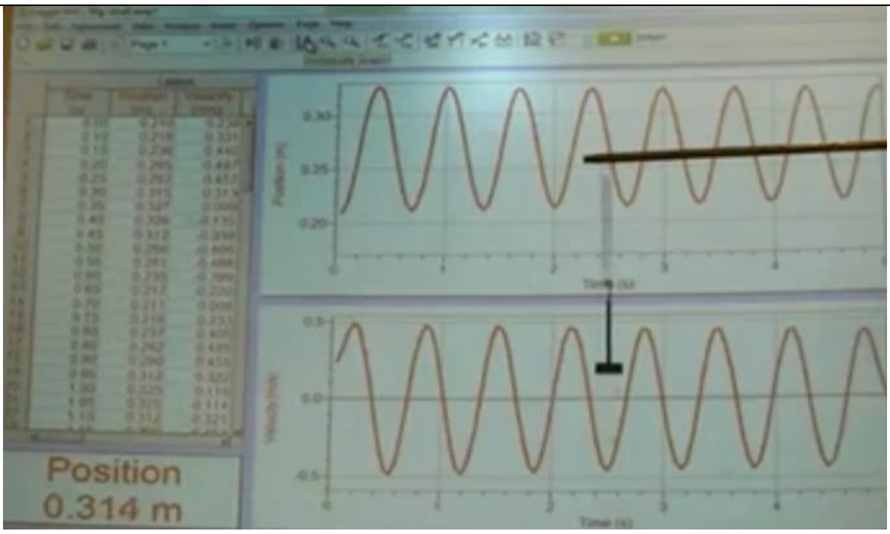


Figure 192. Screenshot of the position and velocity as functions of time for an oscillating spring-mass system in the second situation. Data was collected and graphed by the logger pro Vernier software. https://youtu.be/PjoUTNEvct4

The outcomes

Based on Figure 191 and Figure 192, students could measure the position and velocity as functions of time for an oscillating mass and spring system (objective 1 of the experiment). Moreover, students could determine the amplitude (Δx), period (T), and frequency (f) of the observed simple harmonic motion (objective 2 of the experiment).

By repeating the experiment several times using different masses, students could plot the graph between the restoring force (F) and the extension or the displacement (Δx), which should be a linear function, as shown in Figure 193. The slope of the linear function is equal to the spring constant (K), and the area under the graph is equal to the elastic potential energy (P.E).

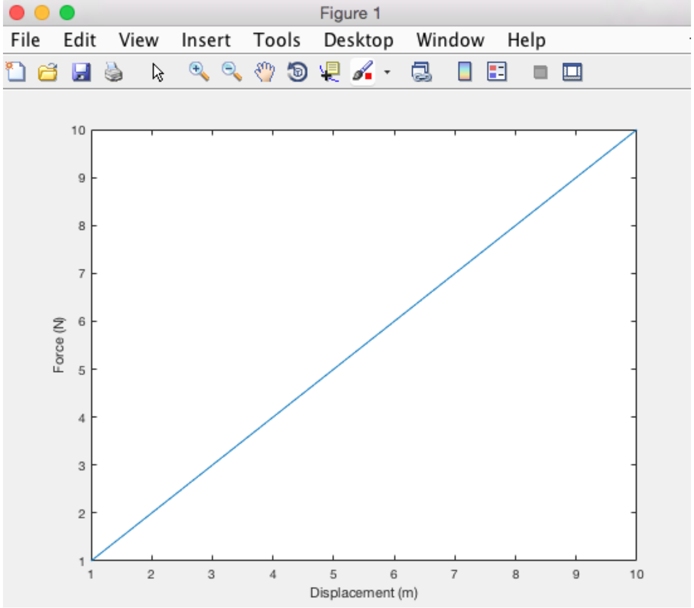


Figure 193. MatLab software was used to plot a graph of force applied against extension produced

The value of the spring constant and the amplitude or the extension (Δx), allowed students to:

I. Calculate the restoring force using Hooke's law $F = -K\Delta X$.

II. Calculate the elastic potential energy using the equation $P.E = \frac{1}{2}KX^2$, students compared their results with the area under the graph.

Note: in this experiment, the terms amplitude, extension and displacement indicate the same meaning and have one symbol, which is Δx.

As an extra curriculum activity, students were asked to compare the observed motion of a mass and spring system to a mathematical model of simple harmonic motion, i.e., $y = A\ \sin(2\pi ft)$ or $y = A\ \cos(2\pi ft)$. Where $\sin(2\pi ft)$ and $\cos(2\pi ft)$ are trigonometric functions are used to describe the shown pattern of the oscillation, see Figure 191 and Figure 192.

The Second Lesson: Newton's Second Law (C3 P3 T0)

This lesson was implemented using nondigital technology-based learning (T0). The C3, P3, T0 strategy was applied to implement the learning objectives. It means that three kinds of content (curriculum) were used: theoretical, practical and interactive; zero per cent of the content was integrated with digital technology (none of the learning objectives was integrated with digital technology); three pedagogical dimensions were used to deliver the content: direct teaching, social (collaborative) learning and cognitive learning.

The same pedagogical dimensions and kinds of curriculum that were used to teach the first lesson, simple harmonic motion, were used to teach this lesson as well. In other words, the only difference between the implementation of these two lessons is the existence of digital technology in the first lesson and the absence of it in this lesson. The results of the assessments conducted afterwards were used to calculate the influence of digital technology on students' attainment.

Following is a detailed description of how each of the five learning objectives was implemented.

Note: Newton's first and third laws were included as well. However, the main focus was Newton's second law. Please refer to learning object number two.

Learning objective number one

Define force, inertia, mass, equilibrium and acceleration.

Three pedagogical dimensions (P3) were used to implement this learning objective.

Firstly, direct teaching; the definitions of these terms were explained, written on the board and copied by students to their notebooks. The following points were covered (summary of the lecture notes):

Forces

I. Force is commonly imagined as a push or pull on an object.

II. Force is a vector quantity.

III. Forces are divided into two kinds, contact forces and field forces:

  a. Contact forces result from physical contact between two objects

  b. Field forces act between disconnected objects

Inertia

I. Inertia is the tendency of an object to continue in its original motion.

II. Thought experiment, using a golf ball and a bowling ball. Hit a golf ball with a force (F1). Hit a bowling ball with the same force (F1). The golf ball will travel farther. Both resist changes in their motion.

Mass

I. A measure of the resistance of an object to changes in its motion due to a force.

II. The larger the mass, the less it accelerates under the action of a given force.

III. The international unit, which is used to measure the mass is kg.

IV. Mass is a scalar quantity.

Equilibrium

I. An object either at rest or moving with a constant velocity is said to be in equilibrium.

II. The net force acting on the object is zero (since the acceleration is zero)

$$\Sigma F = 0$$

Acceleration

I. Acceleration is the rate of change in velocity. Alternatively, the change of velocity per unit time.

II. Acceleration is a vector quantity.

III. Acceleration has magnitude and direction.

IV. Change in velocity could be a change in speed, direction or both.

$$a = \frac{\Delta v}{\Delta t}$$

Secondly, collaborative learning; students were divided into groups and asked to define these terms in their own words, share and discuss these definitions with their peers and the teacher.

Finally, cognitive learning; students were asked several short questions about these terms, for instance, questions related to the definitions, characters and the units for each quantity. Thus, the teacher could check students' knowledge and understanding of these terms. Students were asked to form an initial understanding of the relationship between mass and acceleration. They were allowed to use their books (hardcopy). Students, as active members in the learning process, shared their ideas and discussed it with their teacher.

Three kinds of the curriculum (C3) were used to implement this learning objective.

Firstly, theoretical curriculum; external notes (paper-based) were distributed to students. Lecture notes were written on the board and copied by students. Please refer to the covered points during the direct teaching (summary of the lecture notes).

Secondly, interactive curriculum; the teacher displayed hardcopy posters related to acceleration and different kinds of forces, such as gravitational force, tension force and electric force. The posters were printed out and distributed to students, see Figure 194 and Figure 195.

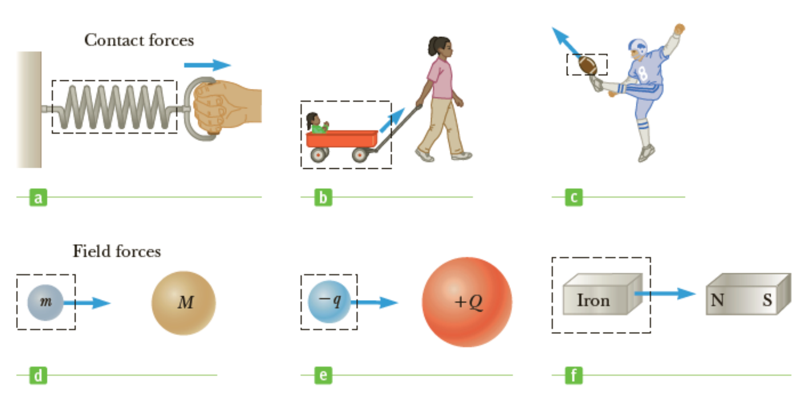


Figure 194. Examples of forces applied to various objects. In each case, a force acts on the object surrounded by the dashed lines. Something in the environment external to the boxed area exerts the force. (Serway & Vuille, 2013, p. 89)

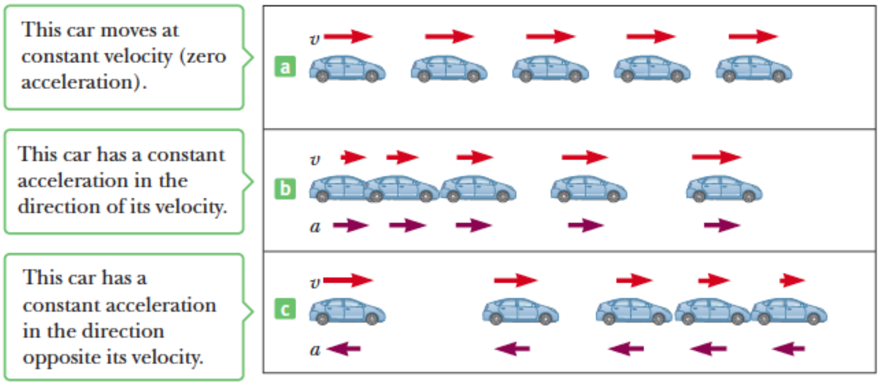


Figure 195. Motion diagrams of a car moving along a straight roadway in a single direction. The velocity at each instant is indicated by a red arrow, and the constant acceleration is indicated by a purple arrow. (Serway & Vuille, 2013, p. 37)

Finally, practical curriculum; the following experiment was implemented to describe the force. Instructions with illustrations below were printed out and given to students together with all the materials required to conduct it.

Build a Balloon Hovercraft - Teach Force and Motion

The idea of this experiment was taken from YouTube, but I confirm that the below link was not shared with students as this lesson was implemented without using digital technology.

https://www.youtube.com/watch?v=pzvqVch__T8&feature=youtu.be

- This experiment is used to describe force, motion and Newton's laws.
- Materials required: some strong glue, CD, sports bottle cap, a balloon and wire to secure the balloon to the bottle cap.

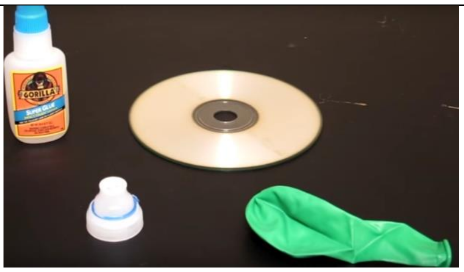


Figure 196. Materials required

- Procedures: stick using super glue the bottle top to the centre of the CD. Leave it to dry firmly (give it at least ten minutes)

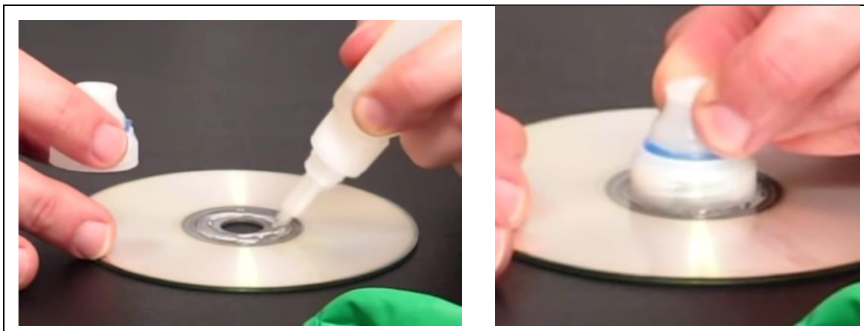


Figure 197. Glue the bottle cap in the centre of the CD

- The air is going to flow from the top right through the bottom of the CD.

Figure 198. Airflow during the experiment

- Blow up the balloon and tie it up to the bottle cap with wire, so that the balloon will not separate from the bottle cap.

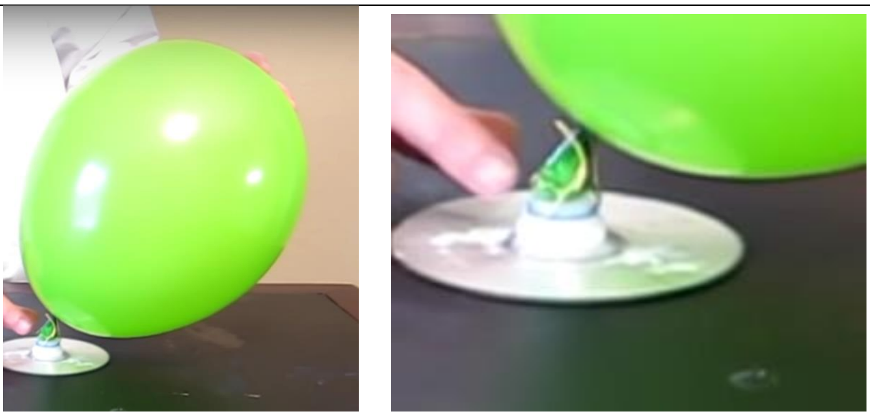


Figure 199. Blow up the balloon and use wire to attach it to the bottle cap

- Let it go when you are ready and observe the gliding; it will start gliding over the surface of the table.

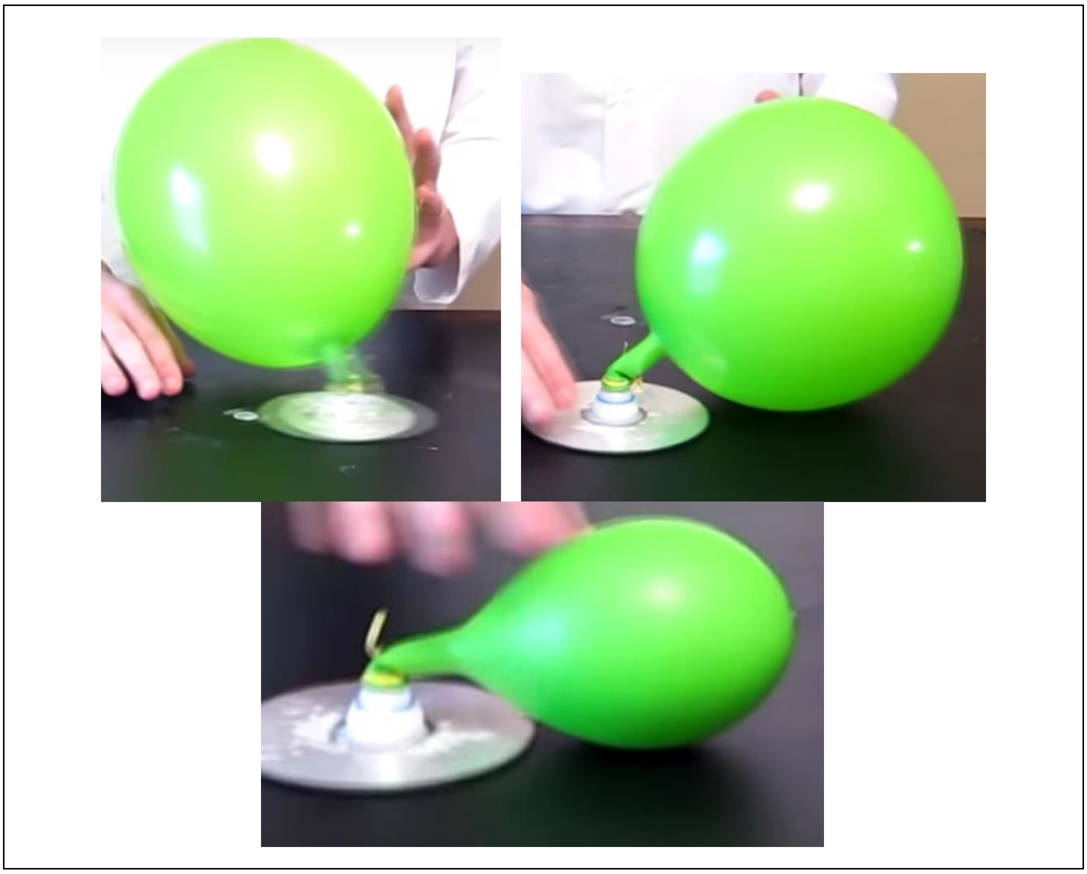


Figure 200. Let it go and observe the gliding

By implementing this experiment and monitoring the air-filled balloon's behaviour as it releases the air, students could conclude that the force is a push or a pull; action and reaction.

Learning objective number two

State and apply Newton's second law: $\Sigma F = ma$, where F stands for the force, m is the mass, and a is the acceleration. Newton's first and third laws were revised with students.

Three pedagogical dimensions (P3) were used in this learning objective.

Firstly, direct teaching; the teacher stated and discussed with students Newton's laws (first, second and third laws) including the mathematical formula of Newton's second law, $\Sigma F = ma,$ and explained the proportionality between force, mass and acceleration.

Summary of the covered points during this learning objective:

Newton's First Law

I. An object moves with a velocity that is constant in magnitude and direction unless acted on by a nonzero net force.
II. The net force is defined as the vector sum of all the external forces exerted on the object.
III. An external force is any force that results from the interaction between the object and its environment.

IV. Internal forces are:
    a. Forces that originate within the object itself
    b. They cannot change the object's velocity

Newton's Second Law

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

The mathematical formula of Newton's second law: $\Sigma F = ma$

I. Newton's Second Law can be applied three-dimensionally (x, y and z).

II. Forces cause changes in motion.
III. All the forces acting on an object are added as vectors to find the net force acting on the object.
IV. ma is *not* a force itself.
V. Newton's Second Law is a vector equation.

Newton's Third Law

I. If object one and object two interact, the force exerted by object one on object two is equal in magnitude but opposite in direction to the force exerted by object two on object one, see Figure 201.

$$F_{12} = -F_{21}$$

II. The mathematical description of Newton's Third Law is equivalent to saying that a single isolated force cannot exist.

III. F_{12} may be called the *action* force and F_{21} the *reaction* force, as shown in Figure 201. Either force can be the action or the reaction force.

IV. The action and reaction forces act on different objects.

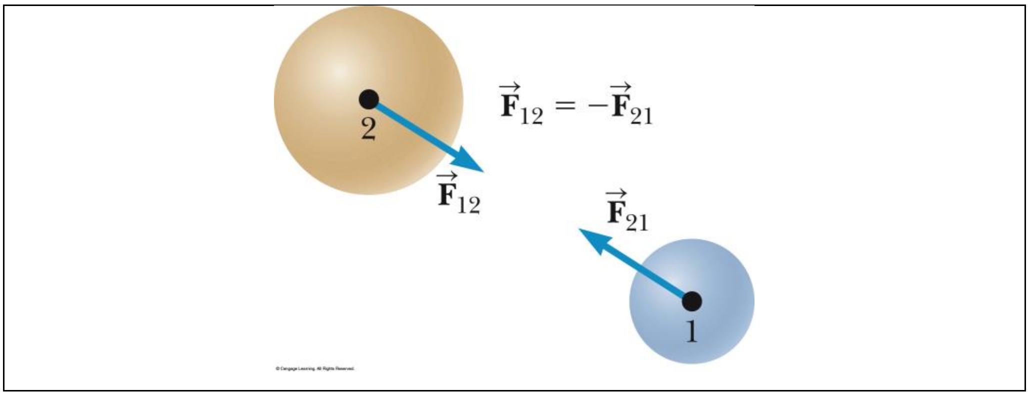
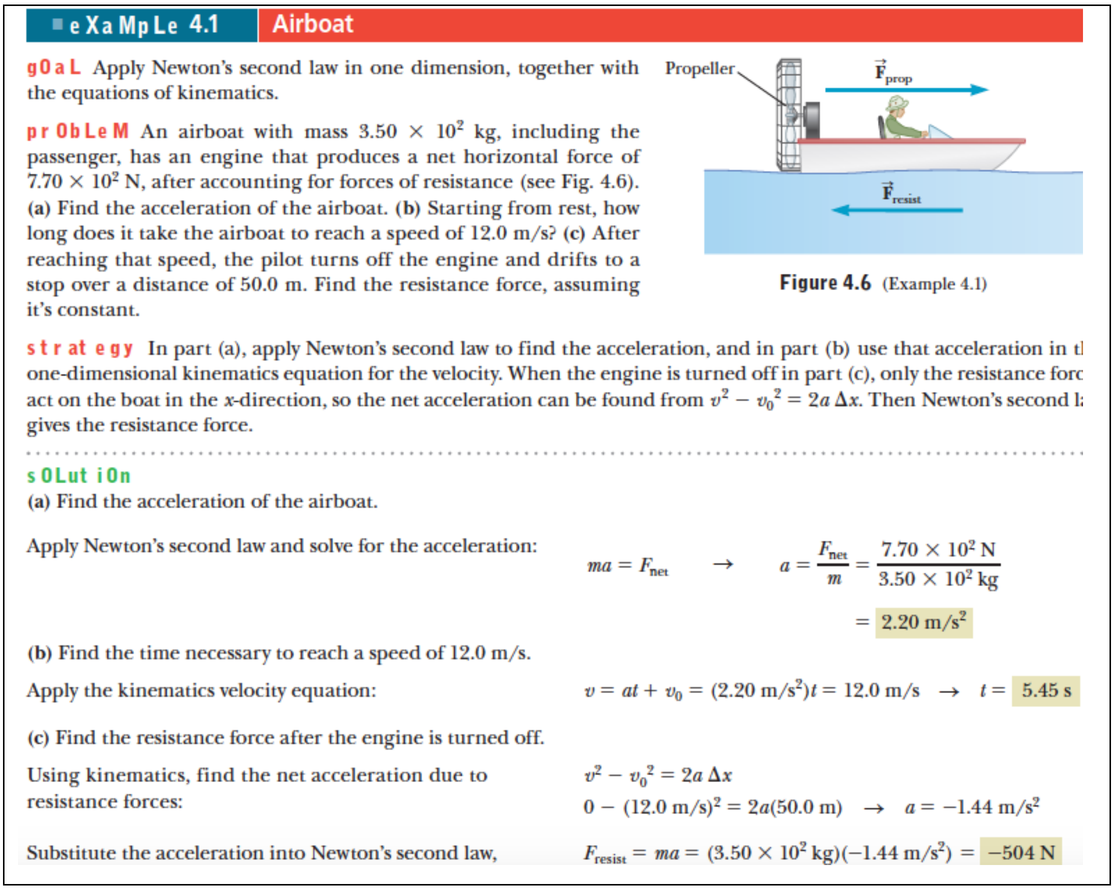


Figure 201. The force F12 exerted by object one on object two is equal in magnitude and opposite in direction to the force F21 exerted by object two on object one. (Serway & Vuille, 2013, p. 98)

Secondly, collaborative learning; students were given a chance to discuss these laws between themselves, rephrase it in their own words and exchange their responses with other peers and the teacher. Students were asked to work together to apply Newton's second law in one dimension, see the task in Figure 202. Students were asked to share their responses. High achieving students were asked to support low achievers; students exchanged their experience and ideas. The answer key was given to students later on.



■ eXaMpLe 4.1 Airboat

gOaL Apply Newton's second law in one dimension, together with the equations of kinematics.

prObLeM An airboat with mass 3.50×10^2 kg, including the passenger, has an engine that produces a net horizontal force of 7.70×10^2 N, after accounting for forces of resistance (see Fig. 4.6). **(a)** Find the acceleration of the airboat. **(b)** Starting from rest, how long does it take the airboat to reach a speed of 12.0 m/s? **(c)** After reaching that speed, the pilot turns off the engine and drifts to a stop over a distance of 50.0 m. Find the resistance force, assuming it's constant.

Figure 4.6 (Example 4.1)

strategy In part (a), apply Newton's second law to find the acceleration, and in part (b) use that acceleration in tl one-dimensional kinematics equation for the velocity. When the engine is turned off in part (c), only the resistance forc act on the boat in the *x*-direction, so the net acceleration can be found from $v^2 - v_0{}^2 = 2a\,\Delta x$. Then Newton's second l: gives the resistance force.

sOLutiOn

(a) Find the acceleration of the airboat.

Apply Newton's second law and solve for the acceleration:

$$ma = F_{\text{net}} \quad \rightarrow \quad a = \frac{F_{\text{net}}}{m} = \frac{7.70 \times 10^2 \text{ N}}{3.50 \times 10^2 \text{ kg}}$$

$$= \boxed{2.20 \text{ m/s}^2}$$

(b) Find the time necessary to reach a speed of 12.0 m/s.

Apply the kinematics velocity equation:

$$v = at + v_0 = (2.20 \text{ m/s}^2)t = 12.0 \text{ m/s} \quad \rightarrow \quad t = \boxed{5.45 \text{ s}}$$

(c) Find the resistance force after the engine is turned off.

Using kinematics, find the net acceleration due to resistance forces:

$$v^2 - v_0{}^2 = 2a\,\Delta x$$

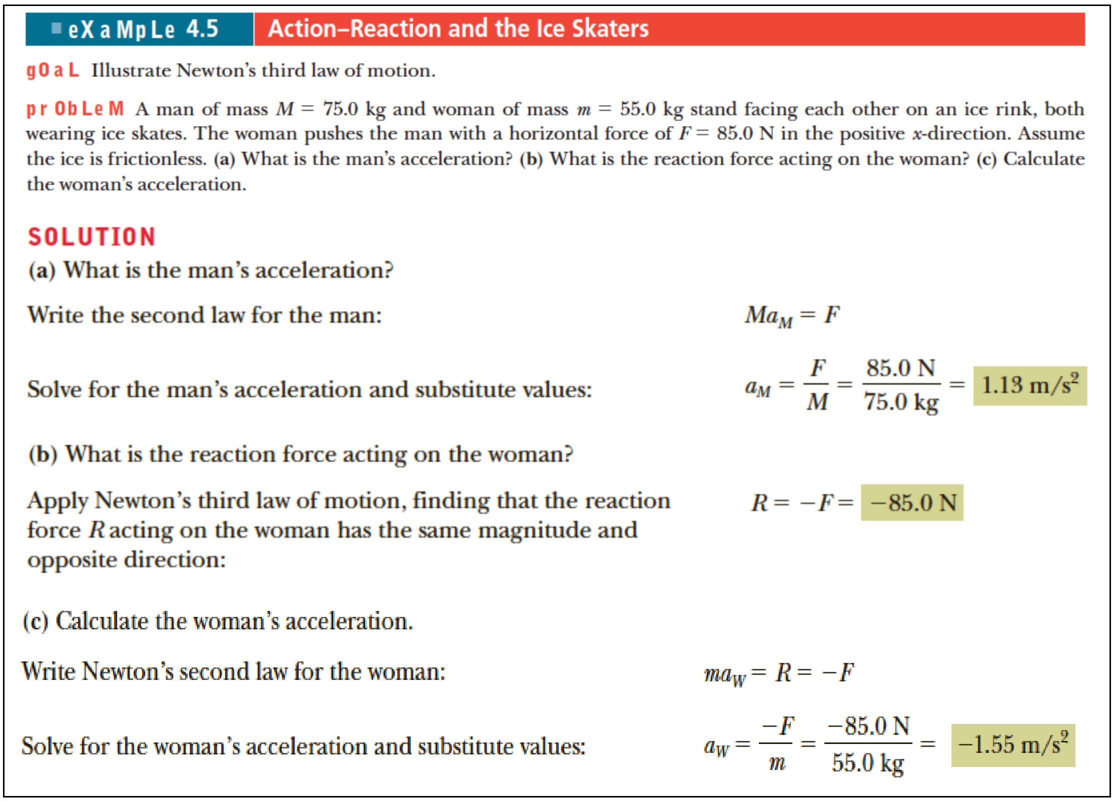
$$0 - (12.0 \text{ m/s})^2 = 2a(50.0 \text{ m}) \quad \rightarrow \quad a = -1.44 \text{ m/s}^2$$

Substitute the acceleration into Newton's second law,

$$F_{\text{resist}} = ma = (3.50 \times 10^2 \text{ kg})(-1.44 \text{ m/s}^2) = \boxed{-504 \text{ N}}$$

Figure 202. Practice related to Newton's second law (Serway & Vuille, 2013, p. 93)

Finally, cognitive learning; the teacher refreshed students' knowledge about Newton's laws. The content was summarised and divided into several organised chunks. The first part was allocated for the definitions of the terms force and acceleration (revision of the first learning objective). The second part was used for Newton's laws in general and the proportionality between the three variables (F, m and a) in Newton's second law in particular. The last part was used to give examples that connect Newton's laws with real-life applications, such as the movement of a cart on a table as a result of applying a force upon it, or a piece of iron under the effect of magnetic field (magnetic force). At first, students were asked to complete the task, which is shown in Figure 203 individually, and then to compare their answers with their peers. The given task required higher-order thinking skills, such as critical thinking and analysis. The answer key was shared with students after they completed the task.



EXAMPLE 4.5 Action–Reaction and the Ice Skaters

GOAL Illustrate Newton's third law of motion.

PROBLEM A man of mass $M = 75.0$ kg and woman of mass $m = 55.0$ kg stand facing each other on an ice rink, both wearing ice skates. The woman pushes the man with a horizontal force of $F = 85.0$ N in the positive x-direction. Assume the ice is frictionless. (a) What is the man's acceleration? (b) What is the reaction force acting on the woman? (c) Calculate the woman's acceleration.

SOLUTION

(a) What is the man's acceleration?

Write the second law for the man: $Ma_M = F$

Solve for the man's acceleration and substitute values: $a_M = \frac{F}{M} = \frac{85.0\text{ N}}{75.0\text{ kg}} = 1.13\text{ m/s}^2$

(b) What is the reaction force acting on the woman?

Apply Newton's third law of motion, finding that the reaction force R acting on the woman has the same magnitude and opposite direction: $R = -F = -85.0\text{ N}$

(c) Calculate the woman's acceleration.

Write Newton's second law for the woman: $ma_W = R = -F$

Solve for the woman's acceleration and substitute values: $a_W = \frac{-F}{m} = \frac{-85.0\text{ N}}{55.0\text{ kg}} = -1.55\text{ m/s}^2$

Figure 203. Practice related to Newton's second and third laws (Serway & Vuille, 2013, p. 99)

Three kinds of the curriculum (C3) were used to implement this learning objective.

Firstly, theoretical curriculum; lecture notes were explained and written by the teacher on the board and copied by students to their notebooks (see the covered points during the direct teaching). The textbook (hardcopy), which was used, is college physics Serway 10th edition (Serway & Vuille, 2013).

Secondly, interactive curriculum: the teacher displayed hardcopy posters related to Newton's laws. The posters were printed on A3 size papers, see Figure 204 and Figure 205. Physical tools were provided to students to interact with it physically, such as cart with wheels, pulleys and ropes. Thus, students could experience the applied force in general, and the tension force in particular.

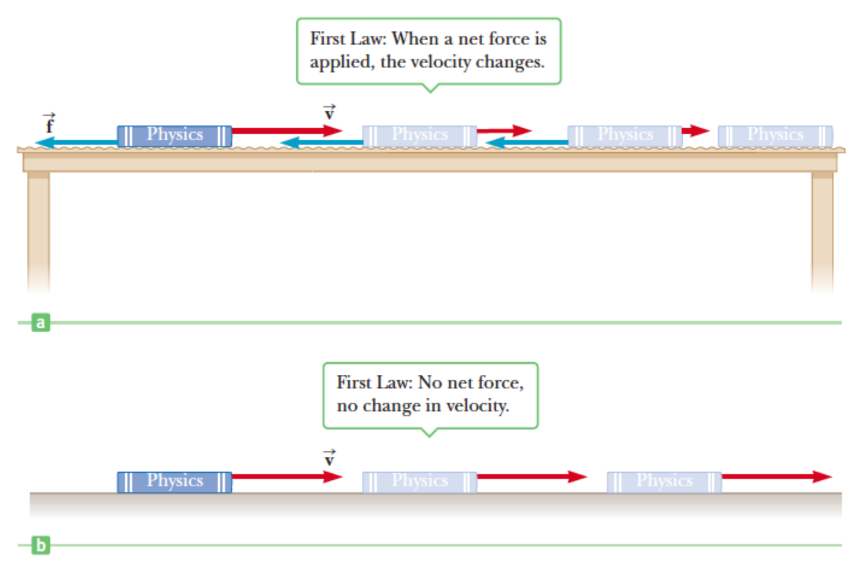


Figure 204. The first law of motion. (a) A book moves at an initial velocity on a surface with friction. Because there is a friction force acting horizontally, the book slows to rest. (b) A book moves at velocity (v) on a frictionless surface. In the absence of a net force, the book keeps moving at velocity (v) (Serway & Vuille, 2013, p. 90)

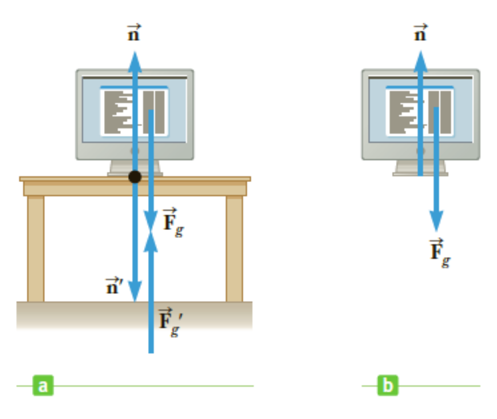


Figure 205. When a monitor is sitting on a table, the forces acting on the monitor are the normal force (n) exerted by the table and the force of gravity (Fg) (Serway & Vuille, 2013, p. 99)

Finally, practical curriculum, represented by the experiment conducted in this lesson, *verification of Newton's second law*.

Learning objective number three

For an object, plot the graph of the force applied against the produced acceleration, relate the slope of the line to the mass of the object (m), and draw a free body diagram of objects at equilibrium or those accelerating and combine forces to find the net force and the acceleration.

Three pedagogical dimensions (P3) were used to implement this learning objective.

Firstly, direct teaching; the teacher explained the term equilibrium (the net force, $F_{net} = 0$; hence, the acceleration = 0). Following are the points that were covered in this learning objective (summary of the lecture notes).

Force-acceleration graph

According to Newton's second law, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. Using the mathematical formula $\Sigma F = ma$, the relationship between the force and acceleration was graphed by the teacher (direct teaching pedagogy) as a linear function see Figure 209.

Free-Body Diagram

I. A diagram of the forces acting on an object
II. Must identify all the forces acting on the object of interest
III. Choose an appropriate coordinate system
IV. If the free body diagram is incorrect, the solution will likely be incorrect
V. Only forces acting directly on the object are included in the free-body diagram
    a. Reaction forces act on other objects and so are not included
    b. The reaction forces do not directly influence the object's motion

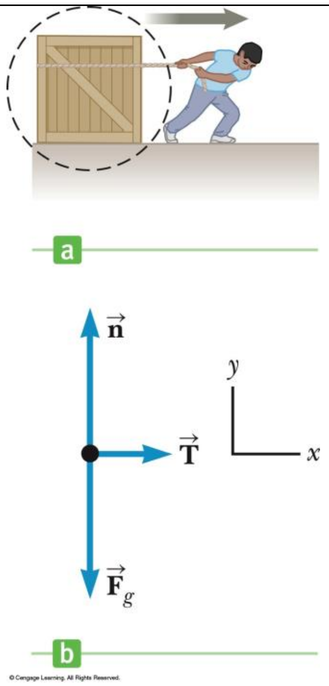
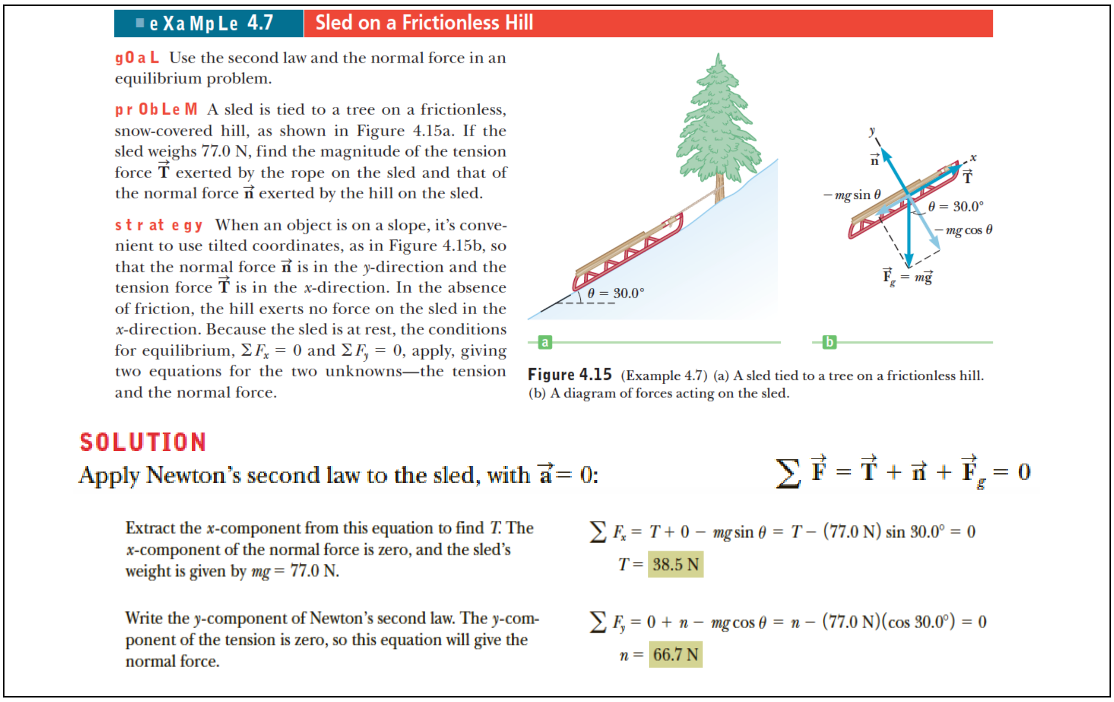


Figure 206. Free-body diagram shows all the forces acting on the box (Serway & Vuille, 2013, p. 100)

The magnitude of force **T** in Figure 206 is the tension acting on the box. The tension is the same at all points along the rope. Normal force (**n**) and the gravitational force are the forces exerted by the earth and the ground, see Figure 206.

Secondly, collaborative learning; students were distributed to groups, each of which was made out of five students and were asked to draw a free body diagram of a book lying down on a table. After which they shared their diagrams with other groups and exchanged their knowledge. Afterwards, in the same groups, students had to complete two tasks. Firstly, draw the free body diagram. Secondly, calculate the net force and acceleration (see Figure 207 and Figure 208). Answer keys were given to them after they completed the tasks.



EXAMPLE 4.7 **Sled on a Frictionless Hill**

GOAL Use the second law and the normal force in an equilibrium problem.

PROBLEM A sled is tied to a tree on a frictionless, snow-covered hill, as shown in Figure 4.15a. If the sled weighs 77.0 N, find the magnitude of the tension force $\vec{\mathbf{T}}$ exerted by the rope on the sled and that of the normal force $\vec{\mathbf{n}}$ exerted by the hill on the sled.

STRATEGY When an object is on a slope, it's convenient to use tilted coordinates, as in Figure 4.15b, so that the normal force $\vec{\mathbf{n}}$ is in the y-direction and the tension force $\vec{\mathbf{T}}$ is in the x-direction. In the absence of friction, the hill exerts no force on the sled in the x-direction. Because the sled is at rest, the conditions for equilibrium, $\Sigma F_x = 0$ and $\Sigma F_y = 0$, apply, giving two equations for the two unknowns—the tension and the normal force.

Figure 4.15 (Example 4.7) (a) A sled tied to a tree on a frictionless hill. (b) A diagram of forces acting on the sled.

SOLUTION

Apply Newton's second law to the sled, with $\vec{\mathbf{a}} = 0$:

$$\sum \vec{\mathbf{F}} = \vec{\mathbf{T}} + \vec{\mathbf{n}} + \vec{\mathbf{F}}_g = 0$$

Extract the x-component from this equation to find T. The x-component of the normal force is zero, and the sled's weight is given by $mg = 77.0$ N.

$$\sum F_x = T + 0 - mg\sin\theta = T - (77.0\text{ N})\sin 30.0° = 0$$

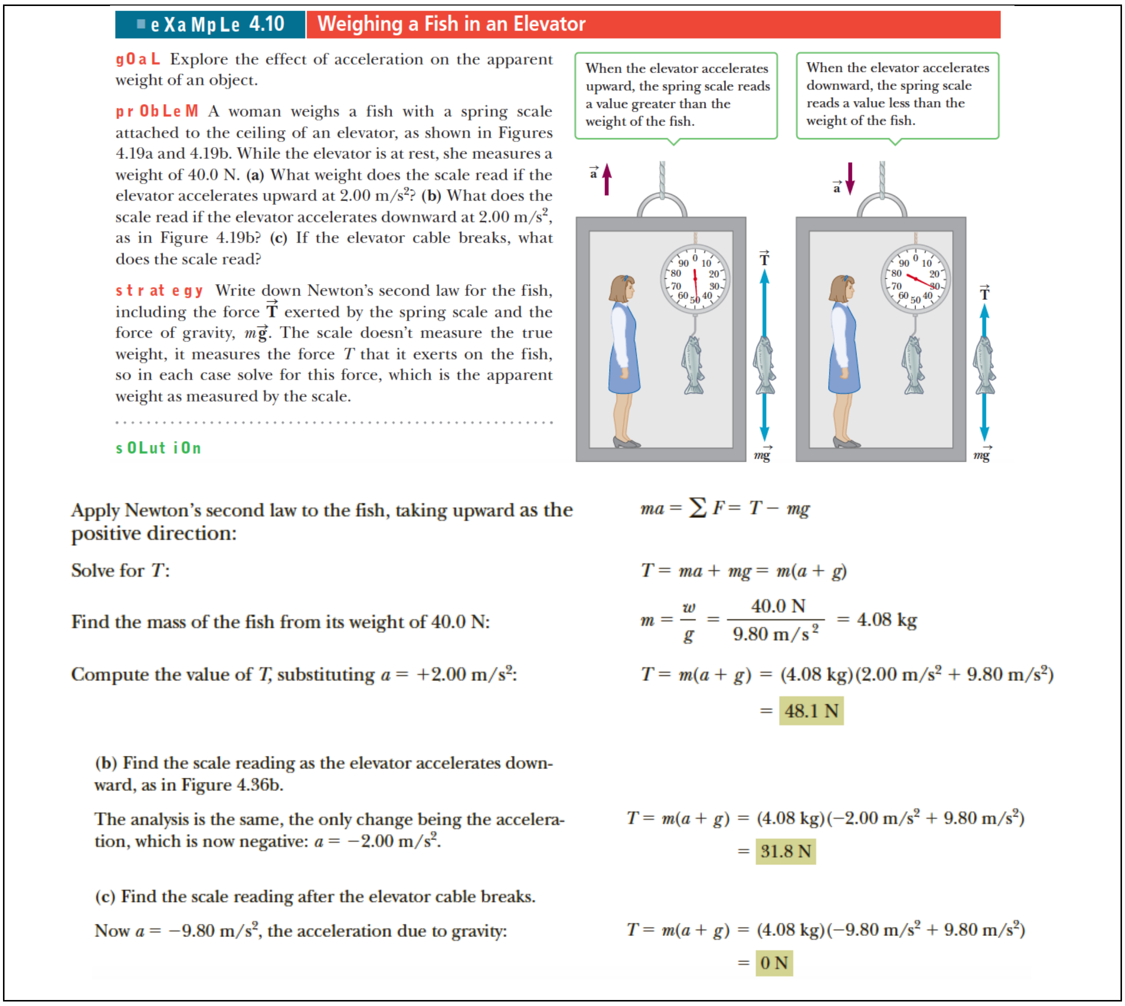
$$T = \boxed{38.5\text{ N}}$$

Write the y-component of Newton's second law. The y-component of the tension is zero, so this equation will give the normal force.

$$\sum F_y = 0 + n - mg\cos\theta = n - (77.0\text{ N})(\cos 30.0°) = 0$$

$$n = \boxed{66.7\text{ N}}$$

Figure 207. Practice related to Newton's second law (Serway & Vuille, 2013, p. 103)



EXAMPLE 4.10 **Weighing a Fish in an Elevator**

GOAL Explore the effect of acceleration on the apparent weight of an object.

PROBLEM A woman weighs a fish with a spring scale attached to the ceiling of an elevator, as shown in Figures 4.19a and 4.19b. While the elevator is at rest, she measures a weight of 40.0 N. **(a)** What weight does the scale read if the elevator accelerates upward at 2.00 m/s^2? **(b)** What does the scale read if the elevator accelerates downward at 2.00 m/s^2, as in Figure 4.19b? **(c)** If the elevator cable breaks, what does the scale read?

STRATEGY Write down Newton's second law for the fish, including the force $\vec{\mathbf{T}}$ exerted by the spring scale and the force of gravity, $m\vec{\mathbf{g}}$. The scale doesn't measure the true weight, it measures the force T that it exerts on the fish, so in each case solve for this force, which is the apparent weight as measured by the scale.

When the elevator accelerates upward, the spring scale reads a value greater than the weight of the fish.

When the elevator accelerates downward, the spring scale reads a value less than the weight of the fish.

SOLUTION

Apply Newton's second law to the fish, taking upward as the positive direction:

$$ma = \sum F = T - mg$$

Solve for T:

$$T = ma + mg = m(a + g)$$

Find the mass of the fish from its weight of 40.0 N:

$$m = \frac{w}{g} = \frac{40.0\text{ N}}{9.80\text{ m/s}^2} = 4.08\text{ kg}$$

Compute the value of T, substituting $a = +2.00$ m/s^2:

$$T = m(a + g) = (4.08\text{ kg})(2.00\text{ m/s}^2 + 9.80\text{ m/s}^2)$$

$$= \boxed{48.1\text{ N}}$$

(b) Find the scale reading as the elevator accelerates downward, as in Figure 4.36b.

The analysis is the same, the only change being the acceleration, which is now negative: $a = -2.00$ m/s^2.

$$T = m(a + g) = (4.08\text{ kg})(-2.00\text{ m/s}^2 + 9.80\text{ m/s}^2)$$

$$= \boxed{31.8\text{ N}}$$

(c) Find the scale reading after the elevator cable breaks.

Now $a = -9.80$ m/s^2, the acceleration due to gravity:

$$T = m(a + g) = (4.08\text{ kg})(-9.80\text{ m/s}^2 + 9.80\text{ m/s}^2)$$

$$= \boxed{0\text{ N}}$$

Figure 208. Practice related to Newton's second law (Serway & Vuille, 2013, p. 106)

Finally, cognitive learning; the teacher refreshed students' knowledge about the term net force, equilibrium and acceleration. Students were asked to calculate the slope of the line in Figure 209 and to conclude to which quantity the slope is related (it should be related to the mass).

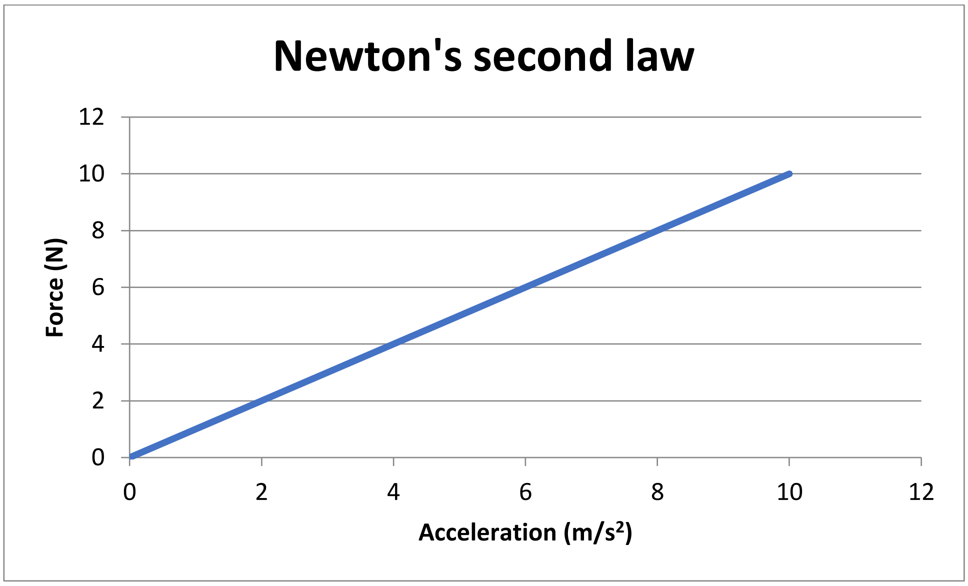
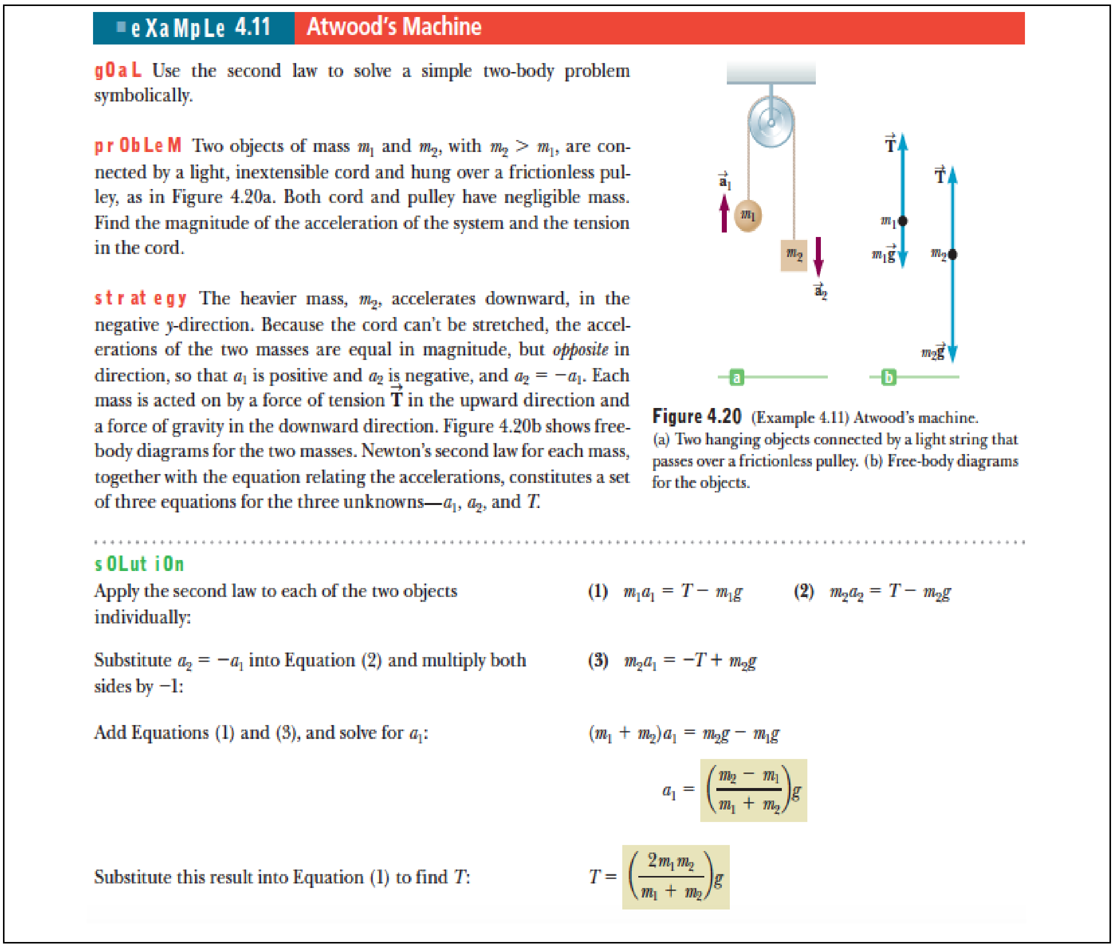


Figure 209. The relationship between force and acceleration according to Newton's second law

Students were asked to work individually and within groups to complete the following tasks, which require higher-order thinking skills. Students used Newton's second law to solve two-body problem symbolically, see Figure 210. Students applied the second law of motion for a system not in equilibrium, together with a kinematics equation, see Figure 211.



EXAMPLE 4.11 **Atwood's Machine**

GOAL Use the second law to solve a simple two-body problem symbolically.

PROBLEM Two objects of mass m_1 and m_2, with $m_2 > m_1$, are connected by a light, inextensible cord and hung over a frictionless pulley, as in Figure 4.20a. Both cord and pulley have negligible mass. Find the magnitude of the acceleration of the system and the tension in the cord.

STRATEGY The heavier mass, m_2, accelerates downward, in the negative y-direction. Because the cord can't be stretched, the accelerations of the two masses are equal in magnitude, but *opposite* in direction, so that a_1 is positive and a_2 is negative, and $a_2 = -a_1$. Each mass is acted on by a force of tension $\vec{\mathbf{T}}$ in the upward direction and a force of gravity in the downward direction. Figure 4.20b shows free-body diagrams for the two masses. Newton's second law for each mass, together with the equation relating the accelerations, constitutes a set of three equations for the three unknowns—a_1, a_2, and T.

Figure 4.20 (Example 4.11) Atwood's machine. (a) Two hanging objects connected by a light string that passes over a frictionless pulley. (b) Free-body diagrams for the objects.

SOLUTION

Apply the second law to each of the two objects individually: (1) $m_1a_1 = T - m_1g$ (2) $m_2a_2 = T - m_2g$

Substitute $a_2 = -a_1$ into Equation (2) and multiply both sides by -1: (3) $m_2a_1 = -T + m_2g$

Add Equations (1) and (3), and solve for a_1:

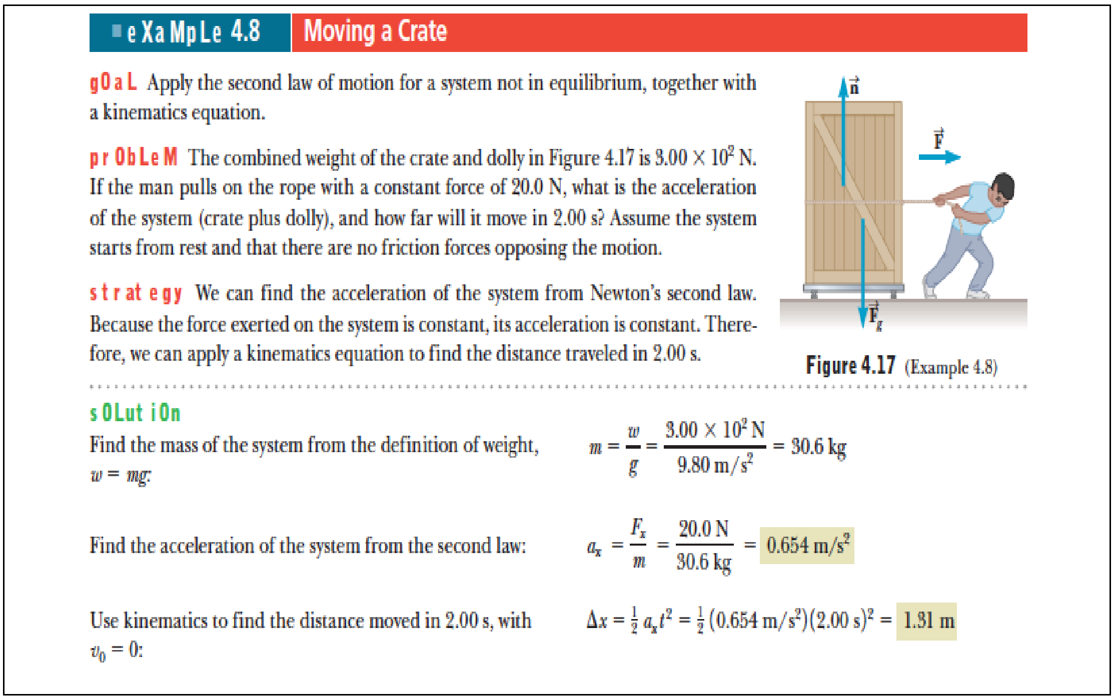
$$(m_1 + m_2)a_1 = m_2g - m_1g$$

$$a_1 = \boxed{\left(\frac{m_2 - m_1}{m_1 + m_2}\right)g}$$

Substitute this result into Equation (1) to find T:

$$T = \boxed{\left(\frac{2m_1m_2}{m_1 + m_2}\right)g}$$

Figure 210. Practice related to Atwood's machine, Newton's second law (Serway & Vuille, 2013, p. 107)



EXAMPLE 4.8 **Moving a Crate**

GOAL Apply the second law of motion for a system not in equilibrium, together with a kinematics equation.

PROBLEM The combined weight of the crate and dolly in Figure 4.17 is 3.00×10^2 N. If the man pulls on the rope with a constant force of 20.0 N, what is the acceleration of the system (crate plus dolly), and how far will it move in 2.00 s? Assume the system starts from rest and that there are no friction forces opposing the motion.

STRATEGY We can find the acceleration of the system from Newton's second law. Because the force exerted on the system is constant, its acceleration is constant. Therefore, we can apply a kinematics equation to find the distance traveled in 2.00 s.

Figure 4.17 (Example 4.8)

SOLUTION

Find the mass of the system from the definition of weight, $w = mg$:

$$m = \frac{w}{g} = \frac{3.00 \times 10^2 \text{ N}}{9.80 \text{ m/s}^2} = 30.6 \text{ kg}$$

Find the acceleration of the system from the second law:

$$a_x = \frac{F_x}{m} = \frac{20.0 \text{ N}}{30.6 \text{ kg}} = \boxed{0.654 \text{ m/s}^2}$$

Use kinematics to find the distance moved in 2.00 s, with $v_0 = 0$:

$$\Delta x = \tfrac{1}{2}a_xt^2 = \tfrac{1}{2}(0.654 \text{ m/s}^2)(2.00 \text{ s})^2 = \boxed{1.31 \text{ m}}$$

Figure 211. Practice related to Atwood's machine together with a kinematic equation (Serway & Vuille, 2013, p. 104)

Three kinds of the curriculum (C3) were used to implement this learning objective.

Firstly, theoretical curriculum; lecture notes were explained and written by the teacher on the board and copied by students to their notebooks. The hard copy of the textbook was used as well. Several tasks were provided, as shown in Figure 207, Figure 208, Figure 210 and Figure 211.

Secondly, interactive curriculum; the teacher displayed hardcopy posters related to Newton’s second law, see Figure 212, Figure 213 and Figure 214. The teacher provided students with Atwood’s machine, two hanging objects connected by a light string that passes over a frictionless pulley. Hence, students could point out the applied forces, including the tension force, gravitational force. Students’ were asked to draw the free body diagram and to share their responses then discuss it with the teacher.

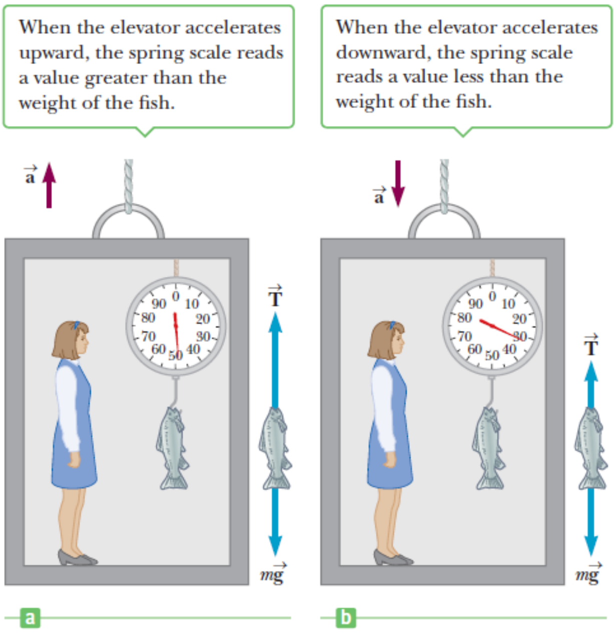


Figure 212. The effect of acceleration on the apparent weight of an object (Serway & Vuille, 2013, p. 106)

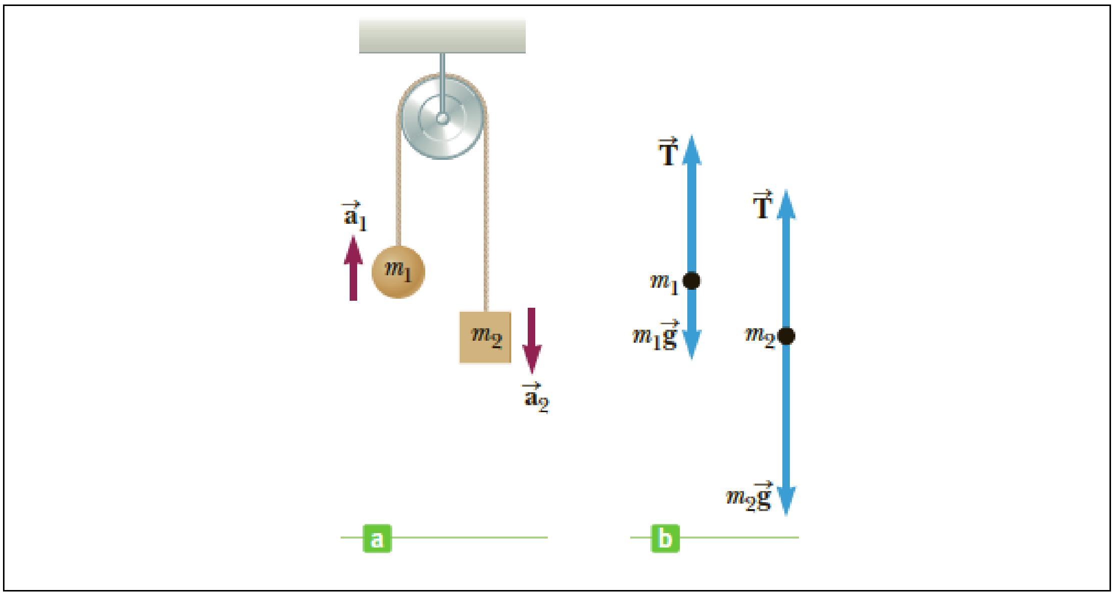


Figure 213. Atwood's machine. (a) Two hanging objects connected by a light string that passes over a frictionless pulley. (b) Free-body diagrams for the objects (Serway & Vuille, 2013, p. 107)

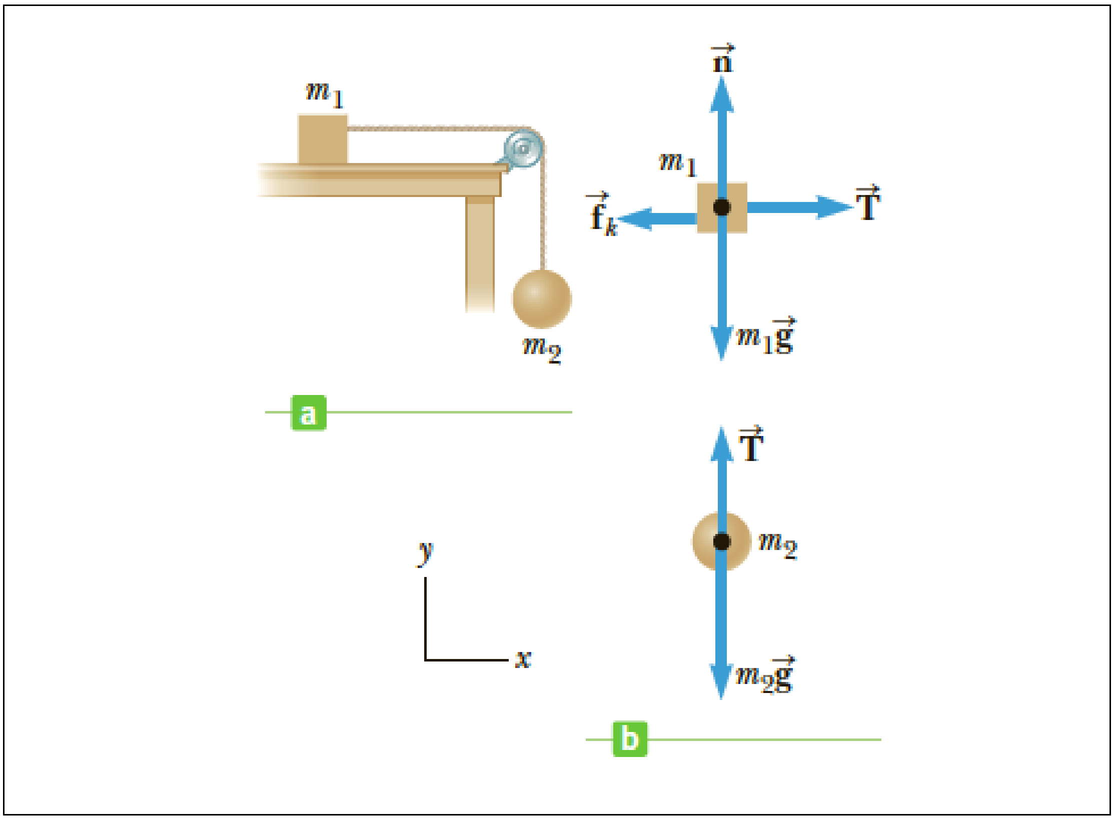


Figure 214. (a) Two objects connected by a light string that passes over a frictionless pulley. (b) Force diagrams for the objects (Serway & Vuille, 2013, p. 112)

Finally, practical curriculum, the following experiment was implemented in the physics laboratory. The idea of this experiment was taken from YouTube, https://www.youtube.com/watch?v=XgUsIxLNnz4&feature=youtu.be. However, I confirm that this link was not shared with students. The Instructions and highlights of the experiment were printed out and distributed to students. Figure 215, Figure 216 and Figure 217 are licensed under CC by-NC-SA 3.0 US.

Experiment: Free body diagram, Newton's Laws

Materials required: a block of two kilograms, two strings that are as identical as possible (they come from the same batch).

Figure 215. Materials required

The block is hanging from one string up and another string down. Considering g=10 m/s^2, the tension in string 1 (T_1) should be equal to 20 N (T1 = mg). The tension in the other string is very close to 0, T2= 0 N as nothing is hanging on it and the string has no weight (approximately), see Figure 216.

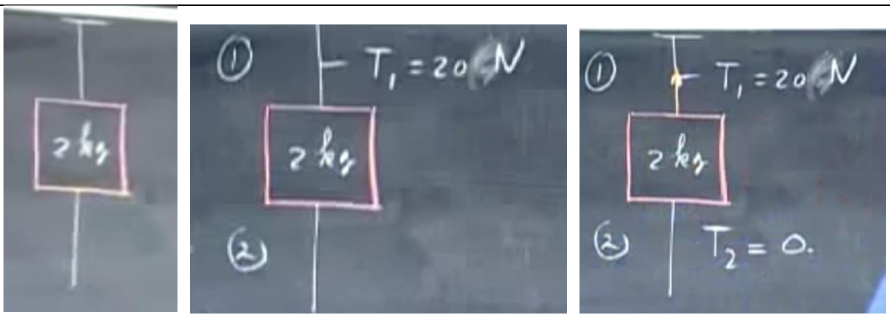


Figure 216. The free-body diagram of the investigated object

Pull-on the second string (the bottom one) and increase the tension on it. This implies that the lower tension T2 will be increased since the object is not being accelerated (a=0); the other tension T1 must increase as well. *Using the free body diagram of the object, compare the values of T1 and T2?*

The following answer was shared with the students later on. The answer is based on the free body diagram of the object as follows:

Before pulling the second string down the tension in the first string was equal to the weight of the object (T1=mg). After pulling the second string down, the magnitude of T2 is no longer equal to zero. Thus, the tension in the first string becomes equal to the weight of the object plus the new value of T2, i.e., (T1= mg + T2). Therefore, the tension will be increased in both strings.

Using the last equation (T1= mg + T2). Students were asked to compare the values of T1 and T2, which one of them is greater.

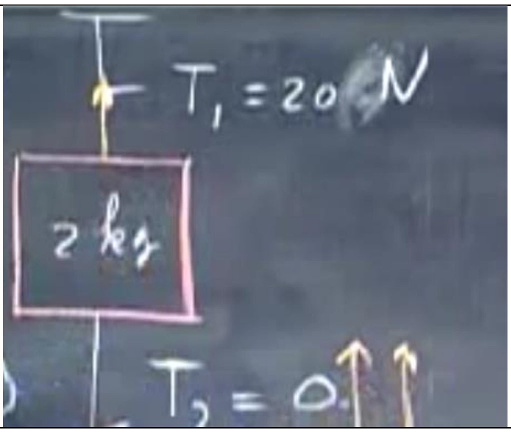


Figure 217. The free-body diagram of the investigated object

Learning objective number four

Conclude the mathematical relationship between Newton’s second law and another concept in physics, the linear momentum and describe some real-life applications related to both concepts (Newton’s second law and linear momentum), such as the seat belts and airbags in the car.

Note: students studied the linear momentum previously. The main goal was to conclude and derive the mathematical relationship between Newton’s second law and the linear momentum. The author confirms that the students were not asked to solve mathematical problems related to the linear momentum in this lesson, as the main target was Newton’s laws in general and in Newton’s second law in particular.

Three pedagogical dimensions (P3) were used to implement this learning objective:

Firstly, direct teaching, the teacher discussed with students the following points:

I. The linear momentum of an object of mass m moving with velocity is defined as the product of the mass and the velocity $P = mv$

   a. SI Unit (International System of Units) which is used to measure the linear momentum is kg.m / s

   b. Linear momentum is a vector quantity; the direction of the momentum is the same as the velocity’s direction

II. In order to change the momentum of an object, a force must be applied

III. The time rate of change of momentum of an object is equal to the net force acting on it. This statement can be expressed mathematically by $F = \frac{\Delta p}{\Delta t} = ma$

Secondly, collaborative learning, which was accomplished using the hardcopy book and the lecture notes; students worked in groups to investigate the concept of linear momentum and Newton’s second law.

Cognitive learning, the students worked in groups to conclude the following derivation, which shows the mathematical relationship between Newton’s second law and the linear momentum.

$$F = ma$$

$$a = \frac{\Delta v}{\Delta t}$$

$$F = m\frac{\Delta v}{\Delta t}$$

$$F\,\Delta t = m\,\Delta v$$

$$\Delta p = m\,\Delta v$$

$$F\,\Delta t = \Delta p$$

$$\boldsymbol{F} = \frac{\Delta \boldsymbol{p}}{\Delta t} = m\boldsymbol{a}$$

Note: F (force), p (linear momentum) and a (acceleration) are vector quantities (have magnitude and direction).

Three kinds of the curriculum (C3) were used.

Firstly, the theoretical curriculum, which included lecture notes and the textbook (Serway & Vuille, 2013). Please refer to the discussed points with students during the direct teaching of this learning objective.

Secondly, interactive curriculum represented by diagrams and figures (hard copies) related to Newton's second law and linear momentum, such as the diagram shown in Figure 218.

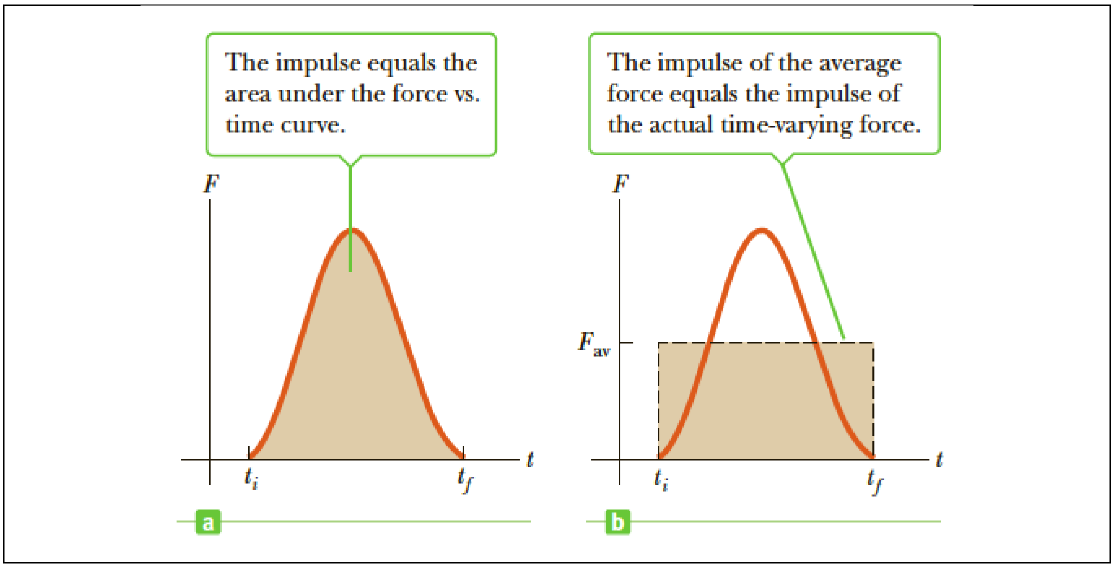


Figure 218 (a) A net force acting on a particle may vary in time. (b) The value of the constant force F_{av} (horizontal dashed line) is chosen so that the area of the rectangle ($F\,\Delta t$) in (b) is the same as the area under the curve in (a) (Serway & Vuille, 2013, p. 172)

Finally, practical curriculum; students were provided with physical tools, such as balls and balloons, by colliding these two objects, students could have an idea about the relationship between the linear momentum and Newton's laws. Different masses and inclined planes were provided; masses were left to scroll down freely on the inclined planes. Students were asked to describe how difficult it is to stop each mass, being aware that the definition of linear momentum in physics is related to how difficult it is to stop a moving object.

Students were asked to use the concept of linear momentum to describe real-life applications, such as the seat belt and airbags in the car. After which, they were asked to share their thoughts and discuss them with the teacher.

Learning objective number five

Solve problems related to Newton's second law, which includes drawing the free body diagram, calculating the net force and acceleration. Students were trained to deal with Atwood's machine (see Figure 213 and Figure 214) and the inclined planes, including the superposition of forces.

The problems that were included in this learning objective had different levels of complexities. Thus, it fits the different academic levels of students.

Three pedagogical dimensions (P3) were used to implement this learning objective.

Firstly, direct teaching; the teacher offered students direct support to start solving the given problems. The following instructions and strategies were discussed and shared with students:

Problem-solving strategy - Newton's Second Law

I. Read the problem at least once

II. Draw a picture of the system
   a. Identify the object of primary interest
   b. Indicate forces with arrows

III. Label each force. Use labels that bring to mind the physical quantity involved

IV. Draw a free body diagram
   a. If additional objects are involved, draw separate free body diagrams for each object
   b. Choose a convenient coordinate system for each object

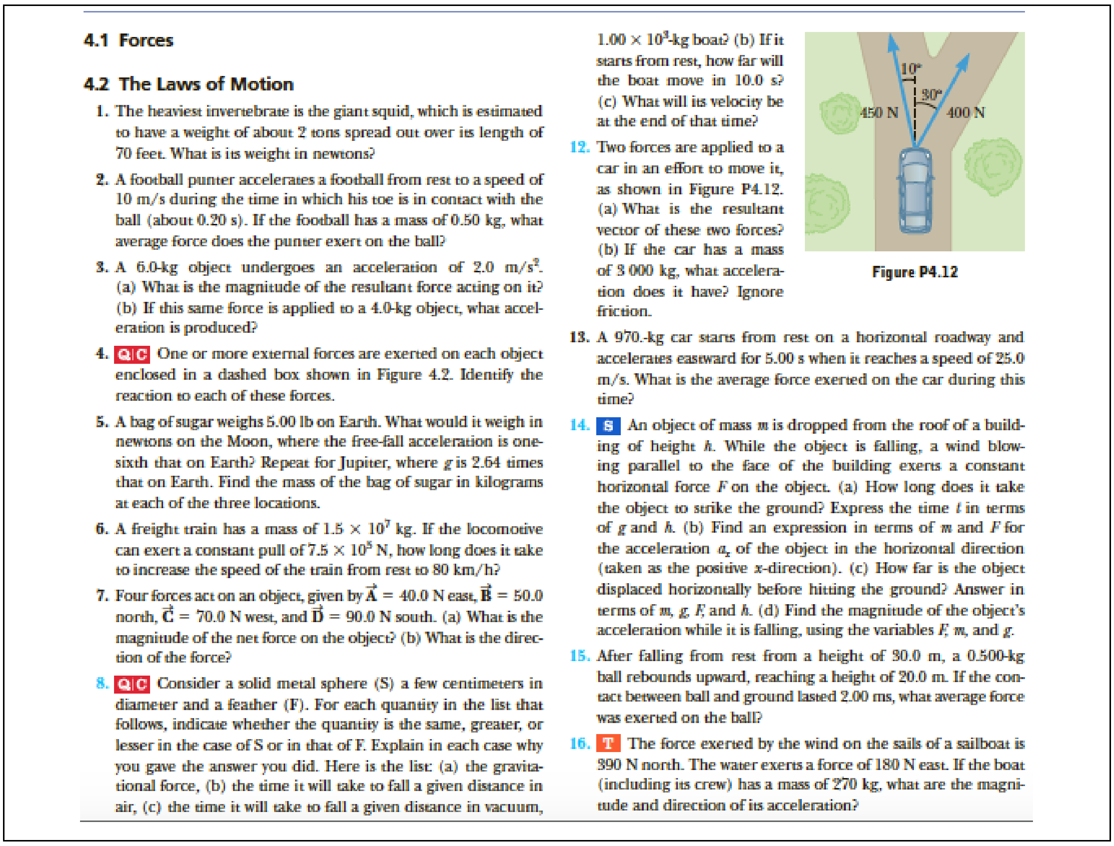
V. Apply Newton’s Second Law
VI. Solve for the unknown(s)

Secondly, collaborative learning; students were distributed to work in groups to finalise the tasks shown in Figure 219, Figure 220 and Figure 221. Each group of students consisted of high and low achievers, i.e., heterogeneous distribution. High achieving students were asked to support low achievers. Students’ responses were shared amongst themselves and discussed with the teacher.

Finally, cognitive learning, students used their previous knowledge, current knowledge, lecture notes and the hardcopy book to solve challenging tasks. Students were involved effectively in solving the problems.

Three kinds of the curriculum (C3) were used. Firstly, theoretical curriculum, which included selected problems from the textbook (College Physics Serway). The selected problems covered different levels of complexities. Secondly, interactive curriculum; related figures were included within the selected problems. Students were given a chance to see the hardcopy posters that were displayed in the previous learning objectives. Finally, practical curriculum, please see the conducted experiment in this lesson, verification of Newton's Second Law.

Figure 219, Figure 220 and Figure 221 show screenshots of the problems that were given to students to implement learning objective number five. The teacher discussed these problems inside the classroom with the students after they had their chance to solve them on their own (in groups). Afterwards, answer keys to these problems were shared with the students.



4.1 Forces

4.2 The Laws of Motion

1. The heaviest invertebrate is the giant squid, which is estimated to have a weight of about 2 tons spread out over its length of 70 feet. What is its weight in newtons?

2. A football punter accelerates a football from rest to a speed of 10 m/s during the time in which his toe is in contact with the ball (about 0.20 s). If the football has a mass of 0.50 kg, what average force does the punter exert on the ball?

3. A 6.0-kg object undergoes an acceleration of 2.0 m/s^2. (a) What is the magnitude of the resultant force acting on it? (b) If this same force is applied to a 4.0-kg object, what acceleration is produced?

4. Q|C One or more external forces are exerted on each object enclosed in a dashed box shown in Figure 4.2. Identify the reaction to each of these forces.

5. A bag of sugar weighs 5.00 lb on Earth. What would it weigh in newtons on the Moon, where the free-fall acceleration is one-sixth that on Earth? Repeat for Jupiter, where g is 2.64 times that on Earth. Find the mass of the bag of sugar in kilograms at each of the three locations.

6. A freight train has a mass of 1.5×10^7 kg. If the locomotive can exert a constant pull of 7.5×10^5 N, how long does it take to increase the speed of the train from rest to 80 km/h?

7. Four forces act on an object, given by $\vec{\mathbf{A}} = 40.0$ N east, $\vec{\mathbf{B}} = 50.0$ north, $\vec{\mathbf{C}} = 70.0$ N west, and $\vec{\mathbf{D}} = 90.0$ N south. (a) What is the magnitude of the net force on the object? (b) What is the direction of the force?

8. Q|C Consider a solid metal sphere (S) a few centimeters in diameter and a feather (F). For each quantity in the list that follows, indicate whether the quantity is the same, greater, or lesser in the case of S or in that of F. Explain in each case why you gave the answer you did. Here is the list: (a) the gravitational force, (b) the time it will take to fall a given distance in air, (c) the time it will take to fall a given distance in vacuum,

1.00×10^3-kg boat? (b) If it starts from rest, how far will the boat move in 10.0 s? (c) What will its velocity be at the end of that time?

12. Two forces are applied to a car in an effort to move it, as shown in Figure P4.12. (a) What is the resultant vector of these two forces? (b) If the car has a mass of 3 000 kg, what acceleration does it have? Ignore friction.

Figure P4.12

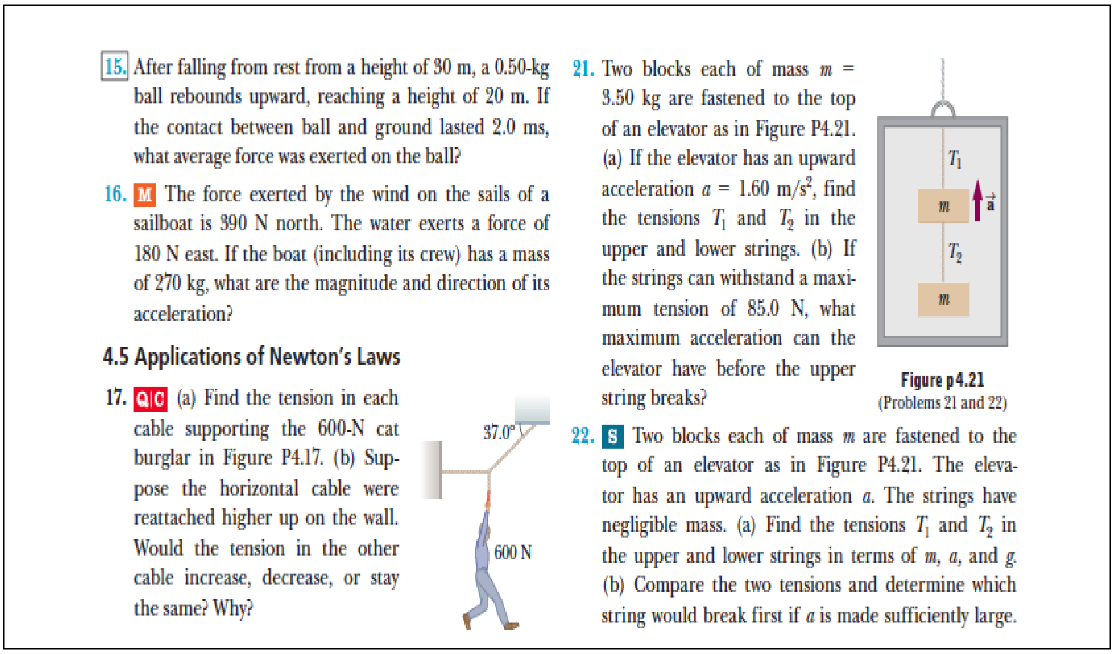
13. A 970.-kg car starts from rest on a horizontal roadway and accelerates eastward for 5.00 s when it reaches a speed of 25.0 m/s. What is the average force exerted on the car during this time?

14. S An object of mass m is dropped from the roof of a building of height h. While the object is falling, a wind blowing parallel to the face of the building exerts a constant horizontal force F on the object. (a) How long does it take the object to strike the ground? Express the time t in terms of g and h. (b) Find an expression in terms of m and F for the acceleration a_x of the object in the horizontal direction (taken as the positive x-direction). (c) How far is the object displaced horizontally before hitting the ground? Answer in terms of m, g, F, and h. (d) Find the magnitude of the object's acceleration while it is falling, using the variables F, m, and g.

15. After falling from rest from a height of 30.0 m, a 0.500-kg ball rebounds upward, reaching a height of 20.0 m. If the contact between ball and ground lasted 2.00 ms, what average force was exerted on the ball?

16. T The force exerted by the wind on the sails of a sailboat is 390 N north. The water exerts a force of 180 N east. If the boat (including its crew) has a mass of 270 kg, what are the magnitude and direction of its acceleration?

Figure 219. Screenshot of the problems that were given to students to implement learning objective five (Serway & Vuille, 2013, p. 118)



15. After falling from rest from a height of 30 m, a 0.50-kg ball rebounds upward, reaching a height of 20 m. If the contact between ball and ground lasted 2.0 ms, what average force was exerted on the ball?

16. M The force exerted by the wind on the sails of a sailboat is 390 N north. The water exerts a force of 180 N east. If the boat (including its crew) has a mass of 270 kg, what are the magnitude and direction of its acceleration?

4.5 Applications of Newton's Laws

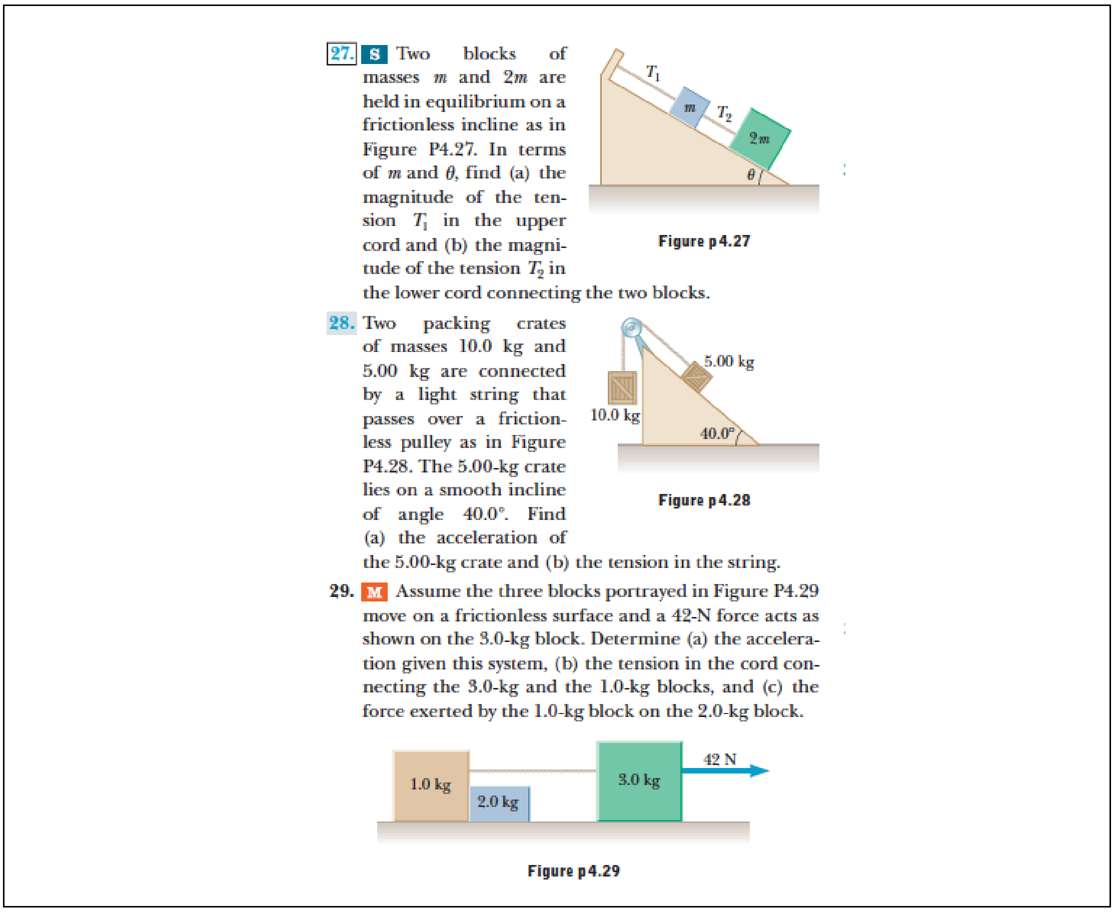
17. Q|C (a) Find the tension in each cable supporting the 600-N cat burglar in Figure P4.17. (b) Suppose the horizontal cable were reattached higher up on the wall. Would the tension in the other cable increase, decrease, or stay the same? Why?

21. Two blocks each of mass m = 3.50 kg are fastened to the top of an elevator as in Figure P4.21. (a) If the elevator has an upward acceleration a = 1.60 m/s^2, find the tensions T_1 and T_2 in the upper and lower strings. (b) If the strings can withstand a maximum tension of 85.0 N, what maximum acceleration can the elevator have before the upper string breaks?

Figure p4.21
(Problems 21 and 22)

22. S Two blocks each of mass m are fastened to the top of an elevator as in Figure P4.21. The elevator has an upward acceleration a. The strings have negligible mass. (a) Find the tensions T_1 and T_2 in the upper and lower strings in terms of m, a, and g. (b) Compare the two tensions and determine which string would break first if a is made sufficiently large.

Figure 220. Screenshot of the problems that were given to students to implement learning objective five (Serway & Vuille, 2013, p. 119)



27. S Two blocks of masses m and $2m$ are held in equilibrium on a frictionless incline as in Figure P4.27. In terms of m and θ, find (a) the magnitude of the tension T_1 in the upper cord and (b) the magnitude of the tension T_2 in the lower cord connecting the two blocks.

28. Two packing crates of masses 10.0 kg and 5.00 kg are connected by a light string that passes over a frictionless pulley as in Figure P4.28. The 5.00-kg crate lies on a smooth incline of angle 40.0°. Find (a) the acceleration of the 5.00-kg crate and (b) the tension in the string.

29. M Assume the three blocks portrayed in Figure P4.29 move on a frictionless surface and a 42-N force acts as shown on the 3.0-kg block. Determine (a) the acceleration given this system, (b) the tension in the cord connecting the 3.0-kg and the 1.0-kg blocks, and (c) the force exerted by the 1.0-kg block on the 2.0-kg block.

Figure 221. Screenshot of the problems that were given to students to implement learning objective five (Serway & Vuille, 2013, p. 120.)

The experiment conducted in this lesson: Verification of Newton's Second law

Note: Instructions with illustrations below were printed out and given to students together with all the materials required to conduct this experiment.

Introduction

Based on Newton’s first law, if the net force acting on an object is zero, then the object must have a constant velocity. However, when a nonzero net force acts on the object, it accelerates. In this experiment, students will verify Newton’s second law and check the relationship between the net force applied to an object and its acceleration. In this experiment, students need to use the equation of motion:

$$\Delta x = vit + \frac{1}{2}at^2$$

Δ x is the displacement (m)

v_i is the initial velocity (m/s).

t is the required time (s)

a is the acceleration (m/s^2)

In this experiment, the object started from rest, initial velocity (vi) = 0.

Hence, the acceleration, $a = \frac{2\Delta x}{t^2}$

Objectives

In this experiment, students need to:

1. Draw the free body diagram.
2. Collect the data related to force (gravitational forces), displacement, and time as a cart is accelerated on a table.
3. Use the equation of motion $a = \frac{2\Delta x}{t^2}$, to determine the acceleration of the cart, while travelling between two points on the table. See Figure 222.
4. Determine the relationship between the mass and acceleration.
5. Determine the relationship between the cart's acceleration and the net force applied to it.

Figure 222. Visual representation of the experiment

Materials

1. Cart with wheels has mass m1
2. Meter stick
3. Stopwatch
4. Sphere has mass m2
5. Pulley
6. Rope
7. Mass hanger

Procedures

Each group of students was provided with a cart (m1), the mass of this cart is 500 grams (0.5 kg), rope, and pulley to be fixed at the edge of the table, as shown in Figure 222 and Figure 223. The twine on the cart is passed over the pulley to a weight hanger. A mass of 0.050 kg is hung on the weight hanger. As soon as m2 is released, the cart (m1) starts moving until it is stopped by the blockade, which is 2.5 m from the cart's initial position. Students noted the distance travelled by the cart and the time was taken to travel 2.5 m, see Table 92. Thus, students could calculate the acceleration of the object using the formula $a = \frac{2\Delta x}{t^2}$. Students calculated the values of m2g and ((m1+m2) a). These values were found to be equal to each other. Hence, Newton's second law is verified. Please see the equations below.

Mass of the cart, m1 (kg)	The vertical mass m2 in (kg)	Distance travelled (Δx) in (m)	Time (s)	Acceleration of the object $a = \frac{2\Delta x}{t^2}$	m2g (N)	(m1+m2)*a (N)
0.5	0.05	2.5	2.36	0.89	0.49	0.49

Table 92. Verification of Newton's second law

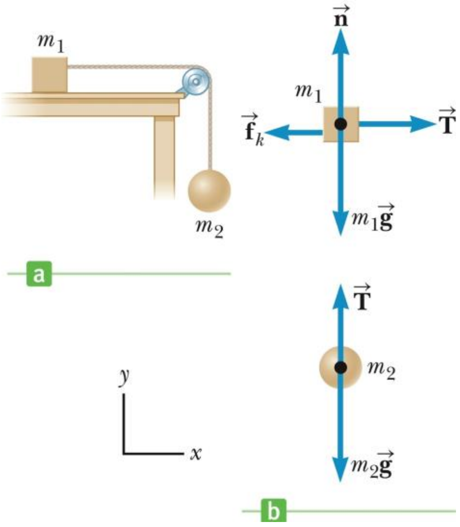


Figure 223. The free body diagram of m1 and m2. T is the tension force, *fk* is the friction force. m1g and m2g are the gravitational forces (Serway & Vuille, 2013, p. 112)

The surface of the table used in this experiment was smooth. Therefore, the friction force (f_k) could be ignored.

According to the free body diagram, which is shown in Figure 223:

$$T = m1a$$

$$m2g - T = m2a$$

By adding these two equations:

$$m2g = (m1+m2)\ a$$

Hence,

$$a = \frac{m2g}{(m1 + m2)}$$

The final equation allowed students to calculate the value of acceleration for the system shown in Figure 222 and Figure 223. Substituting the value of acceleration in any of the above equations allowed students to calculate the tension force. Moreover, the value of (m1g) gave students the possibility to calculate the normal force as $m1g = n$, see Figure 223.

EXAMPLE TWO: BIOLOGY – C3, P3, T4 AND C3, P3, T0

This example shows two biology lessons (two different contents) that were implemented in this study. The first lesson, Photosynthesis, was delivered using digital technology-based learning (C3, P3, T4). The second lesson, Respiration, was delivered without using digital technology, nondigital technology-based learning (C3, P3, T0). The timeline for implementing each lesson was three weeks (three teaching hours a week). Students were examined in week number four. The purpose of this example is to allow the reader to:

i. Know how lessons were constructed and implemented.
ii. Know how learning objectives were integrated with digital technology.
iii. Know how learning objectives were implemented without digital technology.
iv. To see how different pedagogies and kinds of the curriculum were applied to the teaching-learning process.
v. Compare the level of complexities between these two lessons by comparing the learning objectives for each lesson and comparing the assessments conducted after the teaching-learning process.

To measure the impact of digital technology on students' attainment, students were examined after completing each lesson (the conducted exams are shown in this example). To ensure as identical as possible level of complexities, the conducted exams in both cases were constructed according to Bloom's taxonomy.

Two different approaches were discussed and shared with the involved teachers to review the content's cognitive complexity, Florida's original depth of knowledge (DOK) Levels and Webb's four-level DOK, refer to section 3.17.5. It was agreed with the involved teachers to use these approaches to judge the content complexity and ensure that either content delivered, through digital technology or without, have the same level of complexity.

Table 93 shows a summary of the learning objectives of the two biology lessons:

Learning objective	**Depth of Knowledge (DOK)**	**Photosynthesis**	**Cellular Respiration**
Learning objective number one	Level 1: Recall / low cognitive complexity.	Explain where plants get the energy they need to produce food.	Explain where organisms get the energy they need for life processes.
Learning objective number two	Level 1: Recall / low cognitive complexity.	Define the photosynthesis process.	Define the cellular respiration process.
Learning objective number three	Level 2: Basic application of skills and concepts / moderate cognitive complexity.	Explain the relationship between light, pigments and photosynthesis.	Explain the relationship between photosynthesis and cellular respiration.
Learning objective number four	Level 3: Strategic thinking and complex reasoning / high cognitive complexity.	Describe the role of electron carrier molecules in photosynthesis.	Describe what happens during glycolysis.
Learning objective number five	Level 3: Strategic thinking and complex reasoning / high cognitive complexity.	Describe how high-energy electrons are used by the electron transport chain.	Describe what happens during the Krebs cycle.

Table 93. Summary of the learning objectives of the included lessons

The First Lesson: Photosynthesis (C3 P3 T4)

This lesson was implemented using the C3, P3, T4 strategy. The content of the curriculum was delivered using the three approaches (C3): theoretical, practical and interactive, represented by the iBooks, simulation and physical interactive tools. Eighty per cent of the content were integrated with digital technology (T4, i.e., four out of five learning objectives were integrated with digital technology which is equivalent to 80% of the content); students used a range of digital technology tools (software and hardware) to implement learning, such as iPads and laptops, resources and links were shared with students via learning management system (LMS) and email. Following is a detailed description of each learning objective.

Three pedagogical dimensions (P3) were used to deliver the content; direct teaching, collaborative (social) learning and constructive learning. Students were asked to employ their current knowledge as well as the shared links and resources to build new knowledge they did not possess before and to draw conclusions.

Learning objective number one

Explain where plants get the energy they need to produce food.

Table 94 shows the pedagogical dimensions that were used to implement this learning objective

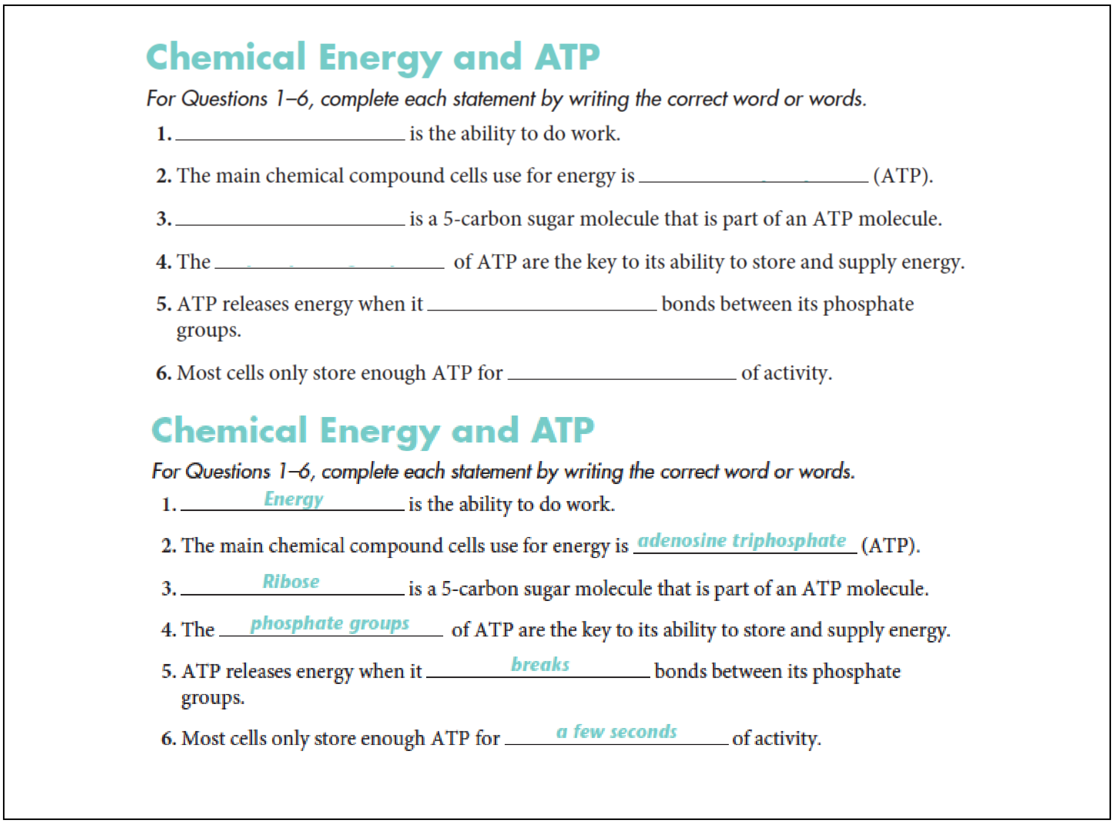
Note: the implementation of this learning objective was not supported by digital technology (nondigital technology-based learning) since four out of five learning objectives only were integrated with digital technology.

The pedagogical dimension	**Procedures**
Direct teaching	The teacher discussed the following points with students (summary of the content): I. Energy is the ability to do work. II. Organisms need energy to stay alive. III. Adenosine triphosphate (ATP) is chemical compound cells use to store and release energy. a. An ATP molecule consists of adenine, the sugar ribose, and three phosphate groups. b. Cells store energy by adding a phosphate group to adenosine diphosphate (ADP) molecules. c. Cells release energy from ATP molecules by subtracting a phosphate group. IV. The energy provided by ATP is used in active transport, to contract muscles, to make proteins, and in many other ways. V. Cells contain only a small amount of ATP at any one time. They regenerate it from ADP as they need it, using energy stored in food. VI. The energy to make ATP from ADP comes from food. Organisms get food in one of the following ways: a. Heterotrophs get food by consuming (eating) other organisms. b. Autotrophs use the energy in sunlight to make their own food. c. Photosynthesis is the process that uses light energy to produce food molecules.

Collaborative learning	Students were divided into groups, each of which five students. Students were asked to define (in their own words) Heterotrophs, Autotrophs, ATP and ADP. Students were asked to share their own definitions with their peers and teacher. Students were asked to work together to complete the task, which is shown in Figure 224. Afterwards, the teacher discussed this task with students; the answer key was shared with the students later on, see Figure 224.
Constructive learning	Students were asked to use the lecture notes, and the textbook to work together to complete task 2 (see Figure 225) that required higher thinking skills, such as the critical thinking and reasoning Answer key was shared with students later on, see Figure 225.

Table 94. Pedagogical dimensions used to implement learning objective number one.

Note: All the figures that are taken from Miller and Levine Biology, 2010, Study Workbook A, are reproduced with the permission of the publisher © 2010 by Savvas Learning Company LLC, or its affiliates.



Chemical Energy and ATP

For Questions 1–6, complete each statement by writing the correct word or words.

1. ____________ is the ability to do work.

2. The main chemical compound cells use for energy is ____________ (ATP).

3. ____________ is a 5-carbon sugar molecule that is part of an ATP molecule.

4. The ____________ of ATP are the key to its ability to store and supply energy.

5. ATP releases energy when it ____________ bonds between its phosphate groups.

6. Most cells only store enough ATP for ____________ of activity.

Chemical Energy and ATP

For Questions 1–6, complete each statement by writing the correct word or words.

1. ___Energy___ is the ability to do work.

2. The main chemical compound cells use for energy is ___adenosine triphosphate___ (ATP).

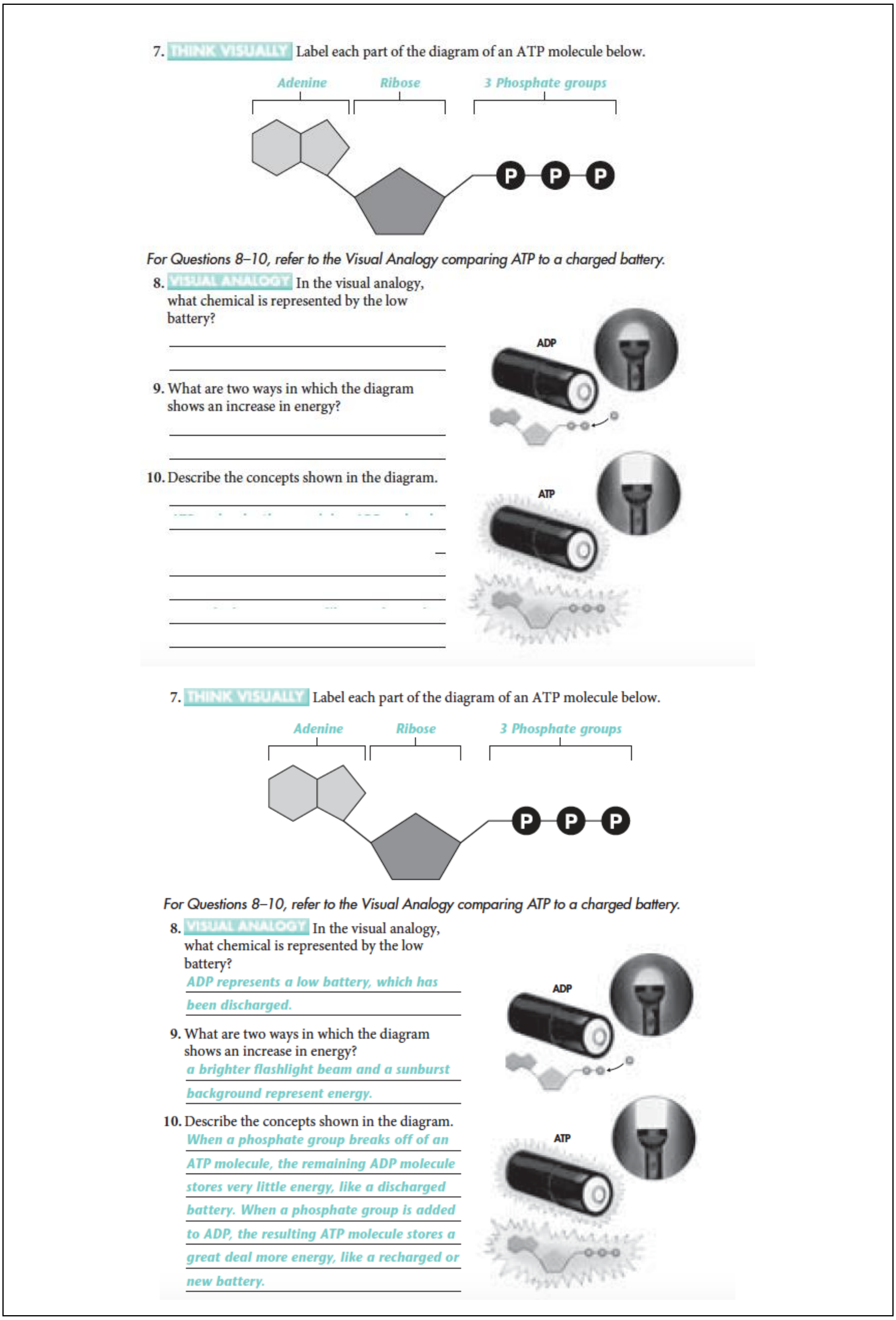
3. ___Ribose___ is a 5-carbon sugar molecule that is part of an ATP molecule.

4. The ___phosphate groups___ of ATP are the key to its ability to store and supply energy.

5. ATP releases energy when it ___breaks___ bonds between its phosphate groups.

6. Most cells only store enough ATP for ___a few seconds___ of activity.

Figure 224. Task 1-chemical energy and ATP (Miller & Levine, 2012, p. 116)



7. **THINK VISUALLY** Label each part of the diagram of an ATP molecule below.

Adenine *Ribose* *3 Phosphate groups*

For Questions 8–10, refer to the Visual Analogy comparing ATP to a charged battery.

8. **VISUAL ANALOGY** In the visual analogy, what chemical is represented by the low battery?

9. What are two ways in which the diagram shows an increase in energy?

10. Describe the concepts shown in the diagram.

7. **THINK VISUALLY** Label each part of the diagram of an ATP molecule below.

Adenine *Ribose* *3 Phosphate groups*

For Questions 8–10, refer to the Visual Analogy comparing ATP to a charged battery.

8. **VISUAL ANALOGY** In the visual analogy, what chemical is represented by the low battery?
ADP represents a low battery, which has been discharged.

9. What are two ways in which the diagram shows an increase in energy?
a brighter flashlight beam and a sunburst background represent energy.

10. Describe the concepts shown in the diagram.
When a phosphate group breaks off of an ATP molecule, the remaining ADP molecule stores very little energy, like a discharged battery. When a phosphate group is added to ADP, the resulting ATP molecule stores a great deal more energy, like a recharged or new battery.

Figure 225. Task 2-chemical energy and ATP (Miller & Levine, 2012, p. 117)

Table 95 shows the kinds of curriculum that were used to implement learning objective one.

Curriculum	Procedures
Theoretical curriculum	The textbook was used (paper-based); lecture notes were written on the board and copied by students to their notebooks, see the covered points during the direct teaching in this learning objective, Table 94.
Interactive curriculum	A diagram of an ATP molecule (paper-based) and charged battery were displayed. This content was displayed in the form of task. See Figure 225.
Practical curriculum	Students were asked to build a scheme of energy and ATP molecule (using papers, colouring tools and glue), and rephrase the significance of Adenosine triphosphate (ATP) (in their own words).

Table 95. Curriculum types used to implement learning objective number one.

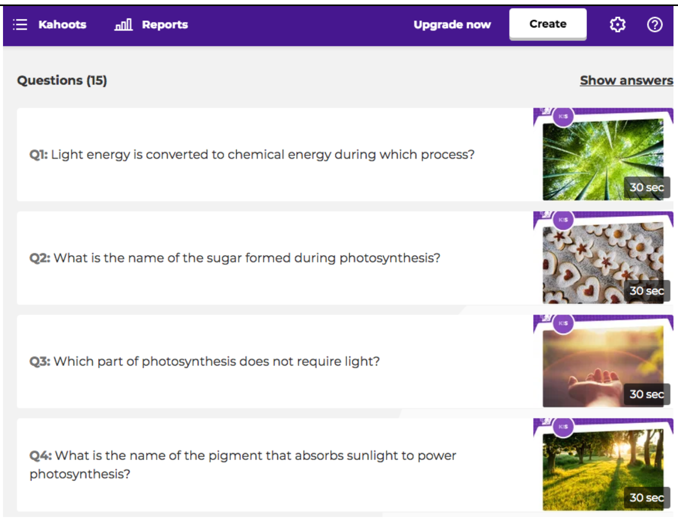
Learning objective number two

Define the photosynthesis process (light-dependent and independent reactions).

Table 96 shows the pedagogical dimensions (supported by digital technology) that were used to implement this learning objective.

The pedagogical dimension supported by digital technology	Procedures
Direct teaching	The teacher offered a description of the process of photosynthesis (light-dependent and independent reactions). The following points were discussed to cover this learning objective, a summary of the content: Photosynthesis usually is summarised by a simple chemical reaction. Photosynthesis is a complex process that involves two interdependent sets of reactions: a. The light-dependent reactions require light, light-absorbing pigments, and water to form NADPH, ATP, and oxygen. b. The light-independent reactions do not use light energy. They use carbon dioxide from the atmosphere, NADPH, and ATP to make energy-rich carbon compounds.
Collaborative learning	Students were divided into groups, each of which five students. Students were asked to rephrase the definition of the photosynthesis process in their own words. Students shared their thoughts about the photosynthesis with their peers and teacher. Students were asked to work together to complete the task, shown in Figure 227.
Constructive learning	The teacher created an online formative assessment about photosynthesis. Students were requested to do the quiz, see Figure 226. Students were asked to use the lecture notes and the iBook to describe the reactants and products of light-dependent and light-independent reactions. Figure 227 assisted the students in completing this task. Students were asked to work together to complete the task, shown in Figure 228. This task required higher-order thinking skills, such as critical thinking, reasoning and synthesis as students were asked to compare the solar power to the light-dependent reactions of photosynthesis. Students were allowed to do online research to assist them in completing this task. The answer key was shared with students after they completed the task.

Table 96. Pedagogical dimensions, supported by digital technology, used to implement learning objective number two



Questions (15)

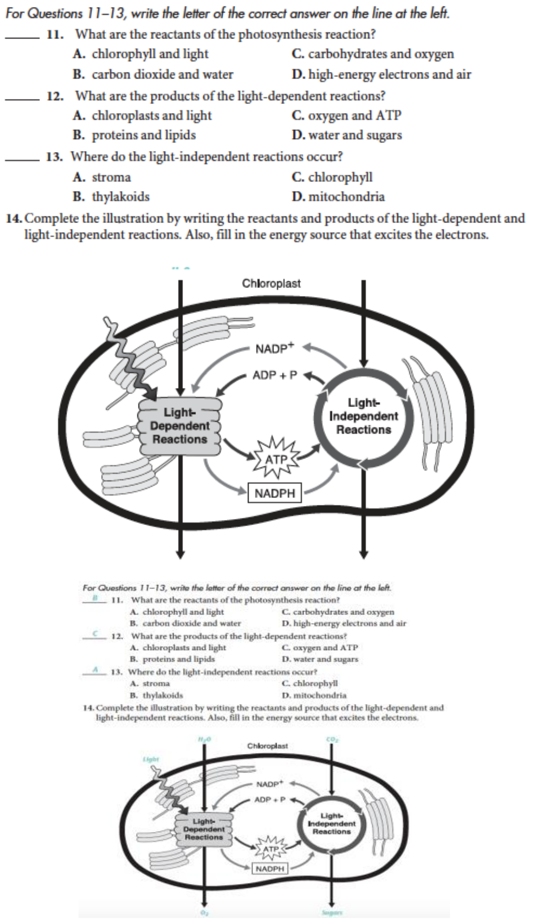
Q1: Light energy is converted to chemical energy during which process?

Q2: What is the name of the sugar formed during photosynthesis?

Q3: Which part of photosynthesis does not require light?

Q4: What is the name of the pigment that absorbs sunlight to power photosynthesis?

Figure 226. Online quiz created using Kahoot.com (https://create.kahoot.it/details/biology-photosynthesis/0dc0c773-4ee9-4ea4-95cd-ebd921f15c59)



For Questions 11–13, write the letter of the correct answer on the line at the left.

_____ **11.** What are the reactants of the photosynthesis reaction?
A. chlorophyll and light **C.** carbohydrates and oxygen
B. carbon dioxide and water **D.** high-energy electrons and air

_____ **12.** What are the products of the light-dependent reactions?
A. chloroplasts and light **C.** oxygen and ATP
B. proteins and lipids **D.** water and sugars

_____ **13.** Where do the light-independent reactions occur?
A. stroma **C.** chlorophyll
B. thylakoids **D.** mitochondria

14. Complete the illustration by writing the reactants and products of the light-dependent and light-independent reactions. Also, fill in the energy source that excites the electrons.

For Questions 11–13, write the letter of the correct answer on the line at the left.

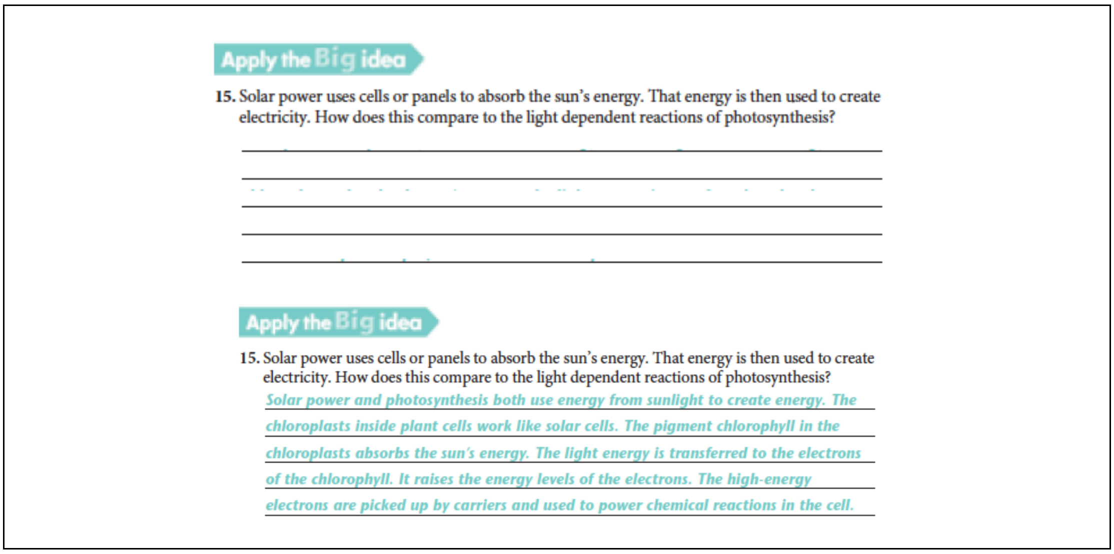
__B__ **11.** What are the reactants of the photosynthesis reaction?
A. chlorophyll and light **C.** carbohydrates and oxygen
B. carbon dioxide and water **D.** high-energy electrons and air

__C__ **12.** What are the products of the light-dependent reactions?
A. chloroplasts and light **C.** oxygen and ATP
B. proteins and lipids **D.** water and sugars

__A__ **13.** Where do the light-independent reactions occur?
A. stroma **C.** chlorophyll
B. thylakoids **D.** mitochondria

14. Complete the illustration by writing the reactants and products of the light-dependent and light-independent reactions. Also, fill in the energy source that excites the electrons.

Figure 227. Task 1-photosynthesis (Miller & Levine, 2012, p. 121)



Apply the Big idea

15. Solar power uses cells or panels to absorb the sun's energy. That energy is then used to create electricity. How does this compare to the light dependent reactions of photosynthesis?

Apply the Big idea

15. Solar power uses cells or panels to absorb the sun's energy. That energy is then used to create electricity. How does this compare to the light dependent reactions of photosynthesis?

Solar power and photosynthesis both use energy from sunlight to create energy. The chloroplasts inside plant cells work like solar cells. The pigment chlorophyll in the chloroplasts absorbs the sun's energy. The light energy is transferred to the electrons of the chlorophyll. It raises the energy levels of the electrons. The high-energy electrons are picked up by carriers and used to power chemical reactions in the cell.

Figure 228. Task 2-photosynthesis (Miller & Levine, 2012, p. 121)

Table 97 shows the kinds of the curriculum (supported by digital technology) that were used to implement learning objective number two.

Curriculum supported by digital technology	**Procedures**
Theoretical curriculum	The iBook was used; lecture notes were displayed using PowerPoint presentation, see the covered points during direct teaching.
Interactive curriculum (Physical tools)	The following link, video related to photosynthesis (light-dependent and independent reactions), was shared with students. https://www.youtube.com/watch?v=DlZh_Gzb7tI (see Figure 229) Students were asked to describe the input and output components of the photosynthesis process. Students were asked to look for new knowledge in the shared link and share it with their peers and the teacher.
Practical curriculum	An experiment about the process of photosynthesis was conducted during this lesson. The detailed description is found at the end of the lesson description.

Table 97. Kinds of curriculum used to implement learning objective number two

Figure 229. The process of photosynthesis (light-dependent and light-independent reactions). https://www.youtube.com/watch?v=DlZh_Gzb7tI

Learning objective number three

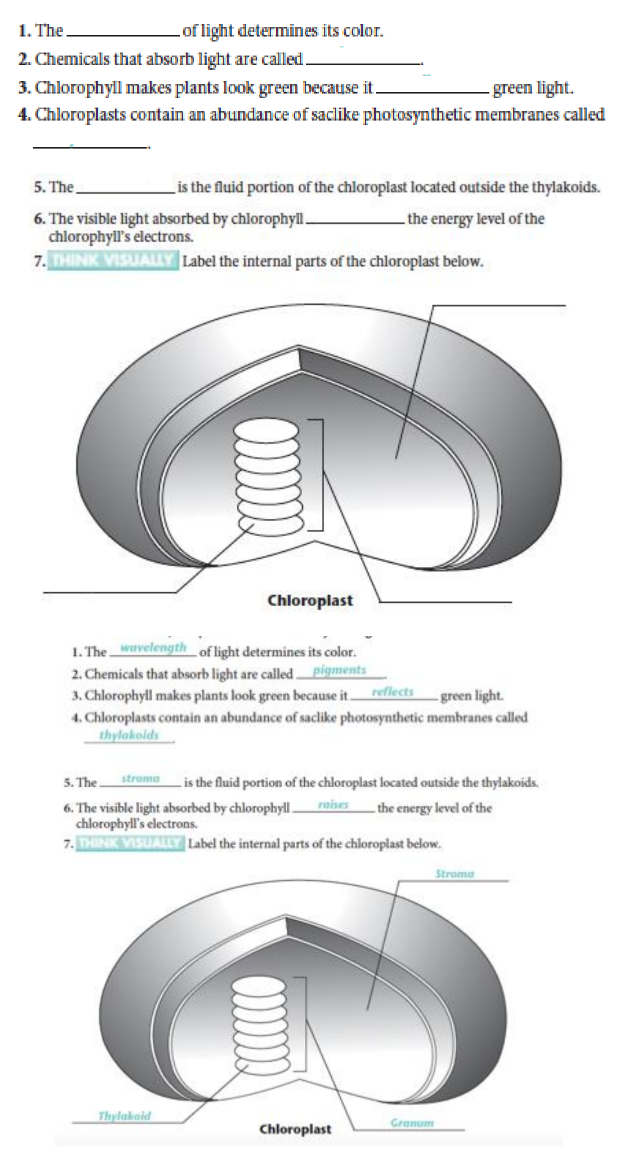
Explain the relationship between light, pigments and photosynthesis.

Table 98 shows the pedagogical dimensions (supported by digital technology) that were used to implement this learning objective.

The pedagogical dimension supported by digital technology	Procedures
Direct teaching	The teacher explained and discussed with students the following points (summary of the displayed content): I. Chlorophyll and Chloroplasts: In eukaryotes, photosynthesis occurs in organelles called chloroplasts. Chloroplasts house light-absorbing chemicals. II. Light is a form of energy. Sunlight is a mixture of all the different colours of visible light. III. Light-absorbing molecules, called pigments, capture the sun's energy. IV. Chlorophyll is the principal pigment in photosynthetic organisms. V. Chlorophyll absorbs blue-violet and red light but reflects green light.
Collaborative learning	Students were divided into groups of five. Students in each group were asked to define in their own words the Chlorophyll and Chloroplasts. Also, to share these definitions. These definitions were discussed with the teacher. Students were asked to work together to complete the task shown in Figure 230. The answer key was shared with students later on.

Constructive learning	Using the iBook and an external online link (see Figure 231), students were asked to construct new knowledge about the complex internal structure of the Chloroplasts, which includes: a. Thylakoids: saclike photosynthetic membranes that contain chlorophyll and other pigments and are arranged in stacks called grana. b. Stroma: the fluid portion outside of the thylakoids The shared link: https://www.youtube.com/watch?v=eOPEn2qYff4&t=107s see (Figure 231).

Table 98. Pedagogical dimensions, supported by digital technology, used to implement learning objective number three



1. The ______ of light determines its color.
2. Chemicals that absorb light are called ______.
3. Chlorophyll makes plants look green because it ______ green light.
4. Chloroplasts contain an abundance of saclike photosynthetic membranes called ______.
5. The ______ is the fluid portion of the chloroplast located outside the thylakoids.
6. The visible light absorbed by chlorophyll ______ the energy level of the chlorophyll's electrons.
7. THINK VISUALLY Label the internal parts of the chloroplast below.

1. The wavelength of light determines its color.
2. Chemicals that absorb light are called pigments.
3. Chlorophyll makes plants look green because it reflects green light.
4. Chloroplasts contain an abundance of saclike photosynthetic membranes called thylakoids
5. The stroma is the fluid portion of the chloroplast located outside the thylakoids.
6. The visible light absorbed by chlorophyll raises the energy level of the chlorophyll's electrons.
7. THINK VISUALLY Label the internal parts of the chloroplast below.

Figure 230. Task 1-Chlorophyll and Chloroplasts (Miller & Levine, 2012, p. 120)

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However, it can be viewed via the link shown in the caption below.

Figure 231. The complex internal structure of the Chloroplasts https://www.youtube.com/watch?v=eOPEn2qYff4&t=107s

Table 99 shows the kinds of curriculum that were used to implement learning objective number three.

Curriculum supported by digital technology	**Procedures**
Theoretical curriculum	Both teacher and students used the textbook (iBook); lecture notes were displayed using PowerPoint presentation, see the covered points during direct teaching.
Interactive curriculum (Physical tools)	The following link, which shows the role of light and pigments in photosynthesis, was shared with students. https://www.youtube.com/watch?v=_KcLV4v6i04 (see Figure 232 and Figure 233). The following link shows a virtual lab related to photosynthesis was shared with students https://www.newpathonline.com/free-curriculum-resources/virtual_lab/The_Effects_of_Carbon_Dioxide_and_Light_on_Photosynthesis/8/8,9,10,11,12,13,14/1880 (see Figure 234). Students were asked to look for new knowledge in these links and share it with each other and discuss it with the teacher.
Practical curriculum	The teacher conducted an experiment to demonstrate that light is necessary for photosynthesis. The following link was shared with students to assist them in understanding the experiment. https://www.youtube.com/watch?v=j6Le0S52wt0&t=106s (See Figure 235).

Table 99. Kinds of curriculum used to implement learning objective number three

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Figure 232. Chlorophyll and Chloroplasts
https://www.youtube.com/watch?v=_KcLV4v6i04

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Copyright restrictions.

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Figure 233. Chlorophyll and Chloroplasts https://www.youtube.com/watch?v=_KcLV4v6i04

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Copyright restrictions.

However, it can be viewed via the link shown in the caption below.

Figure 234. Virtual lab related to photosynthesis, the effect of light on photosynthesis https://www.newpathonline.com/free-curriculum-resources/virtual_lab/The_Effects_of_Carbon_Dioxide_and_Light_on_Photosynthesis/8/8,9,10,11,12,13,14/1880

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Copyright restrictions.

However, it can be viewed via the link shown in the caption below.

Figure 235. Video demonstrates the significance of light for photosynthesis including Chlorophyll and Chloroplasts https://www.youtube.com/watch?v=j6Le0S52wt0&t=106s

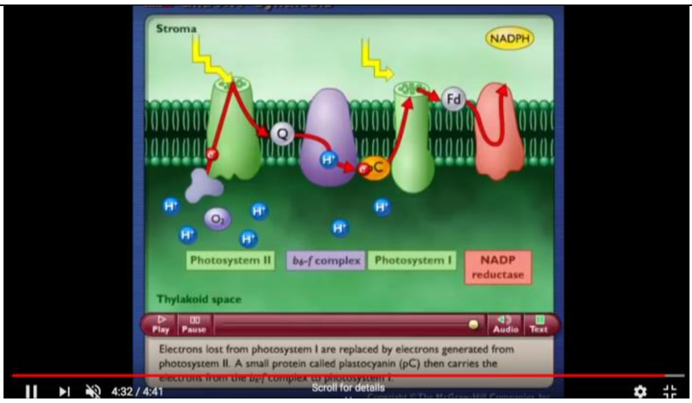
Learning objective four

Describe the role of electron carrier molecules in photosynthesis.

Table 100 shows the pedagogical dimensions (supported by digital technology) that were used to implement learning objective number four.

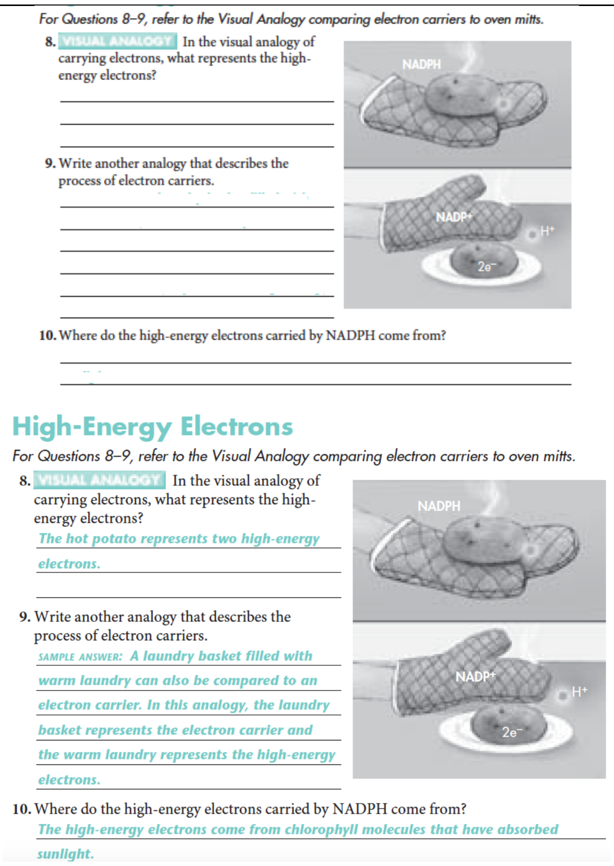
The pedagogical dimension *supported by technology*	**Procedures**
Direct teaching	The teacher discussed with students the following points, summary of the content: High-Energy Electrons: I. The energy in light raises some of the electrons in chlorophyll to higher energy levels. These high-energy electrons are used in photosynthesis. II. Electron carriers are used to transport the electrons from chlorophyll to other molecules during photosynthesis. III. $NADP^+$ is a compound that can accept and hold two high-energy electrons and one hydrogen ion. This process converts $NADP^+$ into NADPH.
Collaborative learning	Students were divided into groups of five. Each group was asked to look for new knowledge related to the electron transport chain using the following link. https://www.youtube.com/watch?v=k17bJQSQeQ4 (See Figure 236). Students were asked to work together to complete the task, which is shown in Figure 237. Students supported each other while completing this task. The answer key was shared with the students later on.
Constructive learning	Using the iBook and external online links (Figure 238 and Figure 239). Students were asked to construct their knowledge regarding the mechanism of Photosynthetic Electron Transport. The following links were shared with students: https://www.youtube.com/watch?v=_hUxKPSNTl0 see Figure 238 https://www.youtube.com/watch?v=mfgCcFXUZRk see Figure 239. Students were asked to share their collected notes from the above links about the mechanism of Photosynthetic Electron Transport with each other and discuss it with the teacher.

Table 100. Pedagogical dimensions used to implement learning objective number four



Electrons lost from photosystem I are replaced by electrons generated from photosystem II. A small protein called plastocyanin (pC) then carries the electrons from the b₆-f complex to photosystem I.

Figure 236. Photosynthesis and electron transport https://www.youtube.com/watch?v=k17bJQSQeQ4



For Questions 8–9, refer to the Visual Analogy comparing electron carriers to oven mitts.

8. VISUAL ANALOGY In the visual analogy of carrying electrons, what represents the high-energy electrons?

9. Write another analogy that describes the process of electron carriers.

10. Where do the high-energy electrons carried by NADPH come from?

High-Energy Electrons

For Questions 8–9, refer to the Visual Analogy comparing electron carriers to oven mitts.

8. VISUAL ANALOGY In the visual analogy of carrying electrons, what represents the high-energy electrons?
The hot potato represents two high-energy electrons.

9. Write another analogy that describes the process of electron carriers.
SAMPLE ANSWER: *A laundry basket filled with warm laundry can also be compared to an electron carrier. In this analogy, the laundry basket represents the electron carrier and the warm laundry represents the high-energy electrons.*

10. Where do the high-energy electrons carried by NADPH come from?
The high-energy electrons come from chlorophyll molecules that have absorbed sunlight.

Figure 237. Task 1-High-energy electrons (Miller & Levine, 2012, p. 120)

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However, it can be viewed via the link shown in the caption below.

Figure 238. The mechanism of Photosynthetic Electron Transport https://www.youtube.com/watch?v=_hUxKPSNTl0

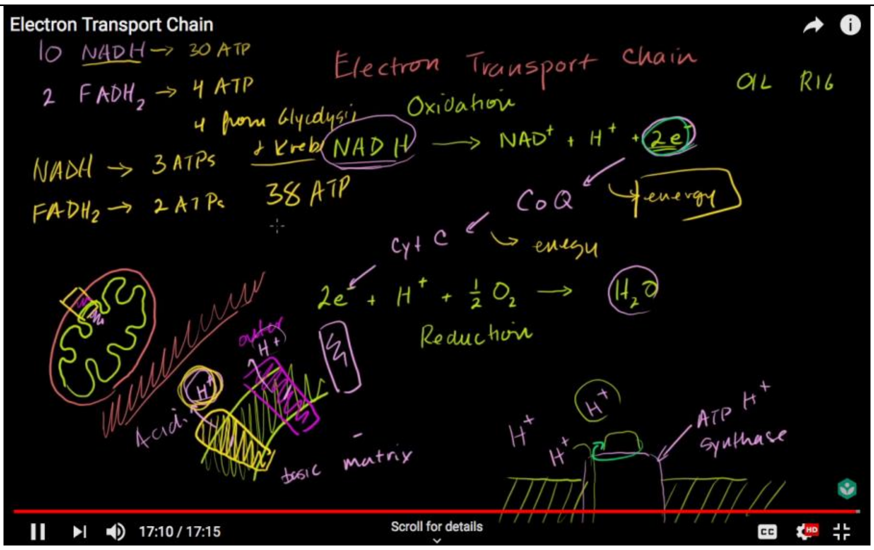
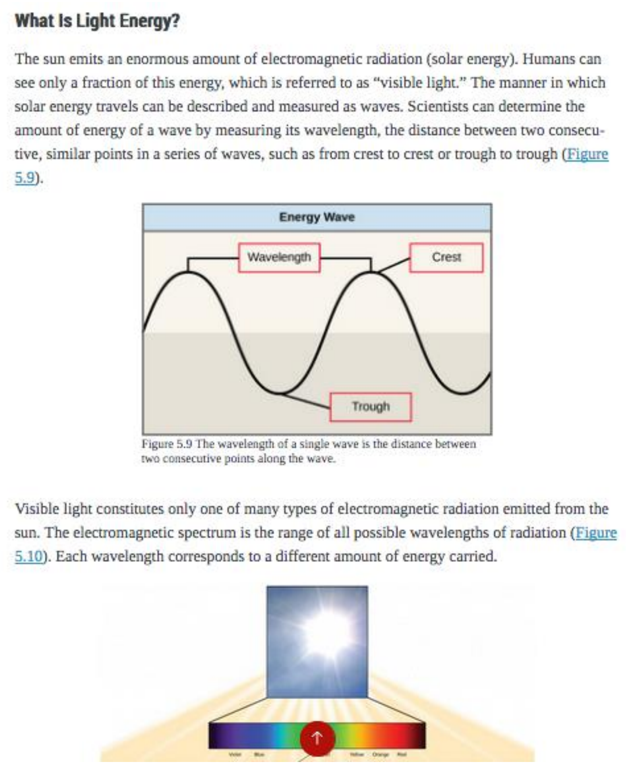


Figure 239. The mechanism of Photosynthetic Electron Transport ©KhanAcademy, CC-by NC-SA-3.0 US https://www.youtube.com/watch?v=mfgCcFXUZRk

Table 101 shows the kinds of the curriculum, supported by digital technology, that were used to implement learning objective number four.

Curriculum *supported by technology*	**Procedures**
Theoretical curriculum	The textbook (iBook) was used; lecture notes were displayed using PowerPoint presentation. The following link was shared with the students: https://opentextbc.ca/biology/chapter/5-2-the-light-dependent-reactions-of-photosynthesis/ See Figure 240 and Figure 241. Students were asked to describe in their own words the electron transport chain, the process of generating an energy carrier (ATP) and energy wave. Students were asked to share their new knowledge.
Interactive curriculum (Physical tools)	The following link was shared with students. https://www.youtube.com/watch?v=G3Y2Ig3YTL0, see Figure 242. Using the shared link, students were asked to describe the role of electron carrier molecules in photosynthesis.
Practical curriculum	The teacher conducted an experiment related to Photosynthesis. The experiment's title Floating Leaf Disks Lab. The following link was shared with students to assist them in understanding and implementing the experiment. The procedures for this experiment are shown in the link. https://www.youtube.com/watch?v=4NM7kGKDk2A see Figure 243.

Table 101. Kinds of curriculum used to implement learning objective number four



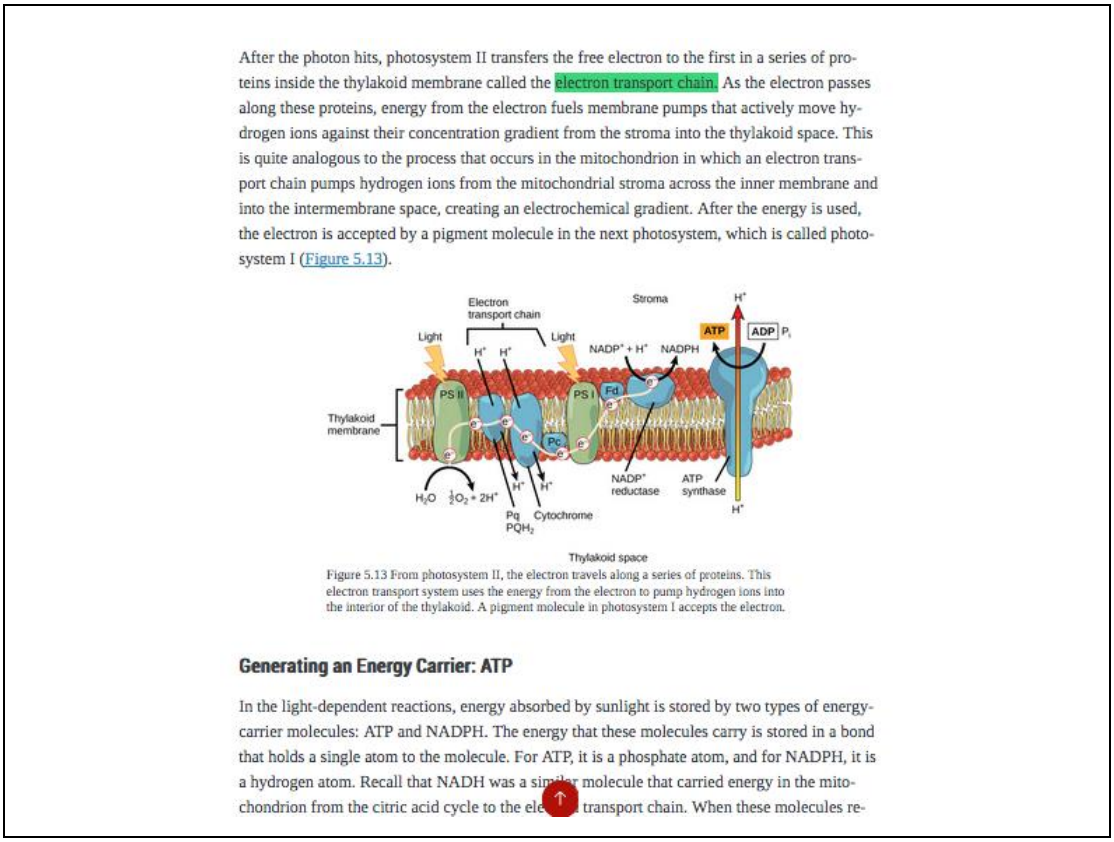
What Is Light Energy?

The sun emits an enormous amount of electromagnetic radiation (solar energy). Humans can see only a fraction of this energy, which is referred to as "visible light." The manner in which solar energy travels can be described and measured as waves. Scientists can determine the amount of energy of a wave by measuring its wavelength, the distance between two consecutive, similar points in a series of waves, such as from crest to crest or trough to trough (Figure 5.9).

Figure 5.9 The wavelength of a single wave is the distance between two consecutive points along the wave.

Visible light constitutes only one of many types of electromagnetic radiation emitted from the sun. The electromagnetic spectrum is the range of all possible wavelengths of radiation (Figure 5.10). Each wavelength corresponds to a different amount of energy carried.

Figure 240. External resource demonstrates light energy ©OpenStaxCollege CC by 4.0 https://opentextbc.ca/biology/chapter/5-2-the-light-dependent-reactions-of-photosynthesis/



After the photon hits, photosystem II transfers the free electron to the first in a series of proteins inside the thylakoid membrane called the electron transport chain. As the electron passes along these proteins, energy from the electron fuels membrane pumps that actively move hydrogen ions against their concentration gradient from the stroma into the thylakoid space. This is quite analogous to the process that occurs in the mitochondrion in which an electron transport chain pumps hydrogen ions from the mitochondrial stroma across the inner membrane and into the intermembrane space, creating an electrochemical gradient. After the energy is used, the electron is accepted by a pigment molecule in the next photosystem, which is called photosystem I (Figure 5.13).

Figure 5.13 From photosystem II, the electron travels along a series of proteins. This electron transport system uses the energy from the electron to pump hydrogen ions into the interior of the thylakoid. A pigment molecule in photosystem I accepts the electron.

Generating an Energy Carrier: ATP

In the light-dependent reactions, energy absorbed by sunlight is stored by two types of energy-carrier molecules: ATP and NADPH. The energy that these molecules carry is stored in a bond that holds a single atom to the molecule. For ATP, it is a phosphate atom, and for NADPH, it is a hydrogen atom. Recall that NADH was a similar molecule that carried energy in the mitochondrion from the citric acid cycle to the ele transport chain. When these molecules re-

Figure 241. External resource demonstrates the electron transport chain ©OpenStaxCollege CC by 4.0 https://opentextbc.ca/biology/chapter/5-2-the-light-dependent-reactions-of-photosynthesis/

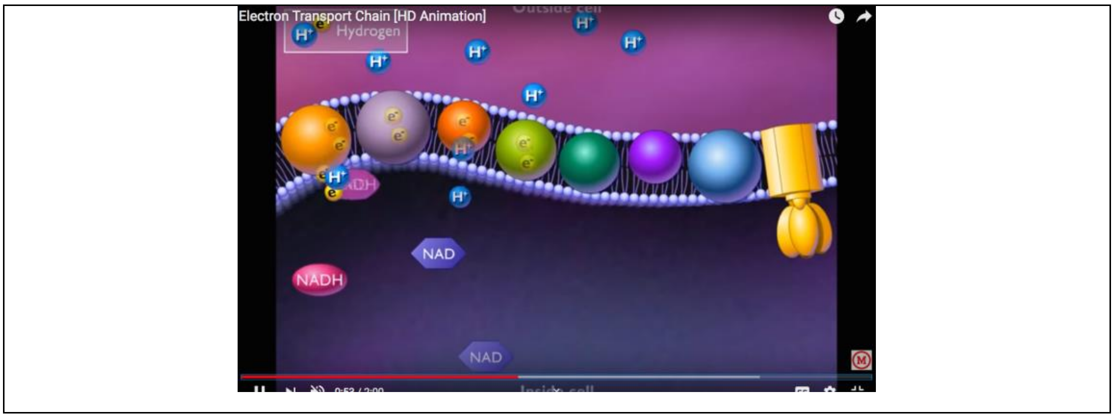


Figure 242. Electron transport chain process https://www.youtube.com/watch?v=G3Y2Ig3YTL0

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Figure 243. Online video demonstrates the floating Leaf Disks Laboratory https://www.youtube.com/watch?v=4NM7kGKDk2A

Learning objective number five

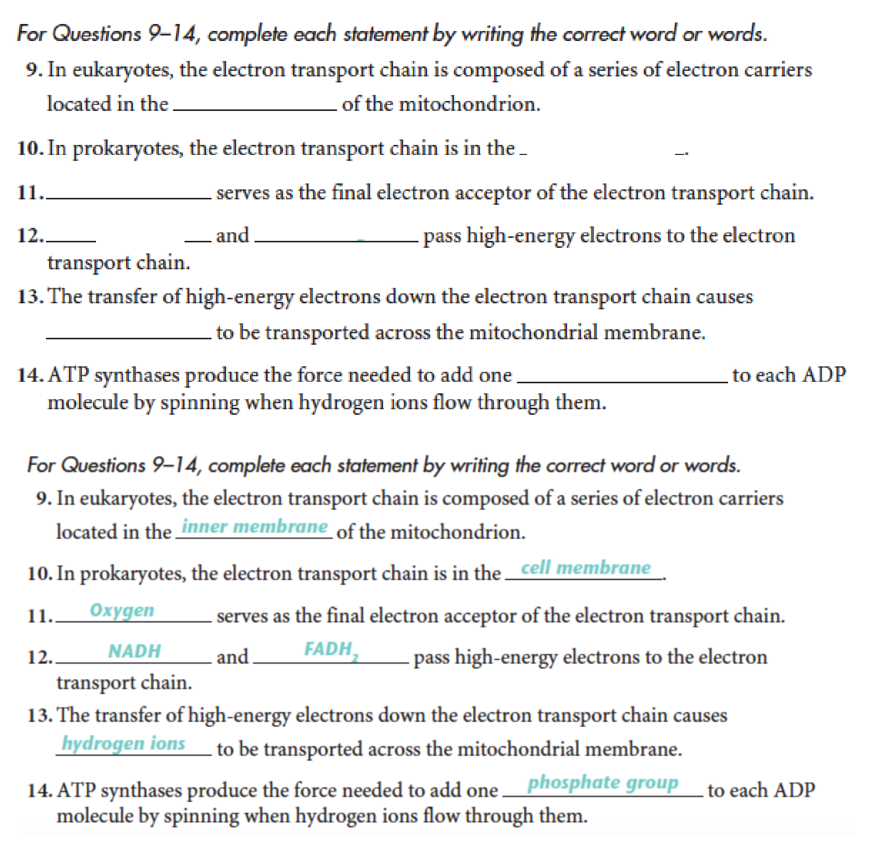
Describe how high-energy electrons are used by the electron transport chain.

Table 102 shows the pedagogical dimensions, supported by digital technology, that were used to implement this learning objective.

The pedagogical dimension supported by digital technology	Procedures
Direct teaching	The teacher covered this learning objective by discussing the following points (summary of the content): I. Electron Transport and ATP Synthesis: The electron transport chain uses the high-energy electrons from glycolysis and the Krebs cycle to convert ADP into ATP. II. The electron carriers produced during glycolysis and the Krebs cycle bring high-energy electrons to the electron transport chain. Oxygen is the final electron acceptor. III. The passing of electrons through the electron transport chain causes H^+ ions to build up in the intermembrane space, making it positively charged relative to the matrix. IV. The charge difference across the membrane forces H^+ ions through channels in enzymes known as ATP synthases. As the ATP synthases spin, a phosphate group is added to ADP, generating ATP.

Collaborative learning	Students were divided into groups, each of which was made out of five students. Students were asked to work together to complete the task, which is shown in Figure 244. The answer key was shared with students after they completed the task. Students in each group were asked to summarise (in their own words) the process of making O2 and NADPH, Cyclic Electron flow. The following link was shared with students to assist them. https://www.youtube.com/watch?v=IHee7zyE8QE, see Figure 245.
Constructive learning	Using the iBook and an external online link, students were asked to develop their own understanding (construct new knowledge) about the light reactions as ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle. Students were asked to share the gained knowledge under the supervision of the teacher. The following link was shared with students to assist them in completing this task: https://www.youtube.com/watch?v=KfvYQgT2M-k (see Figure 246)

Table 102. Pedagogical dimensions used to implement learning objective number five



For Questions 9–14, complete each statement by writing the correct word or words.

9. In eukaryotes, the electron transport chain is composed of a series of electron carriers located in the ______________ of the mitochondrion.

10. In prokaryotes, the electron transport chain is in the ______________.

11. ______________ serves as the final electron acceptor of the electron transport chain.

12. ______________ and ______________ pass high-energy electrons to the electron transport chain.

13. The transfer of high-energy electrons down the electron transport chain causes ______________ to be transported across the mitochondrial membrane.

14. ATP synthases produce the force needed to add one ______________ to each ADP molecule by spinning when hydrogen ions flow through them.

For Questions 9–14, complete each statement by writing the correct word or words.

9. In eukaryotes, the electron transport chain is composed of a series of electron carriers located in the *inner membrane* of the mitochondrion.

10. In prokaryotes, the electron transport chain is in the *cell membrane*.

11. *Oxygen* serves as the final electron acceptor of the electron transport chain.

12. *NADH* and *$FADH_2$* pass high-energy electrons to the electron transport chain.

13. The transfer of high-energy electrons down the electron transport chain causes *hydrogen ions* to be transported across the mitochondrial membrane.

14. ATP synthases produce the force needed to add one *phosphate group* to each ADP molecule by spinning when hydrogen ions flow through them.

Figure 244. Electron Transport and ATP Synthesis – task 1 (Miller & Levine, 2012, p. 135)

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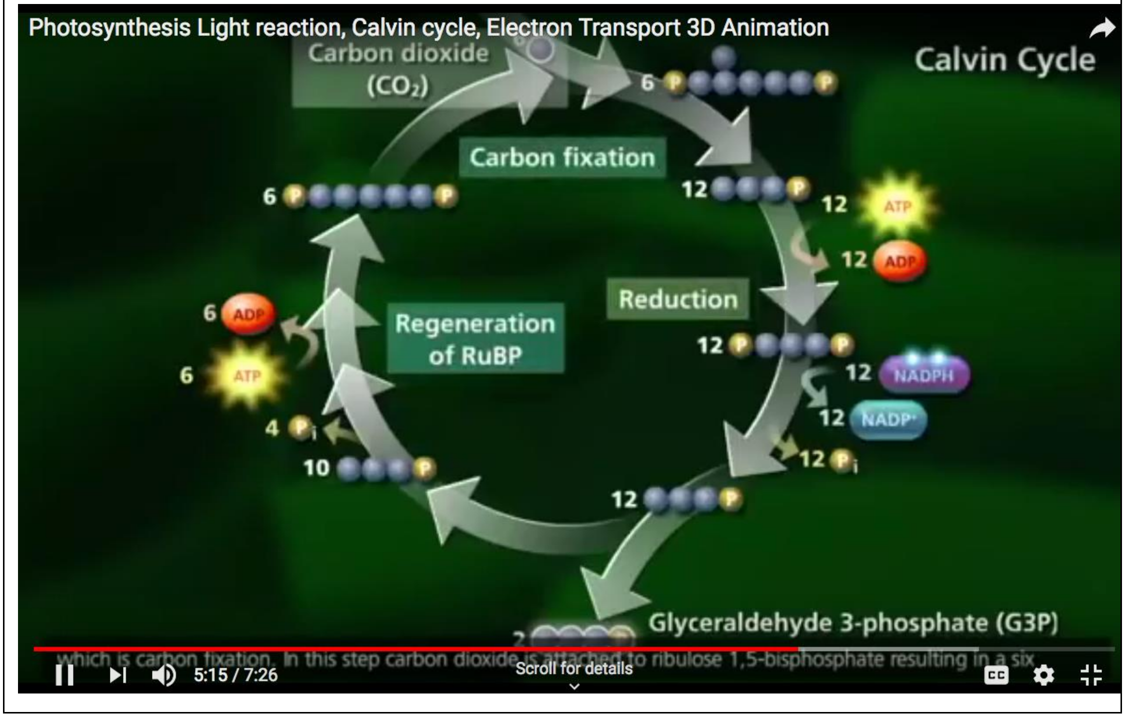
However, it can be viewed via the link shown in the caption below.

Figure 245. Photosynthesis, the Light Reactions, making O2 and NADPH, Cyclic Electron flow https://www.youtube.com/watch?v=IHee7zyE8QE



Photosynthesis Light reaction, Calvin cycle, Electron Transport 3D Animation

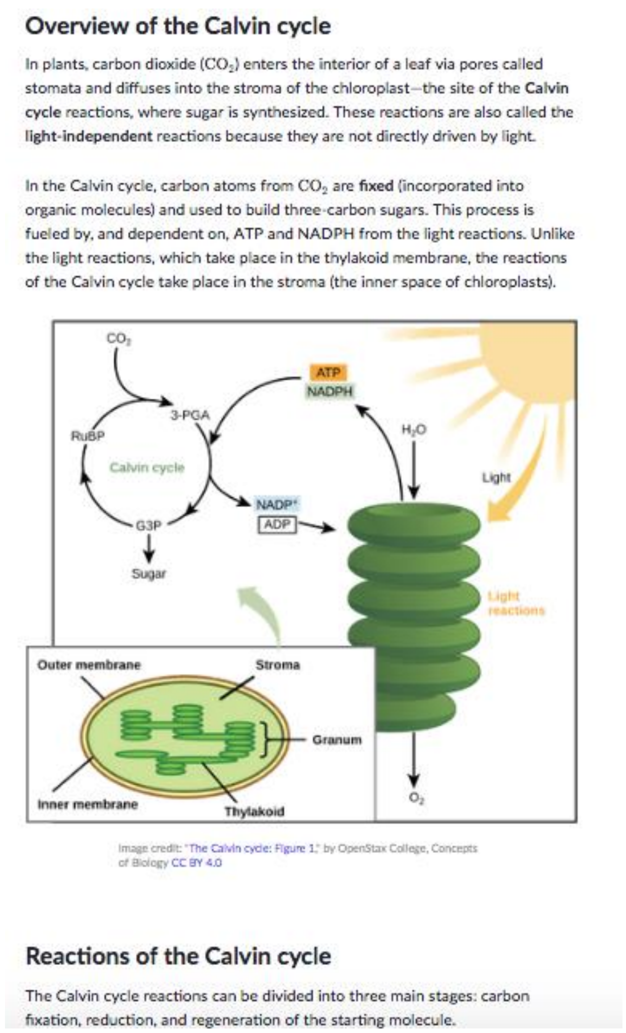
which is carbon fixation. In this step carbon dioxide is attached to ribulose 1,5-bisphosphate resulting in a six

Figure 246. ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle https://www.youtube.com/watch?v=KfvYQgT2M-k.

Table 103 shows the kinds of the curriculum, supported by digital technology that were used to implement learning objective number five.

Curriculum supported by digital technology	**Procedures**
Theoretical curriculum	The textbook (iBook) was used; lecture notes were displayed using PowerPoint presentation, see the covered points during the direct teaching. Students were asked to make notes about the Calvin cycle and discuss them with their peers and teacher after exploring the following shared link: https://www.khanacademy.org/science/biology/photosynthesis-in-plants/the-calvin-cycle-reactions/a/calvin-cycle See Figure 247
Interactive curriculum (Physical tools)	A link related to electron transport chain and ATP synthesis (shown in Figure 248) was shared with students to collect extra notes (construct new knowledge), share their notes with each other and with the teacher.
Practical curriculum	The teacher shared a link of an experiment about the rates of Photosynthesis and ATP synthesis. https://www.youtube.com/watch?v=id0aO_OdFwA See Figure 249. Students were asked to summarise the conducted experiment (procedures and outcomes). Students' work was shared and discussed with the teacher.

Table 103. Types of curriculum, supported by digital technology, used to implement learning objective number five



Overview of the Calvin cycle

In plants, carbon dioxide (CO_2) enters the interior of a leaf via pores called stomata and diffuses into the stroma of the chloroplast—the site of the **Calvin cycle** reactions, where sugar is synthesized. These reactions are also called the **light-independent** reactions because they are not directly driven by light.

In the Calvin cycle, carbon atoms from CO_2 are **fixed** (incorporated into organic molecules) and used to build three-carbon sugars. This process is fueled by, and dependent on, ATP and NADPH from the light reactions. Unlike the light reactions, which take place in the thylakoid membrane, the reactions of the Calvin cycle take place in the stroma (the inner space of chloroplasts).

Image credit: "The Calvin cycle: Figure 1," by OpenStax College, Concepts of Biology CC BY 4.0

Reactions of the Calvin cycle

The Calvin cycle reactions can be divided into three main stages: carbon fixation, reduction, and regeneration of the starting molecule.

Figure 247. External resource demonstrates Calvin cycle © KhanAcademy, CC-by NC-SA-3.0 US https://www.khanacademy.org/science/biology/photosynthesis-in-plants/the-calvin-cycle-reactions/a/calvin-cycle

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Figure 248. External resource demonstrates the electron transport chain and ATP synthesis. http://www.pol2e.com/at06.01.html

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However, it can be viewed via the link shown in the caption below.

Figure 249. Online laboratory demonstrates the rates of photosynthesis and ATP synthesis https://www.youtube.com/watch?v=id0aO_OdFwA

The conducted experiment: the photosynthesis process

Introduction

Photosynthesis is the process of manufacturing food by the green parts of the plant (especially the leaves) in the presence of sunlight and chlorophyll with the help of CO2 and water.

The main objective of this experiment:

Students are expected to prove that light is necessary for photosynthesis.

The required tools (see Figure 250):

I. Potted plant
II. Petri dish
III. Boiling tube
IV. Alcohol (70%)
V. Iodine solution
VI. Bunsen burner
VII. Forceps
VIII. Beaker and water
IX. Dropper
X. Black paper

Note: Figure 250 to Figure 257, including the procedures, were shared with the students before conducting the experiment. These figures are screenshots of a virtual experiment that can be found at https://youtu.be/j6Le0S52wt0

Figure 250. Required tools for the experiment (the photosynthesis process)

Procedures

I. Take a healthy potted plant and place it in the dark for about 72 hours so that the leaves become free from starch (the teacher kept the plant 72 hours in the dark before experimenting).

II. After 72 hours select a leaf on the plant and cover a portion of it on both sides with black paper, see Figure 251.

Figure 251. Step2 – photosynthesis process

III. Keep the potted plant with the covered leaf in sunlight for an hour, see Figure 252

Figure 252. Step3 – photosynthesis process

IV. After an hour, detach the covered leaf from the plant, remove the black papers and boil the leaf in water for a few minutes, see Figure 253.

Figure 253. Step4- photosynthesis process

V. Now boil the leaf in alcohol in a water bath until it becomes dull-white due to the removal of chlorophyll, see Figure 254

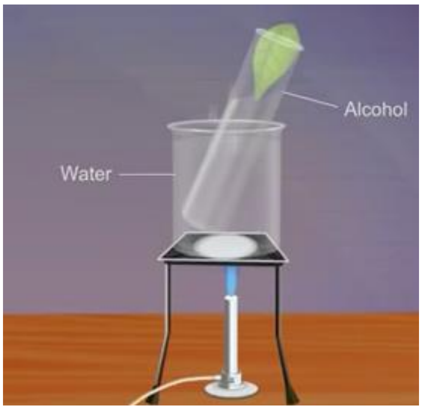


Figure 254. Step5- photosynthesis process

VI. Wash the leaf with water and add iodine solution, see Figure 255 and Figure 256.

Figure 255. Step 6- photosynthesis process

Figure 256. Step 6- photosynthesis process

Observation

The portion of the leaf, which was covered, does not change colour, whereas the portion, which was uncovered, turns blue-black (dark blue), see Figure 257.

Figure 257. The experiment’s observation

Conclusion

The students were asked to write their conclusions.

The Second Lesson: Cellular Respiration (C3, P3, T0)

This lesson was not supported by digital technology (nondigital technology-based learning, which is according to the CPT model described as T0). The C3, P3, T0 strategy was applied to implement this lesson. The curriculum was introduced by all three parts (C3): i) theoretical content, was implemented using nondigital technology tools, such as board and hard copy of the textbook, ii) practical content, related experiments were conducted, iii) interactive content, related posters and models were displayed. Three pedagogical dimensions (P3) were used to deliver the content: direct teaching, collaborative learning and constructive learning. None of the learning objectives was integrated with digital technology (T0).

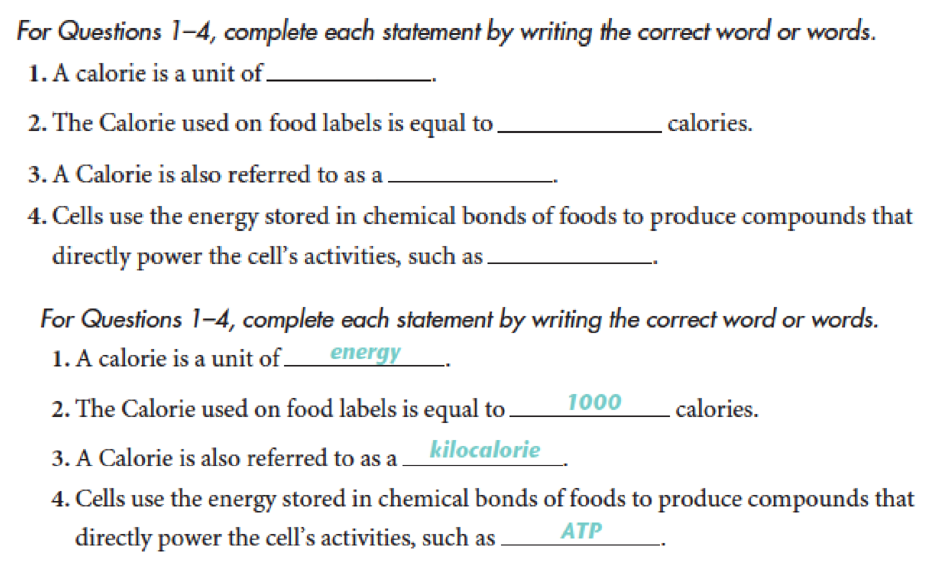
Learning objective number one

Explain where organisms get the energy they need for life processes.

Table 104 shows the pedagogical dimensions that were used to implement this learning objective.

The pedagogical dimension	Procedures
Direct teaching	The teacher discussed with students the following points: Chemical Energy and Food: I. Chemical energy is stored in food molecules. II. Energy is released when chemical bonds in food molecules are broken. III. Energy is measured in a unit called a calorie, which is defined as the amount of energy needed to raise the temperature of 1 gram of water 1 degree Celsius.
Collaborative learning	Students were divided into groups. Students were asked to work together to complete task 1, see Figure 258. The answer key was shared with students later on.
Constructive learning	Students were asked to use the lecture notes and textbook (hard copy) to compare between fats, carbohydrates and proteins in terms of storing energy per gram.

Table 104. Pedagogical dimensions used to implement learning objective number one



For Questions 1–4, complete each statement by writing the correct word or words.

1. A calorie is a unit of ____________.

2. The Calorie used on food labels is equal to ____________ calories.

3. A Calorie is also referred to as a ____________.

4. Cells use the energy stored in chemical bonds of foods to produce compounds that directly power the cell's activities, such as ____________.

For Questions 1–4, complete each statement by writing the correct word or words.

1. A calorie is a unit of energy.

2. The Calorie used on food labels is equal to 1000 calories.

3. A Calorie is also referred to as a kilocalorie.

4. Cells use the energy stored in chemical bonds of foods to produce compounds that directly power the cell's activities, such as ATP.

Figure 258. Task - Cellular Respiration – Chemical Energy and Food (Miller & Levine, 2012, p. 130)

Table 105 shows the kinds of curriculum that were used to implement learning objective number one.

Curriculum	Procedures
Theoretical curriculum	The hardcopy book was used; lecture notes were explained, written on the board and copied by students to their notebooks, please see the covered points during direct teaching.
Interactive curriculum (Physical tools)	Figures and diagrams included in the hard copy book were discussed with students.
Practical curriculum	See the conducted experiment in this lesson (Cellular Respiration laboratory).

Table 105. Types of curriculum used to implement learning objective number one

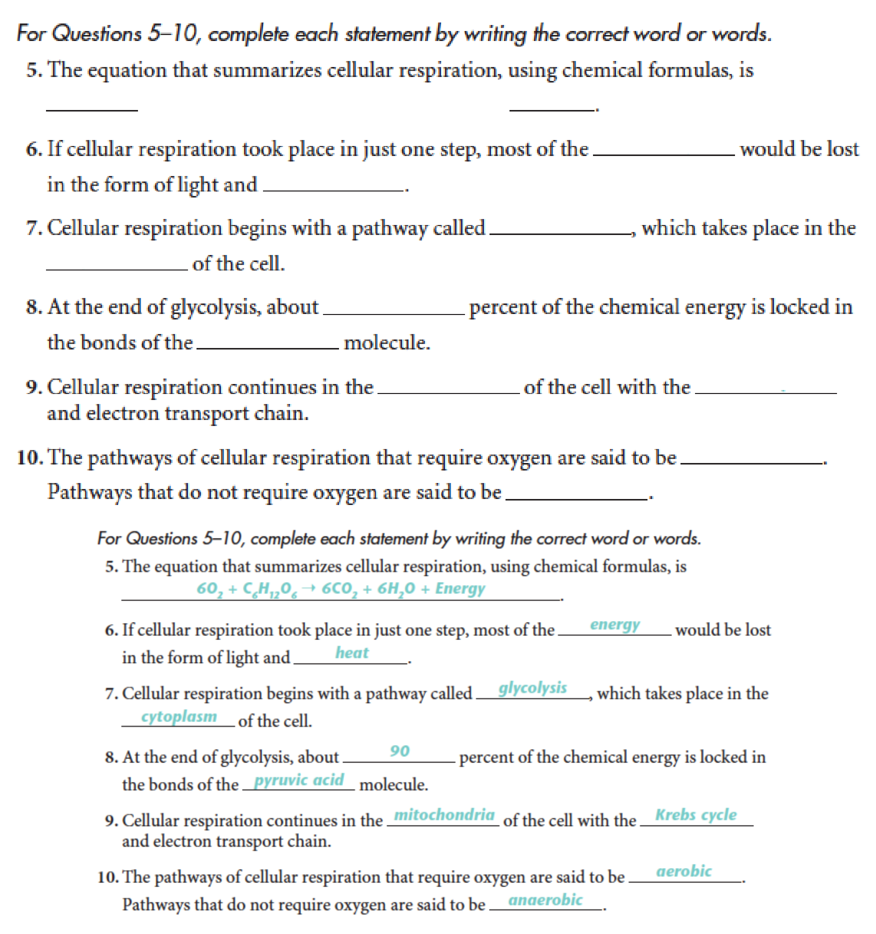
Learning objective number two

Define the cellular respiration process.

Table 106 shows the pedagogical dimensions that were used to implement this learning objective.

The pedagogical dimension	**Procedures**
Direct teaching	The teacher discussed with students the following points: I. Cellular respiration is the process that releases energy from food in the presence of oxygen. II. Cellular respiration captures the energy from food in three main stages: a) Glycolysis b) The Krebs cycle c) The electron transport chain III. Glycolysis does not require oxygen. The Krebs cycle and electron transport chain both require oxygen. IV. The chemical formula of cellular respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$
Collaborative learning	Students were divided into groups of five. Students were asked to rephrase, in their own words, the definition of the cellular respiration. Students were asked to work together to complete the task, which is shown in Figure 259.
Constructive learning	Students were asked to use the lecture notes and the textbook to compare the Aerobic and Anaerobic pathways. Each group made a poster to summarise the comparisons. Students shared and discussed their posters under the supervision of their teacher.

Table 106. Pedagogical dimensions used to implement learning objective number two



For Questions 5–10, complete each statement by writing the correct word or words.

5. The equation that summarizes cellular respiration, using chemical formulas, is ________ ________.

6. If cellular respiration took place in just one step, most of the ________ would be lost in the form of light and ________.

7. Cellular respiration begins with a pathway called ________, which takes place in the ________ of the cell.

8. At the end of glycolysis, about ________ percent of the chemical energy is locked in the bonds of the ________ molecule.

9. Cellular respiration continues in the ________ of the cell with the ________ and electron transport chain.

10. The pathways of cellular respiration that require oxygen are said to be ________. Pathways that do not require oxygen are said to be ________.

For Questions 5–10, complete each statement by writing the correct word or words.

5. The equation that summarizes cellular respiration, using chemical formulas, is $6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + Energy$.

6. If cellular respiration took place in just one step, most of the energy would be lost in the form of light and heat.

7. Cellular respiration begins with a pathway called glycolysis, which takes place in the cytoplasm of the cell.

8. At the end of glycolysis, about 90 percent of the chemical energy is locked in the bonds of the pyruvic acid molecule.

9. Cellular respiration continues in the mitochondria of the cell with the Krebs cycle and electron transport chain.

10. The pathways of cellular respiration that require oxygen are said to be aerobic. Pathways that do not require oxygen are said to be anaerobic.

Figure 259. Task - Cellular Respiration (Miller & Levine, 2012, p. 131)

Table 107 shows the kinds of curriculum that were used to implement learning objective two.

Curriculum	**Procedures**
Theoretical curriculum	The textbook (hard copy) was used; lecture notes were written on the board and copied by students to their notebooks, see the covered points during direct teaching.
Interactive curriculum (Physical tools)	Figures and diagrams that are included in the hard copy book were discussed with students. See Figure 260 as an example.
Practical curriculum	Students conducted a practical experiment related to respiration and carbon dioxide. For more details, refer to the detailed description of the experiment at the end of this lesson (Cellular Respiration laboratory).

Table 107. Types of curriculum used to implement learning objective number two

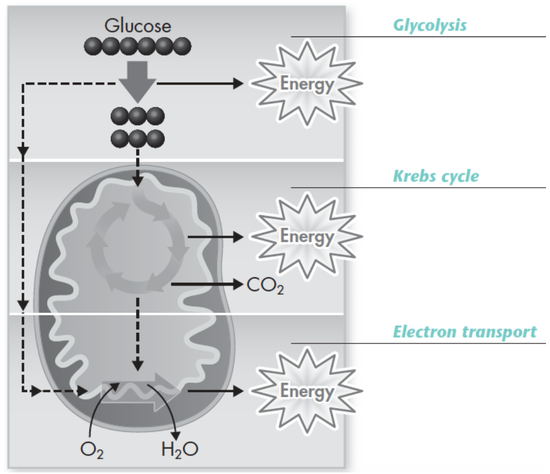


Figure 260. Stages of cellular respiration (Miller & Levine, 2012, p. 131)

Learning objective number three

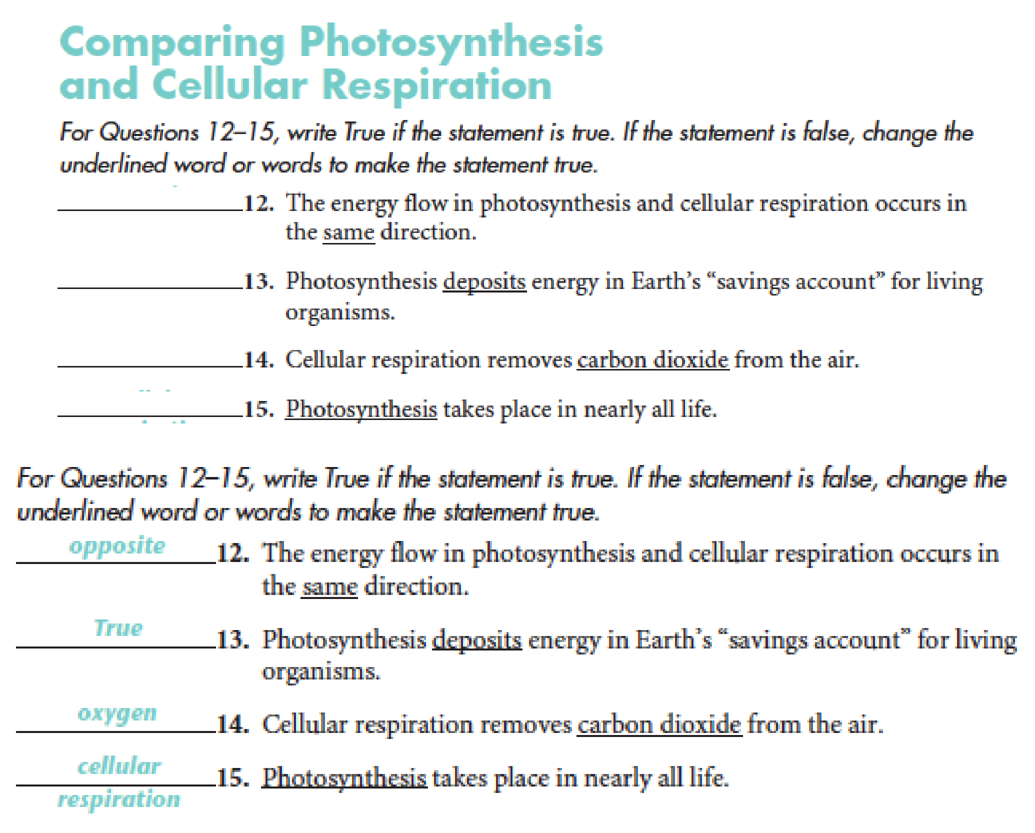
Explain the relationship between photosynthesis and cellular respiration.

Table 108 shows the pedagogical dimensions that were used to implement this learning objective.

The pedagogical dimension	Procedures
Direct teaching	The teacher discussed with students the following points: I. The energy in photosynthesis and cellular respiration flows in opposite directions. Their equations are the reverse of each other. II. Photosynthesis removes carbon dioxide from the atmosphere, and cellular respiration puts it back. III. Photosynthesis releases oxygen into the atmosphere, and cellular respiration uses oxygen to release energy from food.
Collaborative learning	Using the lecture notes, students were requested to work together to complete the task, which is shown in Figure 261. The answer key was shared with students after they completed the task. Students were asked to summarise in their own words the differences between photosynthesis and cellular respiration by creating a Venn diagram.

Constructive learning	Using the lecture notes and the hardcopy book, students were asked to figure out the reactants and products of cellular and photosynthesis process. Students were asked to complete the task shown in Figure 262. This task required higher-order thinking skills, such as critical thinking, and analysis, as students were requested to demonstrate how does an understanding of the process of cellular respiration support the theory that the cell is the basic functional unit of life?. This task can have many possible answers, open-ended case; a sample answer was shared with students after they completed the task.

Table 108. Pedagogical dimensions used to implement learning objective number three



Comparing Photosynthesis and Cellular Respiration

For Questions 12–15, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

__________ 12. The energy flow in photosynthesis and cellular respiration occurs in the same direction.

__________ 13. Photosynthesis deposits energy in Earth's "savings account" for living organisms.

__________ 14. Cellular respiration removes carbon dioxide from the air.

__________ 15. Photosynthesis takes place in nearly all life.

For Questions 12–15, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

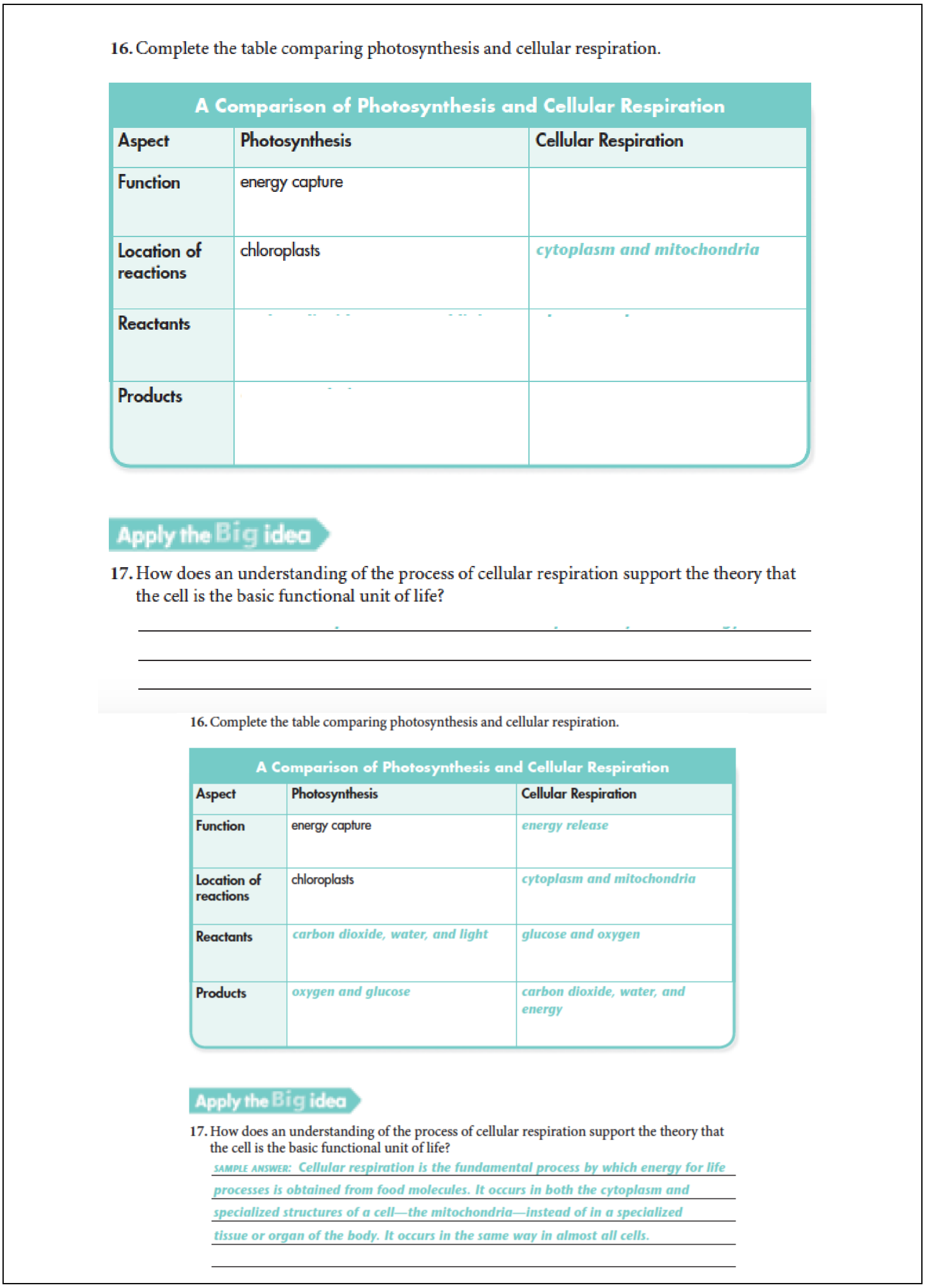
opposite 12. The energy flow in photosynthesis and cellular respiration occurs in the same direction.

True 13. Photosynthesis deposits energy in Earth's "savings account" for living organisms.

oxygen 14. Cellular respiration removes carbon dioxide from the air.

cellular respiration 15. Photosynthesis takes place in nearly all life.

Figure 261. The relationship between photosynthesis and cellular respiration. (Miller & Levine, 2012, p. 132)



16. Complete the table comparing photosynthesis and cellular respiration.

A Comparison of Photosynthesis and Cellular Respiration		
Aspect	**Photosynthesis**	**Cellular Respiration**
Function	energy capture	
Location of reactions	chloroplasts	*cytoplasm and mitochondria*
Reactants		
Products		

Apply the Big idea

17. How does an understanding of the process of cellular respiration support the theory that the cell is the basic functional unit of life?

16. Complete the table comparing photosynthesis and cellular respiration.

A Comparison of Photosynthesis and Cellular Respiration		
Aspect	**Photosynthesis**	**Cellular Respiration**
Function	energy capture	*energy release*
Location of reactions	chloroplasts	*cytoplasm and mitochondria*
Reactants	*carbon dioxide, water, and light*	*glucose and oxygen*
Products	*oxygen and glucose*	*carbon dioxide, water, and energy*

Apply the Big idea

17. How does an understanding of the process of cellular respiration support the theory that the cell is the basic functional unit of life?

SAMPLE ANSWER: Cellular respiration is the fundamental process by which energy for life processes is obtained from food molecules. It occurs in both the cytoplasm and specialized structures of a cell—the mitochondria—instead of in a specialized tissue or organ of the body. It occurs in the same way in almost all cells.

Figure 262. The relationship between photosynthesis and cellular respiration. (Miller & Levine, 2012, p. 132)

Table 109 shows the kinds of curriculum that were used to implement learning objective three.

Curriculum	Procedures
Theoretical curriculum	The textbook was used; lecture notes were written on the board and copied by students to their notebooks, see the covered points during direct teaching.
Interactive curriculum (Physical tools)	A related hardcopy poster was displayed, as shown in Figure 263.
Practical curriculum	The teacher offered students the instructions and materials required for conducting an experiment on respiration and carbon dioxide, as shown in Figure 264.

Table 109. Types of curriculum used to implement learning objective number three.

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However, it can be viewed via the link shown in the caption below.

Figure 263. The relationship between photosynthesis and cellular respiration https://en.ppt-online.org/385879

Experiment: Respiration and carbon dioxide

This experiment was implemented to show that carbon dioxide is given out during respiration

Materials required: freshly prepared lime water in a test tube; cork with two holes, glass tubings bent at 90°.

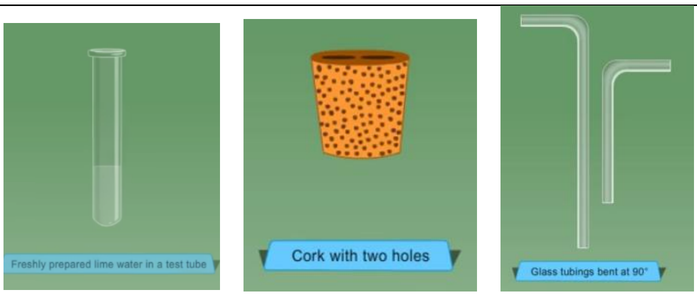


Figure 264. Materials required

Procedures

Take a half-filled test tube with freshly prepared clear limewater. Fix the cork in the test tube. Fix the glass tubes A and B in the cork such that end of glass tubing A is dipping in the lime water.

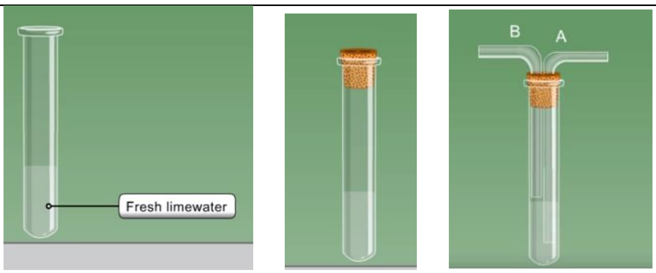


Figure 265. Procedures – setting up the experiment

Put your mouth at the end of tube A and exhale out air with full force. Pass exhaled air vigorously of at least 1 minute.

Figure 266. Procedures-exhaling for 1 minute

Observations: as exhaled air bubbles pass through limewater, it gradually turns limewater milky.

Figure 267. Observation

Conclusions: The clear limewater turns milky only with carbon dioxide. Therefore, we can say that carbon dioxide is present in the exhaled air and is produced by the process of respiration.

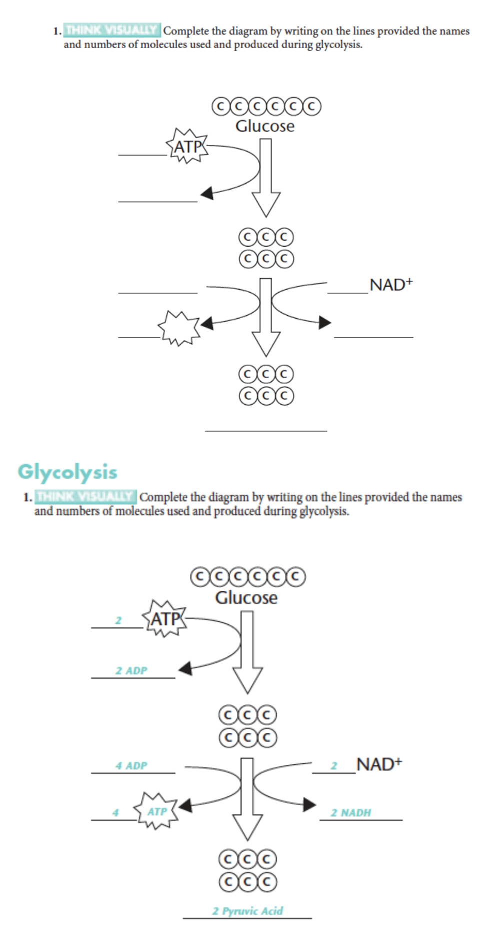
Learning objective number four

Describe what happens during glycolysis.

Table 110 shows the pedagogical dimensions that were used to implement this learning objective.

The pedagogical dimension	Procedures
Direct teaching	The teacher discussed with students the following points: Glycolysis: The first stage of cellular respiration. I. The word glycolysis means “sugar-breaking.” The result is two molecules of a 3-carbon molecule called pyruvic acid. II. Two ATP molecules are used at the start of glycolysis to get the process started. III. High-energy electrons are passed to the electron carrier NAD^+, forming two molecules of NADH. IV. Four ATP are synthesised during glycolysis for a net gain of 2 ATP.
Collaborative learning	Students were divided into groups, and they were asked to complete the task, which is shown in Figure 268. The answer key was shared with students after the completed the task.
Constructive learning	Students were asked to use the lecture notes and the textbook to figure out the advantages of Glycolysis stage. Students were asked to complete the task shown in Figure 269. The answer key was shared with students after they completed the task.

Table 110. Pedagogical dimensions used to implement learning objective number four

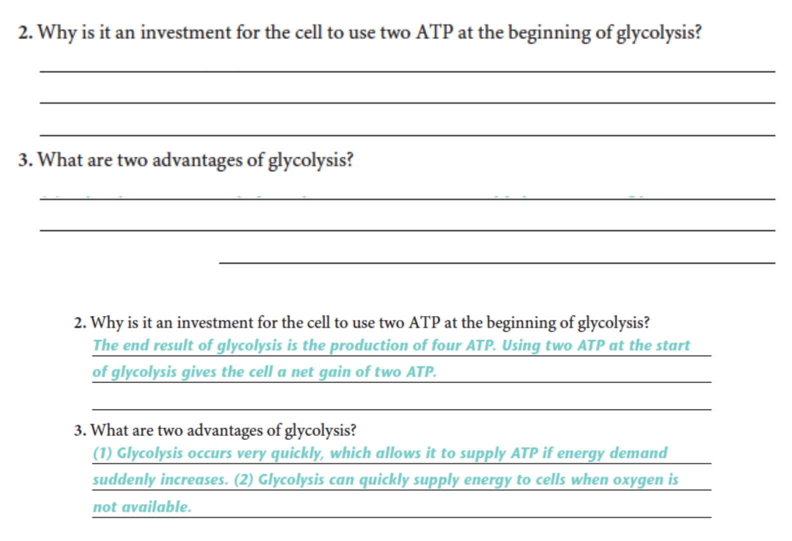


1. THINK VISUALLY Complete the diagram by writing on the lines provided the names and numbers of molecules used and produced during glycolysis.

Glycolysis

1. THINK VISUALLY Complete the diagram by writing on the lines provided the names and numbers of molecules used and produced during glycolysis.

Figure 268. Glycolysis process (Miller & Levine, 2012, p. 134)



2. Why is it an investment for the cell to use two ATP at the beginning of glycolysis?

3. What are two advantages of glycolysis?

2. Why is it an investment for the cell to use two ATP at the beginning of glycolysis?
The end result of glycolysis is the production of four ATP. Using two ATP at the start of glycolysis gives the cell a net gain of two ATP.

3. What are two advantages of glycolysis?
(1) Glycolysis occurs very quickly, which allows it to supply ATP if energy demand suddenly increases. (2) Glycolysis can quickly supply energy to cells when oxygen is not available.

Figure 269. Glycolysis process (Miller & Levine, 2012, p. 134)

Table 111 shows the kinds of curriculum that were used to implement learning objective four.

Curriculum	Procedures
Theoretical curriculum	The textbook was used; lecture notes were explained and written on the board and copied by students to their notebooks.
Interactive curriculum (Physical tools)	A related hardcopy poster was displayed, see Figure 268.
Practical curriculum	Students were asked to design and describe an experiment using the given information in the task shown in Figure 271.

Table 111. Types of curriculum used to implement learning objective number four

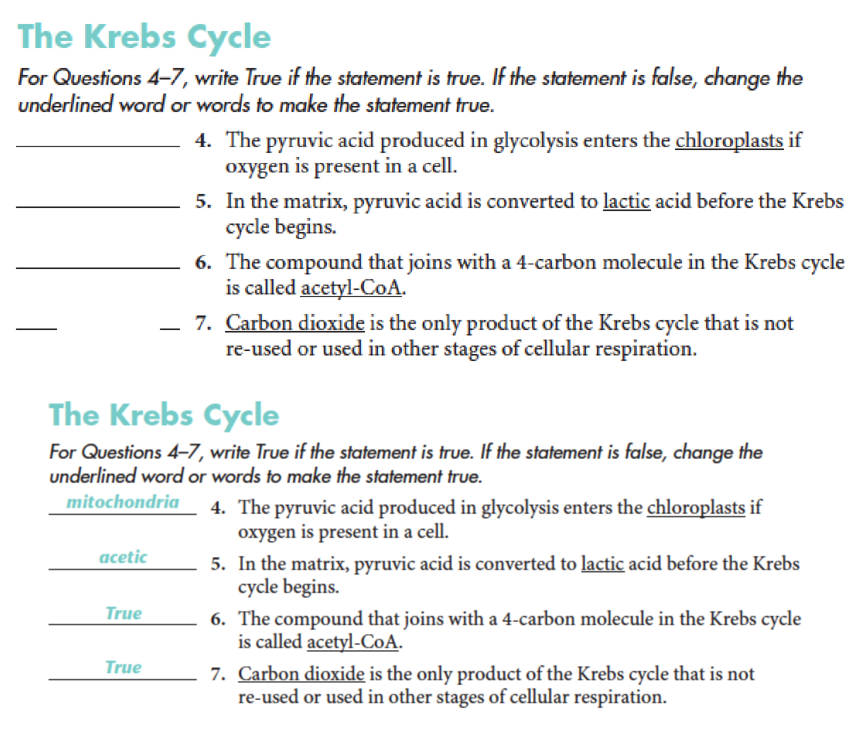
Learning objective number five

Describe what happens during the Krebs cycle.

Table 112 shows the pedagogical dimensions that were used to implement this learning objective.

The pedagogical dimension	Procedures
Direct teaching	The teacher discussed with students the following points (summary of the content): The Krebs Cycle: I. The second stage of cellular respiration is the Krebs cycle, which operates only when oxygen is available. The Krebs cycle is a series of energy-extracting reactions. II. Pyruvic acid produced by glycolysis enters mitochondria. In the inner compartment of a mitochondrion or the matrix, pyruvic acid molecules are broken down into carbon dioxide and Acetyl-CoA molecules. III. Acetyl-CoA combines with a 4-carbon compound, producing a 6-carbon molecule—citric acid. IV. The energy released by the breaking and rearranging of carbon bonds is captured in ATP, NADH, and FADH2.
Collaborative learning	Students were divided into groups of five. Students were asked to complete the task, which is shown in Figure 270. Students' shared their answers under the supervision of their teacher.
Constructive learning	Students were asked to use the lecture notes and the textbook to construct new knowledge, they were asked to summarise and share the gained knowledge about the four types of products of the Krebs cycle: a. High-energy electron carriers (NADH and FADH2). b. Carbon dioxide. c. Two ATP molecules (per glucose molecule). d. The 4-carbon molecule needed to start the cycle again.

Table 112. Pedagogical dimensions used to implement learning objective number five



The Krebs Cycle

For Questions 4–7, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

______ **4.** The pyruvic acid produced in glycolysis enters the <u>chloroplasts</u> if oxygen is present in a cell.

______ **5.** In the matrix, pyruvic acid is converted to <u>lactic</u> acid before the Krebs cycle begins.

______ **6.** The compound that joins with a 4-carbon molecule in the Krebs cycle is called <u>acetyl-CoA</u>.

______ **7.** <u>Carbon dioxide</u> is the only product of the Krebs cycle that is not re-used or used in other stages of cellular respiration.

The Krebs Cycle

For Questions 4–7, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

mitochondria **4.** The pyruvic acid produced in glycolysis enters the <u>chloroplasts</u> if oxygen is present in a cell.

acetic **5.** In the matrix, pyruvic acid is converted to <u>lactic</u> acid before the Krebs cycle begins.

True **6.** The compound that joins with a 4-carbon molecule in the Krebs cycle is called <u>acetyl-CoA</u>.

True **7.** <u>Carbon dioxide</u> is the only product of the Krebs cycle that is not re-used or used in other stages of cellular respiration.

Figure 270. The Kerbs cycle (Miller & Levine, 2012, p. 135)

Curriculum	Procedures
Theoretical curriculum	The textbook was used; lecture notes were explained and written on the board and copied by the students to their notebooks, see the covered points during direct teaching.
Interactive curriculum (Physical tools)	Figures and diagrams that are included in the hard copy book were discussed with students. See Figure 260 as an example.
Practical curriculum	Students conducted a practical experiment related to respiration and carbon dioxide. For more details, refer to the detailed description of the experiment at the end of this lesson (Cellular Respiration laboratory). Students were asked to design and describe an experiment using the given information in the task, which is shown in Figure 271. The answer key was shared with students after they completed it.

Table 113. Kinds of curriculum used to implement learning objective number five

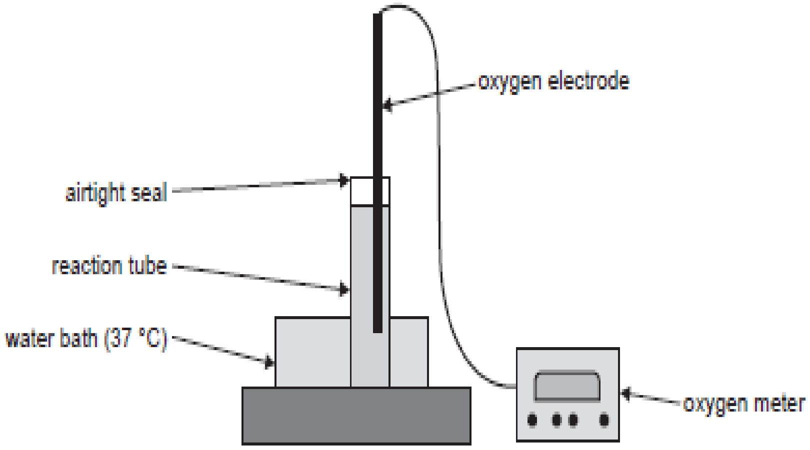
Experiment’s design

The apparatus shown below was used in a series of experiments to study aerobic respiration. Read the given information and refer to Figure 271 to answer questions a-c.

In three different experiments, the reaction tube initially contained the following:

1. Suspension of mitochondria
2. The cytosol of cells from which the mitochondria had been removed
3. Suspension of mitochondria and cytosol of cells

In each experiment, a solution containing glucose was first added to the mixture in the reaction tube, and the oxygen concentration was measured for three minutes. Then, a pyruvate solution was added, and the oxygen concentration was measured again for three minutes.



a. Identify the dependent and independent variable in the experiment.

Independent variable: components of the solution in the reaction tube.

Dependent variable: the amount of oxygen being used.

b. Specify the result of each experiment. Justify your answer.

Experiment 1:

Adding glucose will not change the oxygen concentration since mitochondria use pyruvate as a starter reactant.

Adding pyruvate will reduce the oxygen amount since pyruvate is the starter reactant of the Krebs cycle that occurs in the stroma of mitochondria.

Experiment 2:

Oxygen concentration will stay constant after adding glucose or pyruvate. After adding glucose, glycolysis will progress, but it does not need oxygen. However, after adding pyruvate, nothing will happen since there is no mitochondrion for Krebs cycle to occur.

Experiment 3:

Oxygen concentration will decrease after adding glucose and pyruvate. Glucose will be utilised during glycolysis in the cytoplasm and will be converted into pyruvate that will be used during the Krebs cycle in the stroma of mitochondria (Krebs, ETC need oxygen).

c. Identify all the products of the above photosynthetic stage and specify their final fate.

The products are: Oxygen, ATP, and NADPH

Oxygen will be released outside the plant.

ATP and NADPH will be used in the second photosynthetic stage (Calvin cycle)

Figure 271. Experiment's design

Cellular Respiration laboratory

This experiment, including the procedures, was shared with students in advance.

Introduction

Cellular respiration is the process that releases energy from food in the presence of oxygen.

Cellular respiration releases energy from food in three main stages:

- Glycolysis
- The Krebs cycle
- The electron transport chain.

The chemical formula of cellular respiration:

C6H12O6 + 6O2 --> 6CO2 + 6H2O + Energy

Respiration in plants

Materials required: germinating gram seeds, dropper, conical flask, cotton thread, glass tubing bent twice at right angles, small test tube, cork with one hole, potassium hydroxide solution (KOH), 100 cc beaker half-filled with water, Vaseline.

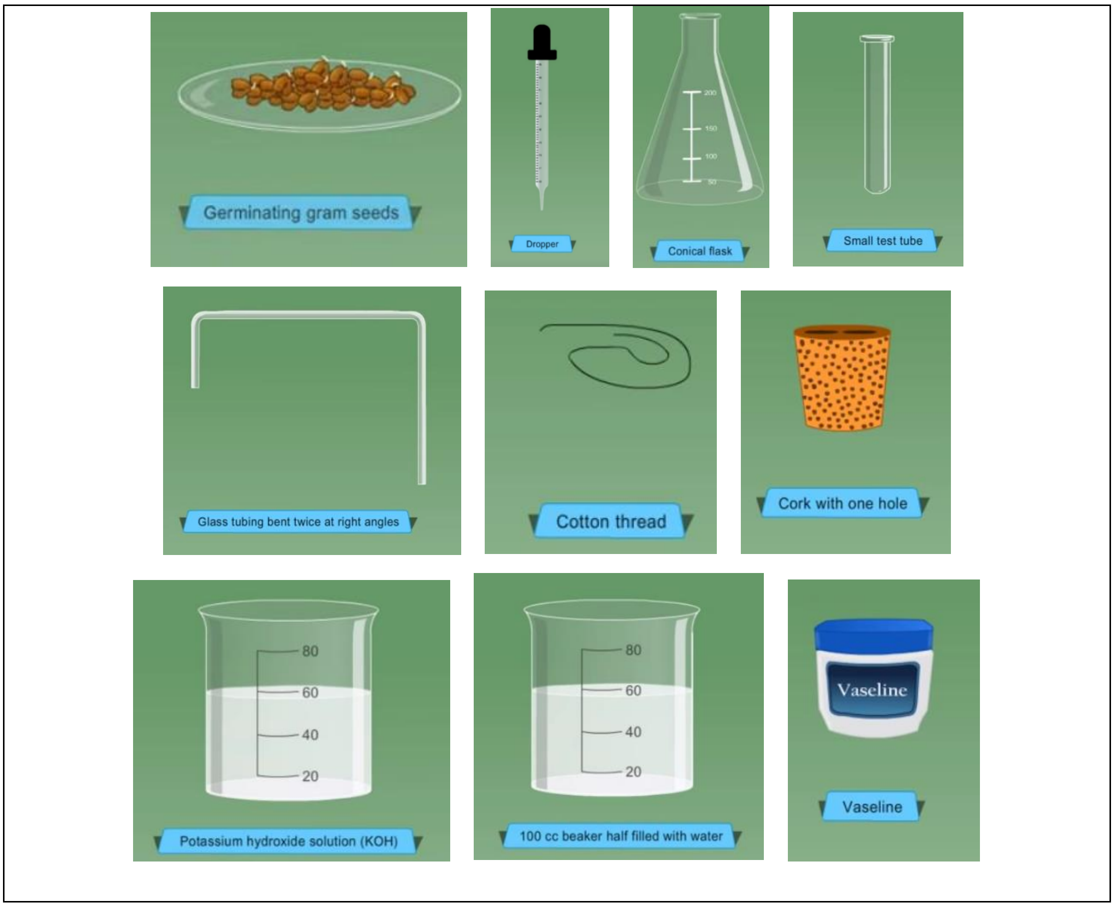


Figure 272. Required materials

Procedures

Place about 50 germinating gram seeds into the conical flask.

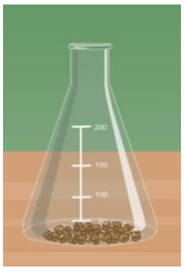


Figure 273. Procedures – preparing the germinating seeds

Tie the cotton thread to the neck of the small test tube and pour about 4ml of KOH solution in it and suspend it in the conical flask.

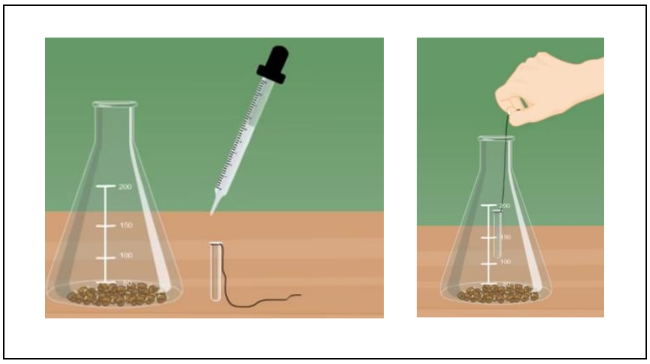


Figure 274. Procedures – introducing KOH

Close the conical tube with a cork in which the delivery tube is fitted. Close it in a way that the thread tied to the small test tube is held firmly.

Figure 275. Procedures – securing the test tube

Fix one end of the twice bent glass tube in the cork, and the other end is dipped in the beaker with water. Apply vaseline on the cork to make an airtight apparatus.

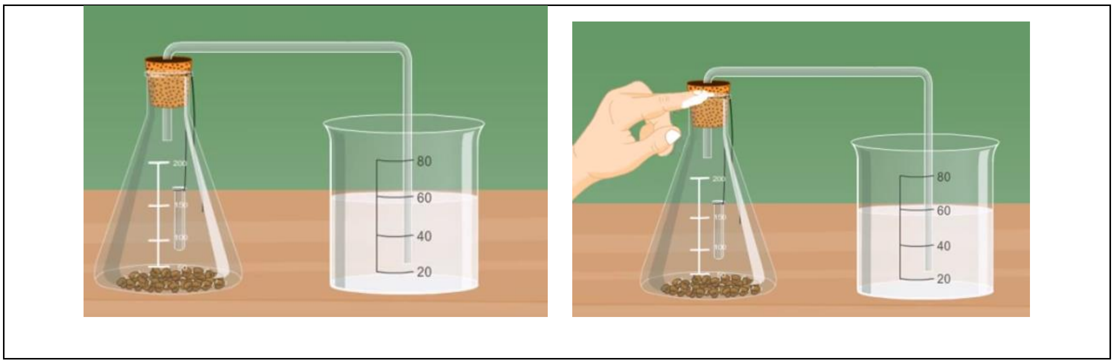


Figure 276. Procedures – creating airtight apparatus

Leave the apparatus undisturbed for one hour

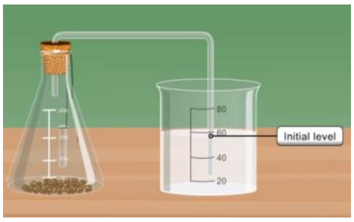


Figure 277. Procedures – initial level

Observations: after one hour the level of water in the delivery tube rises as compared to the level of water in the beaker

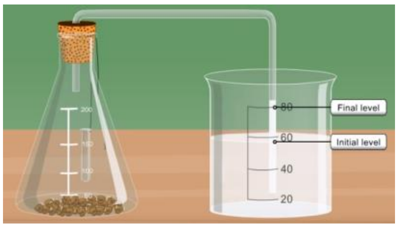


Figure 278. Observations

Conclusions:

Students were asked to write their conclusions.

The following conclusions were shared with students after they wrote their conclusions.

Sample conclusions of the Cellular Respiration laboratory

The rise in the level of water in the delivery tube indirectly proves that germinating seeds produce carbon dioxide.

The potassium hydroxide solution absorbs the carbon dioxide produced by germinating seeds.

As carbon dioxide is produced due to the consumption of oxygen during respiration, the pressure of air within the flask falls. To make up for this loss in pressure, the air from outside exerts pressure. Consequently, forces up the water within the delivery tube.

EXAMPLE THREE – SOCIAL STUDIES: C1, P1, T1 AND C1, P1, T0

The nature of the Social Studies subject allowed each of the two chosen lessons to be implemented within one week (two periods a week, each of which 45 minutes long) with the 30 minutes assessment at the beginning of next week's lesson for each of the learning scenarios (nondigital and digital technology-based learning).

Both lessons belong to the same Unit "Universal Culture" that is a part of the grade 9 curriculum. The first lesson was taught applying C1, P1, T1 strategy entitled "What are the key concepts of Universal Culture?" (unit 3, lesson2). The second one did not involve any digital technologies in its implementation under the strategy C1, P1, T0, entitled "How does the UAE exhibit the core values and beliefs of "Universal Culture"? (Unit 3, lesson 6). Figure 1 represents the screenshot of the student's book showing the list of lessons that are included in Unit 3 "Universal Culture".

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Figure 279. Lessons of Unit 3 "Universal Culture". (MoE, 2016a, p. 3)

The strategy that was tested was C1 P1 T1, which implies that throughout the teaching and learning process, only theoretical curriculum with direct teaching pedagogy style was applied. The teacher was the one in charge of what is happening in the class, in terms of knowledge delivery. Students were not asked to do research or look for additional sources of information on given topics.

Summary of the learning objectives of the Social studies lessons is shown below in Table 114. It shows what the learning objectives were and to which level of depth of knowledge do they belong.

Learning objective (LO)	**Depth of Knowledge (DOK)**	**Lesson 1: What are the key concepts of "Universal Culture'?**	**Lesson 2: How does the UAE exhibit the core values and beliefs of "Universal Culture"?**
LO No1	Level 1: Recall / low cognitive complexity.	Identify main aspects of a Culture: Symbols, Values and Norms	To introduce the Sustainable development goals set by the United Nations
LO No2	Level 2: Basic application of skills and concepts / moderate cognitive complexity.	Define the key concepts of "cultural pluralism", "cultural relativism" and "cultural universals" and give at least one example of each of these concepts.	Identify and describe 4 main key principles of UAE's Vision 2021
LO No3	Level 2: Basic application of skills and concepts / moderate cognitive complexity.	Identify at least three shared traits between your own and another culture.	Explain the six National Priorities outlined in the Vision 2021 as the main areas of focus in achieving the set goals
LO No4	Level 3: Strategic thinking and complex reasoning / high cognitive complexity.	Compare and contrast ethnocentricity and cultural relativism with 1 example for each from your own and another culture.	Show understanding of key concepts of UAE Vision 2021 project by comparing a specific principle of the project with United Nations Sustainable Development Goals and finding at least three common Universal values.
LO No5	Level 4: Extended thinking and complex reasoning / high cognitive complexity.	Express your opinion about given quotes (criticise or defend with your own arguments). Give positive and negative aspects of Universal Culture's influence on your daily life.	Think of specific way how you can contribute to achieving each of the key goals (1 example of each priority)

Table 114. Summary of the learning objectives of the included lessons of Social Studies.

The First Lesson: What are the Key Concepts of Universal Culture? (C1, P1, T1)

This lesson is focused on getting to know and differentiate between the key terminology and concepts of the Universal Culture. In line with the strategy (C1, P1, T1), the teacher used just one type of curriculum (C1): theoretical; one type of pedagogy (P1): direct teaching and only one out of five learning objectives was implemented with the aid of digital technology, which makes it 20% (T1).

The strategies used in the learning process included lecturing, checking for understanding and guided instructions. To check the understanding, the teacher would deliver part of the knowledge and pick one or several students randomly to answer the questions. The random pick ensured the element of objectivity while selecting the students.

Learning objective number one

Identify main aspects of a Culture: Symbols, Values and Norms.

Like all the learning objectives in this lesson, this learning objective was implemented using only theoretical curriculum and applying direct teaching. However, this is the only learning objective that used digital technology tools for its delivery.

As a start of the lesson, the teacher showed the video (see Figure 280) for the students without giving any explanations, notes or comments. Students were asked to watch and note what they considered to be key concepts. Afterwards, the teacher asked 5 randomly picked students to say what they have picked up as essential terms. After a discussion with students, teacher replayed the video, however, this time, the teacher would pause the video and reexplain, analyse and discuss with the students, the key aspects of what a culture is. Table 115 and Table 116 show a more detailed explanation of key concepts discussed and activities that students were asked to make.

Curriculum	**Procedures**
Theoretical	As a start of the lesson, a video (see Figure 280) was shown to the students that spoke about culture in general and what are its main attributes, followed by teacher's explanations and discussion with students about the topic.
Pedagogy applied	**Procedures**
Direct teaching	The teacher gave explanations for the following points: 1. What is culture? It is the way that non-material and material objects come together to form a way of life. 2. Culture is made of two components: Material Culture (things) and Non-material culture (ideas) 3. Non-material culture is the intangible creation of humans, and it has three main components: symbols, values and beliefs, and norms. 4. Symbols have a specific meaning for people sharing a specific culture (like non-verbal gestures or language); 5. Values are the cultural standards that are used to decide what is good or bad, right or wrong. They serve as a guideline for people to live by. 6. Beliefs are people's ideas about what they think is true. 7. Norms are the rules and expectations that guide behaviour within a society (are the behaviours culturally acceptable "normal" or not?).
Digital technology integration	**Procedures**
Yes	Showing a video related to the culture and its attributes https://www.youtube.com/watch?v=kGrVhM_Gi8k&list=PL8dPuuaLjXtMJ-AfB_7J1538YKWkZAnGA&index=11 see Figure 280

Table 115. Summary of learning objective number one.

Students' tasks **Task 1**	- Students were asked to take notes and write down in their copy books the definitions of key concepts of the lesson that the teacher wrote on the board while explaining;
Task 2	- Individually students had to come up with a definition and example for each of the three aspects of non-material culture: symbols, values and beliefs, and norms. - The teacher randomly selected four students to read their examples to the rest of the class

Table 116. Activities that students were asked to complete for learning objective number one.

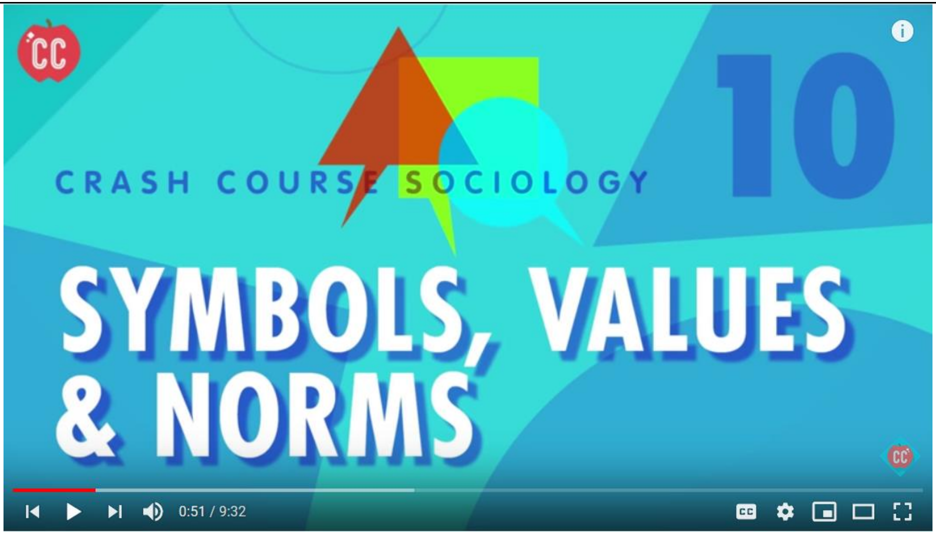

Figure 280. Video related to culture and its attributes © 2017 CrashCourse (https://www.youtube.com/watch?v=kGrVhM_Gi8k&list=PL8dPuuaLjXtMJ-AfB_7J1538YKWkZAnGA&index=1)

Learning objective number two

Define the key concepts of "cultural pluralism", "cultural relativism" and "cultural universals" and give at least one example of each of these concepts.

This learning objective was implemented using only theoretical curriculum and applying direct teaching. Students were using their books and copy books. Students did not have any access to digital technology. Table 117 outlines the implementation of learning objective 2.

Curriculum	**Procedures**
Theoretical	The teacher and students used textbook. Students were asked to answer questions in the textbook or their copybook.
Pedagogy applied	**Procedures**
Direct teaching	The teacher spoke and gave explanations for the following points: 1. Ever since creating UAE in 1971 country had created a multicultural (people from many different cultures) society. Moreover, even though the official language is Arabic, many other languages can be heard in UAE streets.

	2. Cultural pluralism: different cultures in one place, all keeping their own beliefs and cultural characteristics, but living together peacefully and respecting each other. 3. Expressions “salad bowl” and “melting pot” both deal with cultural pluralism, but in a different manner: a. Melting pot refers to the situation when all the immigrants are required to lose their cultural background and have one identity of the country; they are living in b. Bowl of salad refers to the situation when different nationalities adapt to co-exist in peace without compromising their own identity and culture 4. Cultural relativism is the idea about how we perceive other cultures through our own culture 5. Cultural Universals are things that exist in every culture throughout the world. Some examples might include language, family structures, education.
Digital technology integration	**Procedures**
N/A	No digital technology used

Table 117. Summary of learning objective number two.

Students' tasks Task 1	• Students were asked to complete an individual thinking task (MoE, 2016a, p. 20) **This figure has been removed due to Copyright restrictions.**
Task 2	• individually students were asked to read a citation of H.H. Sheikh Mohammed bin Rachid al Maktoum and complete thinking task (MoE, 2016a, p. 21) **This figure has been removed due to Copyright restrictions.**

Task 3	- Students were given image shown below and asked to write what they think and justify their thinking Question asked: is the UAE a Salad bowl or a Melting pot society?  Melting Pot or Salad Bowl Are we melting into one? Or are we still separate? Integrate? https://www.slideshare.net/mikejmoran/melting-pot-or-salad-bowl
Task 4	- Students individually were asked to describe in their words the three main terms “cultural pluralism”, “cultural relativism” and “cultural universals” with an example for each description. The teacher randomly picked three students to read their definitions and examples for these terms.

Table 118. Students’ tasks for learning objective number two.

Learning objective number three

Identify at least three shared traits between your own and another culture.

In this learning objective teacher dived more in-depth into the meaning of Cultural universals. Table 119 and Table 120 show the procedures of the implementation of this learning objective and the task that students had to complete.

Curriculum	**Procedures**
Theoretical	The teacher explained the topic following the textbook. Students were asked to complete the task given in their textbook (refer to Table 120 Figure 281).
Pedagogy applied	**Procedures**
Direct teaching	The teacher reminded that cultural universals are common traits between different cultures and nationalities. Although they are different for each country, still they are the same. For example, each country has its own language, body language and gestures. The teacher showed to the class in the form of a paper printed poster (see Figure 281) and explained each element.
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 119. Summary of learning objective number three.

Students' tasks	• Students were asked to identify at least three characteristics shared between UAE and any other country of their choosing.
Task 1	After completing the task, the teacher asked five randomly picked students to give their answers.

Table 120. Students' tasks for learning objective number three.

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However, it can be viewed via the link shown in the caption below.

Figure 281. paper print-out for the students showing some examples of the Cultural universals. (https://sites.google.com/site/mrmooressociology/vocabulary---sociology-terms/culture)

Learning objective number four

Compare and contrast ethnocentricity and cultural relativism with one example for each from your own and another culture.

In this learning objective, teacher dived deeper into the meaning of Cultural Relativism, comparing it to Ethnocentrism. Table 121 and Table 122 show the procedures of the implementation of this learning objective and the tasks that students had to complete.

Curriculum	**Procedures**
Theoretical	The teacher explained the topic following the textbook. Moreover, the teacher distributed some printed posters, as shown in Figure 282 and Figure 283.
Pedagogy applied	**Procedures**
Direct teaching	The teacher reminded students of the following points: • Cultural relativism is the theory that speaks about the idea that all beliefs, customs and ethics are relative to an individual within their own social context; • Ethnocentrism is when a person is judging other cultures through their own context and labelling "right" and "wrong" according to their own surrounding, without taking into consideration other cultures, their traditions and cultural norms. • The members of a multicultural society should be open-minded to other cultures, not to be judgemental and not to be stuck with the idea that other cultures are "wrong" and mine is the "correct". In other words "see past your nose" (see Figure 283, that was distributed to each student).
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 121. Summary of learning objective number four.

Students' tasks **Task 1**	• Individually students were asked to give a one-sentence explanation on how the given image shows ethnocentrism from the perspective of each woman? (see Figure 282). After completing the task, the teacher asked three randomly picked students to read their answers to the rest of the class.
Task 2	• Individually students were asked to think of another example of ethnocentrism that would involve their own and another culture (what cultural differences they have come across: it may be related to food, gestures, body languages, traditions, etc.). Students were asked to create a poster (draw and describe the situation).

Table 122. Students' tasks for learning objective number four.

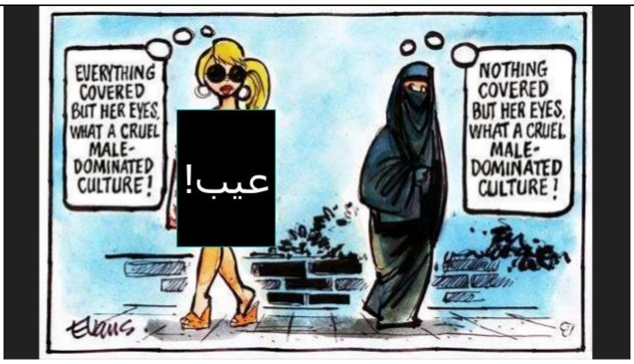

Figure 282. Image printout used to explain ethnocentrism ©newsphonereview.xyz 2016 (http://newsphonereview.xyz/cruel-male-dominated-culture-cartoon/)

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Copyright restrictions.

However, it can be viewed via the link shown in the caption below.

Figure 283. Image printout used to explain ethnocentrism (https://medium.com/@McCTaft/ethnocentrism-or-group-pride-2a54b767a2b1)

Learning objective number five

Express your opinion about given quotes (criticise or defend with your own arguments). Give positive and negative aspects of Universal Culture's influence on your daily life.

In this learning objective teacher involved students into observation and critical thinking activities helping to recognise the influence of various cultures on their daily life, as well as expressing their opinion and defending it with arguments regarding quotes that were said by others. The below Table 123 and Table 124 show the procedures of the implementation of this learning objective and the tasks that students were asked to complete.

Curriculum	**Procedures**
Theoretical	The teacher explained the topic following the textbook. Students were asked to complete tasks given in the textbook (see Table 124).
Pedagogy applied	**Procedures**
Direct teaching	In the implementation of this learning objective, the students were asked to complete two tasks individually (see Table 124).
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 123. Summary of learning objective number five.

Students' tasks **Task 1**	- Students were asked to complete individually the below task, which is given in their textbooks, p. 28 **This figure has been removed due to Copyright restrictions.** After completing the task, the teacher asked two randomly picked students to read their answers out loud to the class.
Task 2	- For their second tasks, students were asked to write on yellow sticky notes positive aspects of living in a multicultural society in their day to day living; and on red sticky notes negative aspects (if any) of living in a multicultural society in their daily life. After completing the task, students were asked to read to the class what they wrote and place their sticky notes on an A3 size poster prepared in advance by the teacher, divided into two parts (one half slightly bigger with the title "Positive effects", a smaller half labelled "Negative effects".

Table 124. Students' tasks for learning objective number five.

The Second Lesson: How does the UAE Exhibit the Core Values and Beliefs of "Universal Culture"? (C1, P1, T0)

The main objective of this lesson was to explore the UAE's Vision 2021 project and link it to the United Nations' Sustainable Development Goals that were set in 2016. In this strategy, C1, P1, T0, the teacher kept this lesson free of any digital technology (T0), employing only theoretical curriculum (C1) and using only direct teaching as the only type of pedagogy used (P1).

As the first lesson, to ensure that learning is taking place and students are getting the knowledge and understand it, the teacher used random selection strategy to ask students questions related to the explained topic. The teacher would explain the content, give individual assignments to students and would randomly pick those who would answer the question or read their answers to the rest of the class.

Learning objective number one

To introduce the Sustainable Development Goals (SDGs) set by the United Nations.

The lesson was started by revisiting Sustainable Development Goals (SDG) set by the United Nations in 2015. These goals were studied previously in lesson 1 of Unit 3 "What is meant by the term "Universal Culture"? (see Figure 279). Hence, the teacher brought back the poster that was created by the students showing all 17 goals. The poster was based on Figure 284, which represents these Sustainable Development Goals. However, the titles of the goals on the poster were covered with a sticky note and were uncovered step by step while students were answering their completed task. The exact procedures are explained below in Table 125 and Table 126.

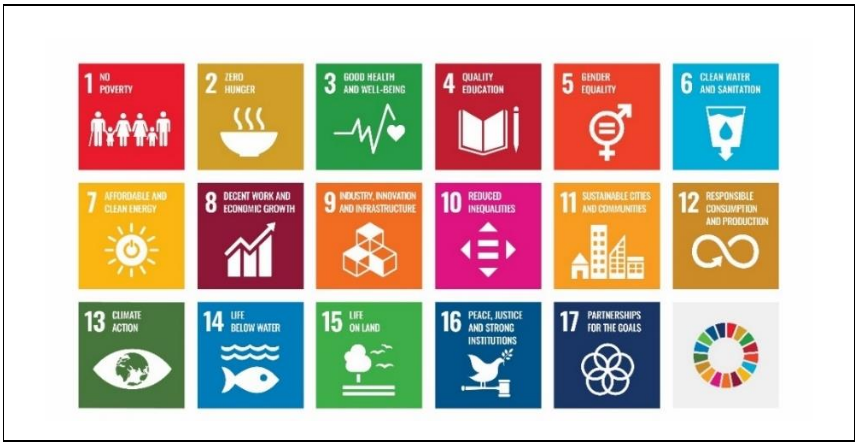


Figure 284. United Nations Sustainable Development Goals ©UnitedNations (https://www.un.org/sustainabledevelopment/news/communications-material/)

Curriculum	**Procedures**
Theoretical	The teacher reintroduced 17 Sustainable development goals using textbook and hardcopy poster, based on Figure 284.
Pedagogy applied	**Procedures**
Direct teaching	For the implementation of this learning objective, the teacher listed on the board all the Sustainable Development goals (not in the order that they appear on the poster): No poverty; Zero hunger; Good health and well-being; Quality education; Gender equality; Clean water and sanitation; Affordable and clean energy; Decent work and economic growth; Industry, innovation and infrastructure; Reduced inequalities; Sustainable cities and communities; Responsible consumption and production; Climate action; Life below water; Life on land; Peace, justice and strong institutions; Partnership for the goals While writing down each title, the teacher explained what each goal stands for and what is its goal. Students were asked to complete an activity detailed in Table 126
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 125. Summary of learning objective number one.

Students' task **Task 1**	- Each student was given a printout of UN's SDGs without titles (as shown below) and was asked to match each title with the corresponding icon for each of the goals and write them down.  After completing the task, the teacher asked randomly picked students to name each goal, while revealing one by one the titles if the students answered correctly.

Table 126. Students' tasks for learning objective number one.

Learning objective number two

Identify and describe four main key principles of UAE's Vision 2021.

Table 127 and Table 128 show the procedures of applied pedagogy, curriculum, and what tasks students were asked to complete to achieve this learning objective.

Curriculum	**Procedures**
Theoretical	The teacher introduced the content using the textbook
Pedagogy applied	**Procedures**
Direct teaching	The teacher introduced and explained the following ideas: - UAE government has launched Vision 2021 that is a project that focuses on national indicators in education, healthcare, the economy, police and security, housing, infrastructure and government services. - There are four key principals outlined in the Vision 2021 and six National Priorities that are set in order to accomplish the vision. They are:

	United in Responsibility (focused on improving social-economic environment): * *Cohesive society and Preserved identity*; *United in Destiny* (commitment to reduce social and economic gaps between people, make safe public and effective judicial system): * *Safe public and Fair Judiciary*; …..*United in Knowledge* (importance of diversifying the economy and developing a highly-skilled local workforce): * *Competitive knowledge economy*; *United in Prosperity* (for the entire UAE community to have best living standards to lead healthy and productive lives in a supportive and safe environment): * *Sustainable environment and infrastructure; * World-class healthcare; * First-rate education system.*
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 127. Summary of learning objective number two.

Students' task **Task 1**	Students were asked to match the titles of the six national priorities with the corresponding icon (image copied from https://www.vision2021.ae/en/national-agenda-2021 and modified to the matching activity by the teacher): 

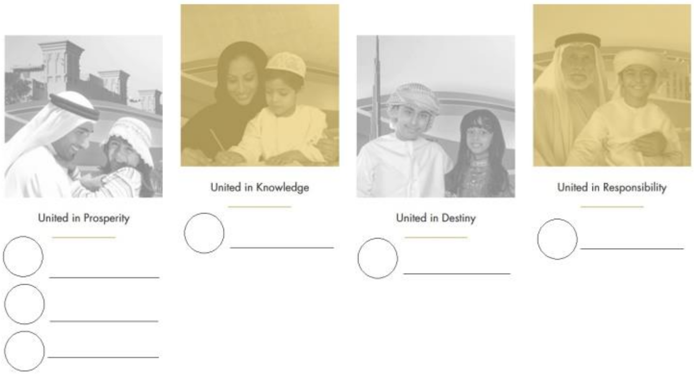
	
Task 2	Each student was given a worksheet and asked to: * write down the National priorities under the correct topic; and * draw the logo of each corresponding National priority in the circle next to the title. (image copied from https://www.vision2021.ae/en/uae-vision and adapted before printing by the teacher)   After completing the task, the teacher checked their answers.

Table 128. Students' tasks for learning objective number two.

Learning objective number three

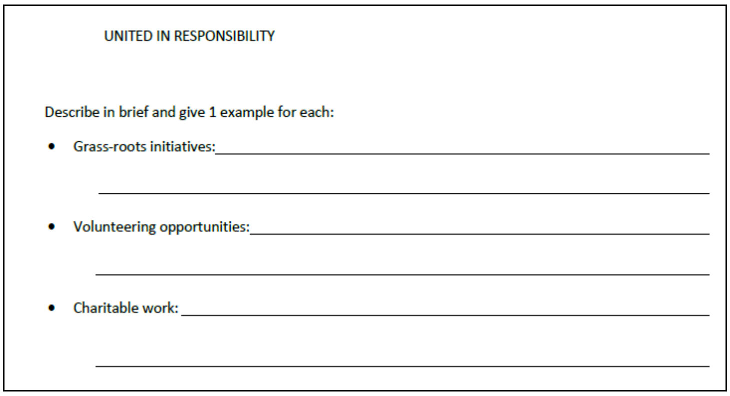
Explain the six National Priorities outlined in the Vision 2021 as the main areas of focus in achieving the set goals.

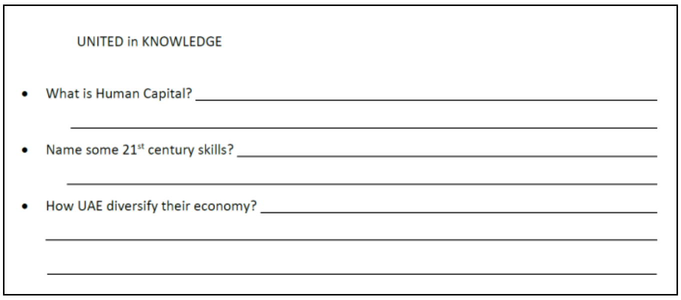
Table 129 and Table 130 show the procedures of the applied pedagogy, curriculum, and what tasks students were asked to complete to achieve this learning objective.

Curriculum	**Procedures**
Theoretical	The teacher introduced the content using the textbook
Pedagogy applied	**Procedures**
Direct teaching	The teacher explained more in detail each of the six National Priorities. The following points were discussed: • United in responsibility: is focused on improving the social-economic environment. Emphasising the duty towards their country, the importance of the family unit as well as active and strong communities. Encouraging every member of the community to participate in charitable work, volunteer and grass-roots initiatives (grass-route initiative is when various members of the society are working together to achieve the same goal) • United in destiny: committing to reduce social and economic gaps between all Emiratis. In order to enhance UAE's position in the international arena, it is important to continue dialogue between Emirati and other cultures; Safe public and fair judiciary – providing safe environment, helps the society to take care of their well-being; maintaining every individual's rights and having a transparent judiciary system, helps to create a fair, just and trusted system. • United in Knowledge: it highlights the importance of diversifying UAE economy and developing the highly skilled local workforce. *Maximising human capital*: installing "can do" attitude amongst the local population, reducing the gap between what is taught in schools and what is transferable to the workplace, teaching skills; *Sustainable and diversified economy* – moving away from only relying on the oil industry; developing sustainable energy sources like solar and wind energy; • United in Prosperity: goal is for all the UAE community to have the best living standards possible to live healthy and productive lives; it focuses on

	three main areas: *World-class health care* – it aims to provide medical services of the best quality for all, promote medical research; *First-rate educational system* – education helps develop responsible, reliable and productive members of the society; educational system not only providing high-quality education but also develop 21^{st}-century skills that are vital in today's modern world; *Sustainable environment and infrastructure* – government is investing substantially in clean, renewable energy sources and protect fragile ecosystems from urban development, ensure smooth transition to green economy, promote biodiversity.
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 129. Summary of learning objective number three.

Students' task **Task 1**	The teacher explained each of the parts (National Priorities) and asked students to complete various tasks, either in their textbooks or on the tasks paper provided by the teacher to each student. This is the paper task provided by the teacher (solving individually):  UNITED IN RESPONSIBILITY Describe in brief and give 1 example for each: - Grass-roots initiatives: - Volunteering opportunities: - Charitable work:
Task 2	Thinking task in the students' textbook, page 70 (solving individually) **This figure has been removed due to Copyright restrictions.**

Task 3	United in Destiny: checkpoint task, students textbook, p 72 (solving individually) **This figure has been removed due to Copyright restrictions.**
Task 4	The paper task provided by the teacher (solving individually)  UNITED in KNOWLEDGE • What is Human Capital? ____________________ • Name some 21^{st} century skills? ____________________ • How UAE diversify their economy? ____________________
Task 5	Action task in students' book, page 76 (solving individually) **This figure has been removed due to Copyright restrictions.**

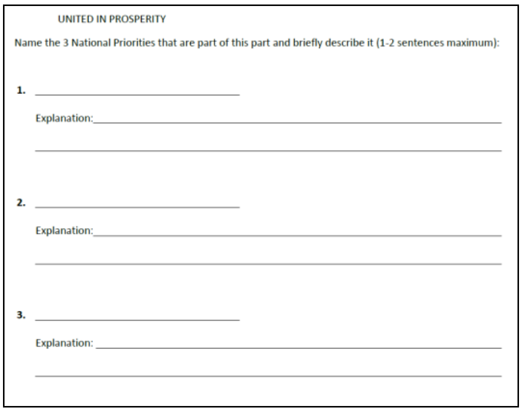
Task 6	The paper task, provided by the teacher (solving individually):  UNITED IN PROSPERITY Name the 3 National Priorities that are part of this part and briefly describe it (1-2 sentences maximum): 1. ______________________ Explanation:______________________ ______________________ 2. ______________________ Explanation:______________________ ______________________ 3. ______________________ Explanation: ______________________ ______________________

Table 130. Students' tasks for learning objective number three.

Learning objective number four

Show understanding of key concepts of UAE Vision 2021 project by comparing a specific principle of the project with United Nations Sustainable Development Goals and finding at least three common Universal values.

Table 131 shows the procedures of the implementation of learning objective number four.

Curriculum	**Procedures**
Theoretical	The teacher introduced the content using the textbook, SDG representing poster used in learning objective 1 (see Figure 284)
Pedagogy applied	**Procedures**
Direct teaching	• The teacher revisited the SDGs (displaying the poster of the goals) • The teacher read a poem by H.H. Sheikh Mohammed bin Rashid al Maktoum (student's textbook, p.79) and asked students to complete a slightly modified self-assessment task (see Table 132)
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 131. Summary of learning objective number four.

Students' task **Task 1**	Students were given Self-Assessment question from their textbooks, page 79. However, there were some modifications to the question. Students were asked to reread the poem, and a) underline the Sustainable Development goals that it reflects, and b) chose and describe 3 of the universal values that are common between this poem and SDGs (minimum of 100 words). After completing part (a) of the task, the teacher randomly picked students to read what are the goals that they underlined. After completing part (b), 3 randomly picked students were asked to read what they wrote about their 3 universal values. **This figure has been removed due to Copyright restrictions.**

Table 132. Students' task related to learning objective number four.

Learning objective number five

Think of specific way how you can contribute to achieving each of the key goals (1 example for each priority)

To achieve this objective, the following procedures were implemented (refer to Table 133 and Table 134).

Curriculum	**Procedures**
Theoretical	The teacher used the textbook
Pedagogy applied	**Procedures**
Direct teaching	• Teacher revisited the four key aspects of Vision 2021, and listed them down again on the board, for students' reference while they are completing their task: * United in Knowledge (Competitive Knowledge Economy) * United in Destiny (Safe Public and Fair Judiciary) * United in Responsibility (Cohesive Society and Preserved Identity) * United in Prosperity (Sustainable Environment and Infrastructure; World-class Healthcare; First-Rate Education System) • The teacher explained that each person has to contribute to their society and that only by committing to their goals, students can impact what is happening around them.
Digital technology integration	**Procedures**
N/A	No digital technology was used to implement this learning objective

Table 133. Summary of learning objective number five.

Students' task **Task 1**	The teacher prepared an A2 size poster with the divided and labelled 4 sections leaving the rest of it empty for students notes to be glued on. Each student was given 4 pieces of paper and was asked to think and write down what he/she can do to help UAE to reach their Vision 2021 (students were asked, but not limited, to give at least 1specific action that they could do for each of the key principles) After completing their writing, each student would read out loud their ideas to the class and stick their notes on the poster.

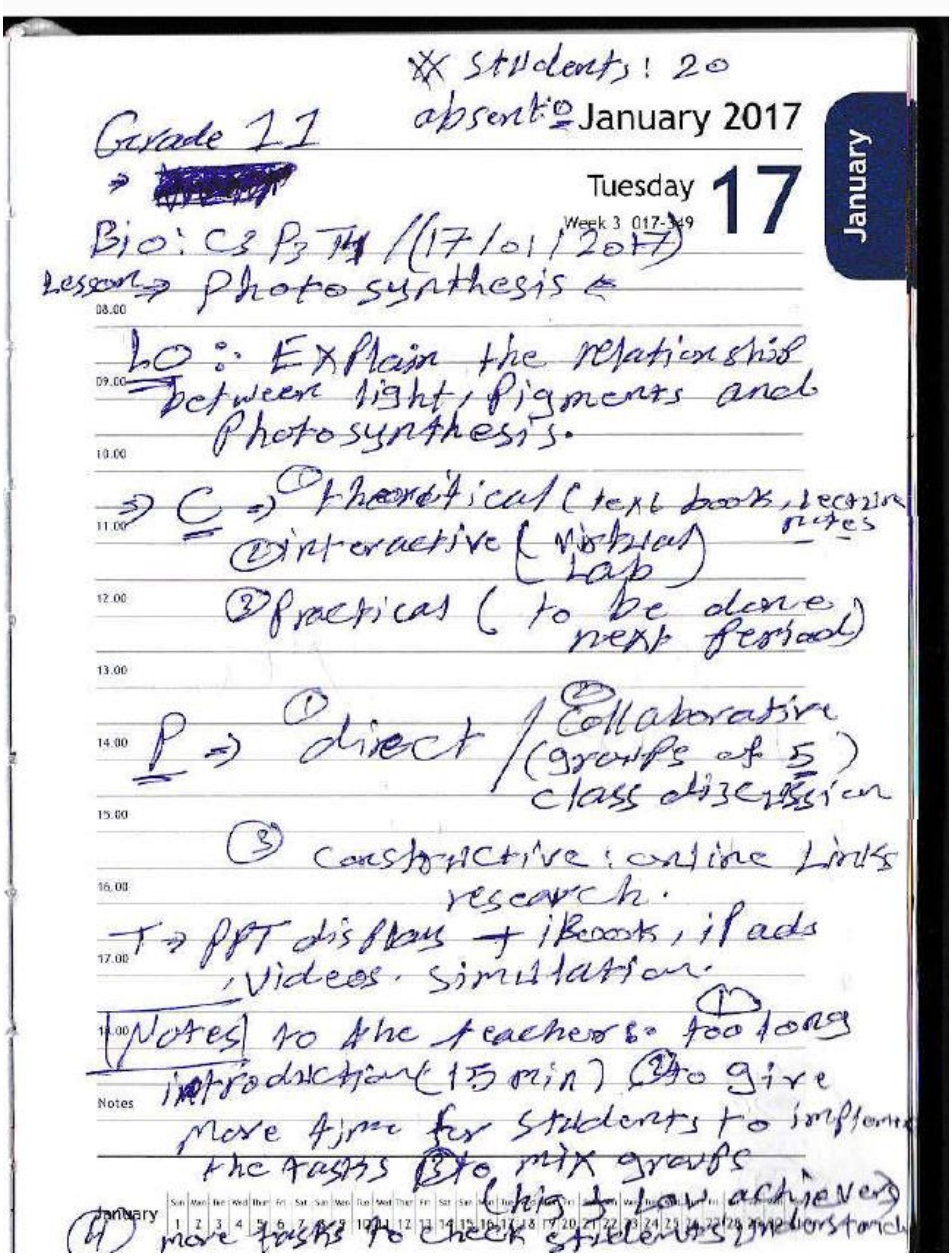
Table 134. Students' task related to learning objective number five.

APPENDIX SEVEN

Samples of Collected Notes During Lesson Observations

APPENDIX 7 – SAMPLES OF COLLECTED NOTES DURING LESSON OBSERVATIONS

Example 1: Biology (C3, P3, T4)



※ students: 20
absent: 0

Grade 11

January 2017

Tuesday 17

Week 3 017-349

January

→ [redacted]

Bio: C3 P3 T4 /(17/01/2017)

Lesson → Photosynthesis ←

08.00

LO: Explain the relationship between light, pigments and photosynthesis.

09.00

10.00

→ C ⇒ ① theoretical (text books, lecture notes)

11.00

② interactive (virtual Lab)

12.00

③ Practicals (to be done next period)

13.00

14.00

P ⇒ ① direct / ② Collaborative (groups of 5) class discussion

15.00

③ constructive: online Links research.

16.00

T ⇒ PPT display + iBooks, iPads, videos. simulation.

17.00

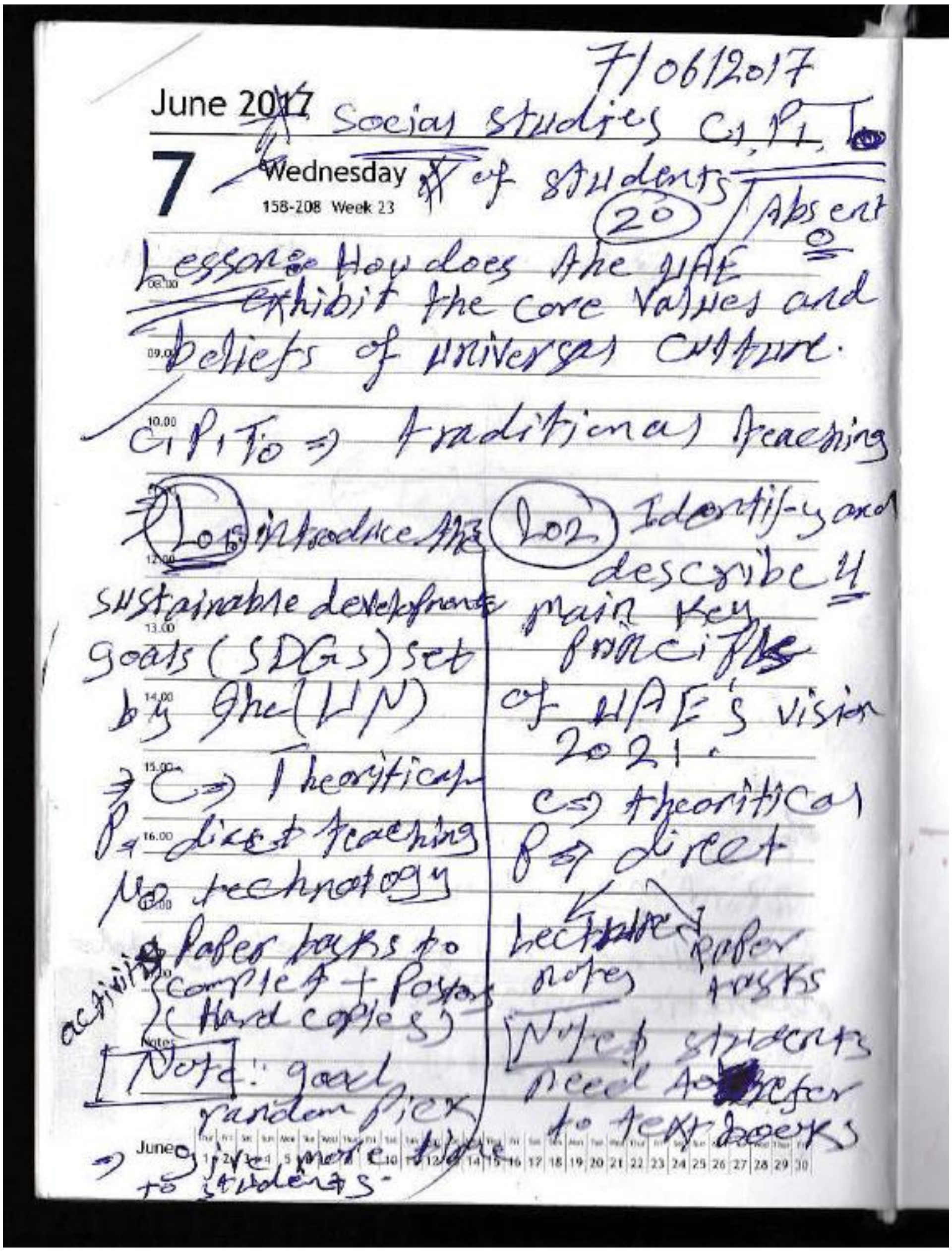
18.00

Notes to the teachers: ① too long introduction (15 min) ② to give more time for students to implem
the tasks ③ to mix groups (high & low achievers)
④ more tasks to check students' understand

Notes

January

Example 2: Social Studies (C1 P1 T0)



7/06/2017

June 2017 Social studies C1, P1, T0

7 Wednesday # of students (20) / Absent 0

158-208 Week 23

Lesson: How does the UAE exhibit the core values and beliefs of universal culture.

C1P1T0 ⇒ traditional teaching

(LO1) introduce the sustainable development goals (SDGs) set by the (UN)

→ C ⇒ Theoritical

P ⇒ direct teaching

No technology

activity { paper tasks to complete + Poster (Hard copies)

[Note]: good random pick

⇒ give more time to students.

(LO2) Identify and describe 4 main key principles of UAE's vision 2021.

C ⇒ theoritical

P ⇒ direct

Lecture notes

paper tasks

[Note] students need to refer to text books

APPENDIX EIGHT

Samples of Exams Conducted During This Study

APPENDIX 8 – SAMPLES OF THE EXAMS CONDUCTED DURING THIS STUDY

PHYSICS: C3, P3, T4 AND C3, P3, T0

(both physics exams were conducted in Term 1, academic year 2016/2017)

Student's Sequence Number		**Subject**	**Physics**
Grade	**11**	**Lesson title**	**Simple harmonic motion**
Duration	**One hour**	**Learning strategy**	**Digital technology-based learning**
Date		**Mark**	**/ 100**

I. Choose the best answer [36 marks, 4 each]

1. A spring has a spring constant of 5 N/m. What is its extension when loaded with 15 N? (Comprehension)

   A. 0.33 m

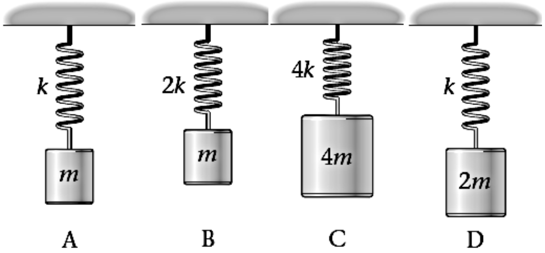
   B. 3.0 m

   C. 10 m

   D. 15 m

   E. 20 m

2. Rank the four mass-spring systems in the figure below in order of their increasing periods. (Application)



A. $A < B < C < D$

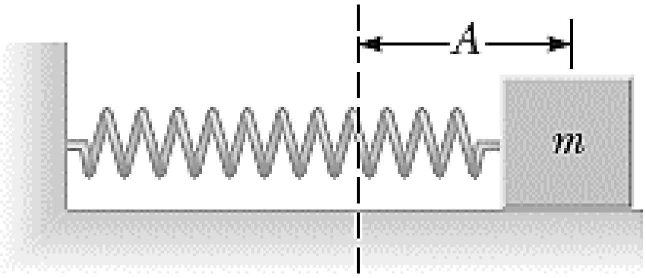
B. $A = B < D < C$

C. $B < A < D < C$

D. $B < A = C < D$

E. $D < A = C < B$

3. A block on the end of a spring is pulled to position $x = A$ and released. Through what total distance does it travel in one full cycle of its motion? (Comprehension)



A. $A/4$

B. $A/2$

C. A

D. $2A$

E. $4A$

4. An object of mass m is attached to a horizontal spring, stretched to a displacement A from equilibrium and released, undergoing harmonic oscillations on a frictionless surface with period T_0. The experiment is repeated with a mass of $4m$. What is the new period of oscillation? (Analysis)

A. $T_0/4$

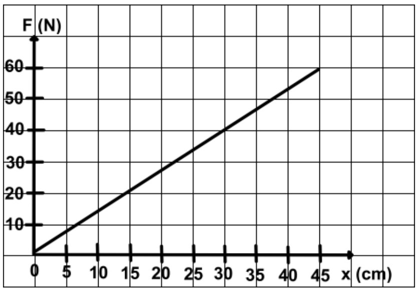
B. $T_0/2$

C. T_0

D. 2 T_0

E. 4 T_0

Questions 5 and 6: Different masses are attached to a spring, and a force-extension graph is obtained, as shown below.



5. What is the spring constant? (Application)

A. 1.33 N/m

B. 13.5 N/m

C. 133 N/m

D. 542 N/m

E. 1350 N/m

6. What is the elastic potential energy when the spring stretches from x = 0 cm to x = 30 cm? (Application)

A. 6.0 J

B. 13.5 J

C. 60 J

D. 120 J

E. 1350 J

7. What is the length of a simple pendulum if it has a period of 1.4 s on Earth? (Application)

   A. 0.22 m

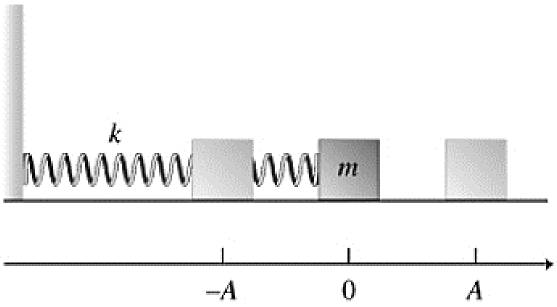
   B. 0.49 m

   C. 1.5 m

   D. 1.9 m

   E. 2.2 m

8. Consider a block of mass m attached to a spring with force constant k, as shown in the figure below. The spring can be either stretched or compressed. The block slides on a frictionless horizontal surface. When the spring is relaxed, the block is located at x = 0. If the block is pulled to the right a distance A and then released, through what total distance does it travel in half a cycle of its motion? (Analysis)



   A. A/4

   B. A/2

   C. A

   D. 2A

   E. 4A

9. In the previous question, if the oscillation has a frequency of (*f*). What is the new frequency if the mass is increased to 9m? (Analysis)

   A. *f* /9

   B. *f* /3

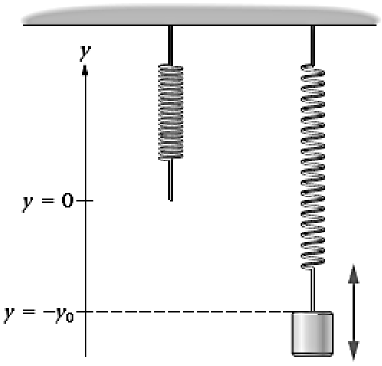
   C. *f*

   D. 3 *f*

   E. 9 *f*

II. Solve the following problems (figure's analysis) [51 marks]

10. A 0.260 kg mass is attached to a vertical spring which stretches to an equilibrium position of y = −y_0 as shown below. When the mass is put into motion, its period is 1.12 s.



a. Find the value of the spring constant? (Application) (9 marks)

$$T = 2\pi\sqrt{\frac{m}{k}}$$ 2 marks

$$k = \frac{4\pi^2 m}{T^2}$$ 2 marks

$$k = \frac{4\pi^2(0.260)}{1.12^2}$$ 2 marks

$k = 8.18\ N/m$ 2 marks for the answer, 1 for the unit

b. How much does the mass stretch the spring when it is at rest in its equilibrium position y = −y_0? (Analysis) (9 marks)

$$mg = ky_0$$ 2 marks

$$y_0 = \frac{mg}{k}$$ 2 marks

$$y_0 = \frac{(0.260)(9.8)}{8.18}$$ 2 marks

$y_0 = 0.311\ m$ 2 marks for the correct answer, 1 mark for the unit

c. Suppose this experiment is repeated on a planet where the acceleration due to gravity g is twice what it is on Earth. By what multiplicative factors do the following quantities change? (Evaluation) (6 marks)

i. The period.

Stays the same, as the period (T) is independent of g (3 marks)

ii. Equilibrium stretch y_0.

Since $y_0 = \frac{mg}{k}$. Thus, the new equilibrium stretch will be $2y_0$ (3 marks)

11. A simple pendulum of length 57 cm makes 80 complete oscillations in 2.00 min.

a. Find the period of the pendulum. (Application) (8 marks)

$$T = \frac{The\ total\ time\ (in\ seconds)}{The\ number\ of\ cycles} \qquad 3\text{ marks}$$

$$T = \frac{2*60}{80} \qquad 2\text{ marks}$$

$T = 1.5\ s$ 2 marks for the correct answer, 1 mark for the unit

b. Find the acceleration due to gravity at the location of this pendulum. (Application) (10 marks)

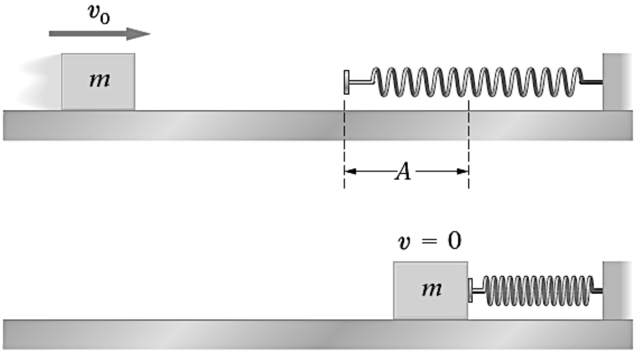
$$T = 2\pi\sqrt{\frac{l}{g}} \qquad 3\text{ marks}$$

$$g = \frac{4\pi^2 l}{T^2} \qquad 2\text{ marks}$$

$$g = \frac{4\pi^2 0.57}{1.5^2} \qquad 2\text{ marks}$$

$g = 10\ m/s^2$ 2 marks for the correct answer, 1 mark for the unit

12. *A* 0.980 kg block slides on a frictionless, horizontal surface with a speed of 1.32 m/s. The block encounters an unstretched spring with force constant of 245 N/m, as shown in the sketch. How far is the spring compressed before the block comes to rest? (Analysis) (9 marks)



$K.E\ max = P.E\ max$ 2 marks

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$ 2 marks

$\frac{1}{2}(0.980)1.32^2 = \frac{1}{2}(245)(x)^2$ 2 marks

$x = 0.0835\ m$ 2 marks for the correct answer, 1 mark for the unit

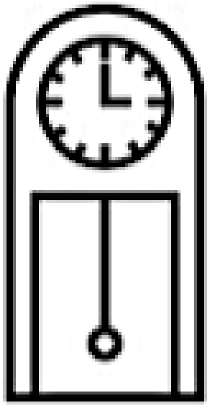
III- Conceptual questions [13 marks]

13. If a pendulum is suspended from a ceiling of a stationary elevator, and its period is recorded as 0.5 s. If the elevator now accelerates upward, will the period increase, decrease or remain the same? Explain. (Analysis) (5 marks)

As the elevator accelerates upward, the apparent value of g increases (2 marks). Hence, from the equation $T = 2\pi\sqrt{\frac{l}{g}}$ (2 marks). The period T should decrease (1 mark)

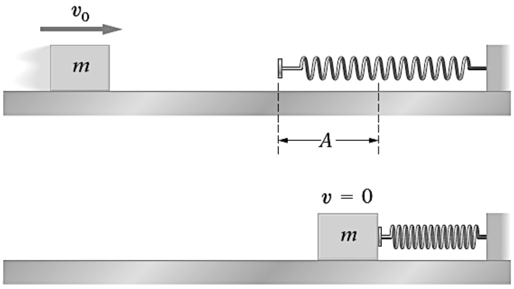
14. A traditional clock contains a simple pendulum, as shown in the figure below. If the clock keeps perfect time on the surface of Earth, will it keep the same time when it is moved to the surface of the moon? Justify your answer. (Comprehension)

(4 marks)



The time given by the clock depends on the period of the simple pendulum (1 mark). Since the period depends on the gravitational acceleration (1 mark), the time given by the clock will change when it is moved to the moon (2 marks).

15. In the following figure. If the initial speed of the mass is increased, how does the time required to bring the block to rest vary? Explain. (Analysis) (4 marks)



Increasing the initial speed increases the amplitude (2 marks). The period is independent of amplitude and so the time remains the same (2 marks)

End of the Quiz

ثانوية التكنولوجيا التطبيقية
Applied Technology High School

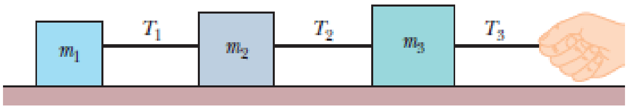
STS
المدرسة الثانوية الفنية
Secondary Technical School

Student's Sequence Number		**Subject**	**Physics**
Grade	**11**	**Lesson title**	**Newton's second law**
Duration	**One hour**	**Learning strategy**	**Nondigital technology-based learning**
Date		**Mark**	**/ 100**

I. Choose the best answer [36 marks, 4 each]

Questions 1& 2: In the figure below, three connected blocks are pulled to the right on a horizontal frictionless table by a force of magnitude $T3$ = 65 N. If $m1$ = 12 kg, $m2$ = 24.0 kg, and $m3$ = 31kg.

1. What is the magnitude of the system's acceleration? (Application)

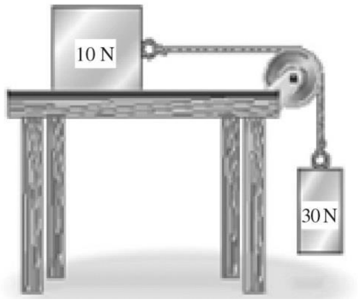


A. 0.57 m/s^2
B. 0.67 m/s^2
C. 0.77 m/s^2
D. 0.87 m/s^2
E. 0.97 m/s^2

2. What is the magnitude of the tension force $T1$? (Application)

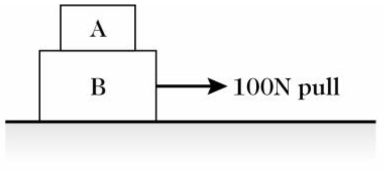
A. 11.4 4N
B. 11.54 N
C. 11.64 N
D. 11.74 N
E. 11.84 N

3. Two boxes are connected by a string, as shown in the figure below. The 10 N box moves without friction on the horizontal table surface. The pulley is ideal, and the string has negligible mass. What is true about the tension T in the string? (Application)

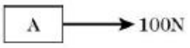


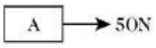
A. T = 30 N
B. T = 20 N
C. T < 30 N
D. T = 10 N
E. T > 30 N

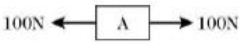
4. Two blocks, A and B, are being pulled to the right along a horizontal surface by a horizontal 100 N pull, as shown below. Both of them are moving together at a constant velocity of 2.0 m/s to the right, and both weigh the same. (comprehension)



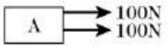
Which of the figures below shows a correct free-body diagram of the horizontal forces acting on the upper block, A?

A.


B.


C.


D.


E.


5. A dog that weighs 500 N at rest on the Earth's surface is standing on a scale on the floor of an elevator. The elevator is accelerating upward in the Earth's gravitational field at a rate of 9.8 m/s^2. What does the scale read? (Application)

   A. 0 N
   B. 250 N
   C. 500 N
   D. 1000 N
   E. 2000 N

6. A student that has a mass of 100 kg is standing on a scale in an elevator car. The elevator is accelerating downward at 5 m/s^2 in the Earth's gravitational field. The reading on the scale in the elevator is most nearly (Application)

   A. 150 N
   B. 500 N
   C. 1000 N
   D. 1500 N
   E. 50 N

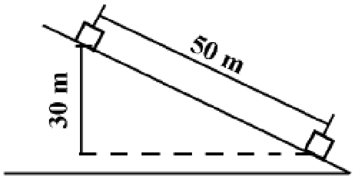
7. How much force is required to vertically lift an object of mass M with acceleration g? (Comprehension)

   A. Mg
   B. 2Mg
   C. Mg2
   D. $2Mg^2$
   E. M /g

8. A wagon of mass m is pulled by a string parallel to its direction of motion. If there is frictional force F acting on the wagon and the tension in the string is T, what is the acceleration of the wagon? (Analysis)

   A. (T – F)/m
   B. (F – T)/m
   C. T/m
   D. (F + T)/m
   E. (F + T) m

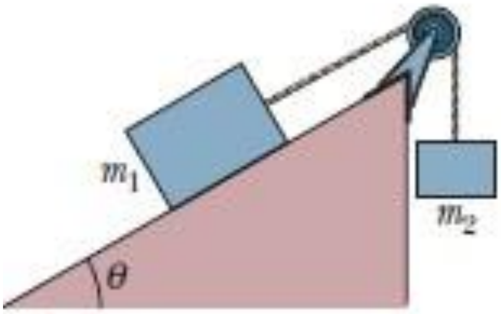
9. Base your answer to the following question on the picture below which shows a 3 kg block sliding 50 m down a frictionless inclined plane dropping a distance of 30 m. What is the magnitude of the acceleration for the block? (Analysis)



A. 3 m/s^2
B. 4 m/s^2
C. 6 m/s^2
D. 8 m/s^2
E. 10 m/s^2

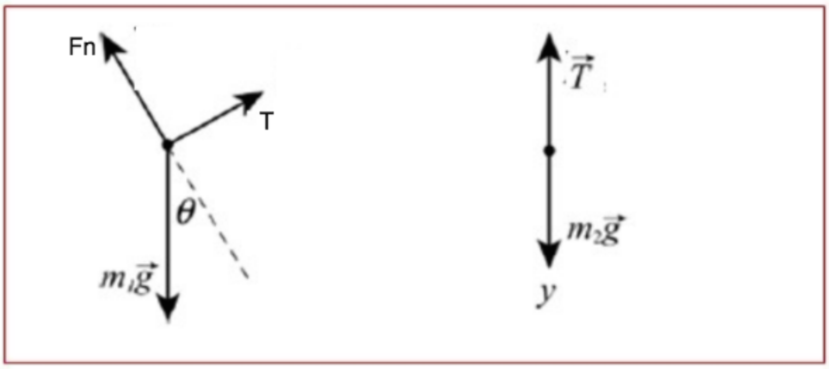
II. Solve the following problems (Figure's analysis) [51 marks]

10. A block of mass $m1$ = 3.7 kg on a frictionless plane inclined at angle 30° is connected by a cord over a frictionless pulley to a second block of mass $m2$ = 2.3 kg, as shown below.



a. Draw a free-body diagram for each block? (Analysis)

(10 marks, 2 marks for each force)



b. What is the magnitude of the acceleration of each block? (Analysis) (11 marks)

$$T - m_1 g \sin\theta = m_1 a$$ 2 marks

$$m_2 g - T = m_2 a$$ 2 marks

$$m_2 g - m_1 g \sin\theta = m_1 a + m_2 a.$$ 2 marks

$$a = \frac{(m_2 - m_1 \sin\theta)g}{m_1 + m_2} = \frac{[2.30\text{ kg} - (3.70\text{ kg})\sin 30.0°](9.80\text{ m/s}^2)}{3.70\text{ kg} + 2.30\text{ kg}} = 0.735\text{m/s}^2.$$

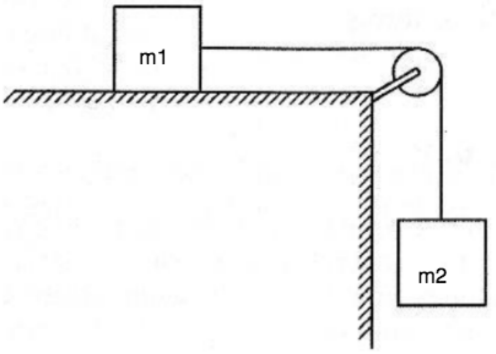
2 marks for correct substitution, 2 marks for the correct answer, 1 mark for the unit.

c. What is the direction of the acceleration of the hanging block? (Analysis/Evaluation) (3 marks)

Vertically Down

11. Two blocks of identical masses of 8 kg each are connected by a light string as shown below. The pulley is massless consider the surface of the table is frictionless.

a. What is the acceleration of both blocks? (9 marks) (Analysis)



T = m1a (2 marks)

m2g -T=m2a (2 marks)

By adding these two equations:

m2g = (m1+m2)a (1 mark)

Hence,

$a = \frac{m2g}{(m1+m2)}$ (1 mark)

$a = \frac{8\times9.8}{(8+8)}$ (1 mark)

$a = 4.9\ m/s^2$ (1 mark for the correct answer, 1 mark for the unit)

b. Find the tension force in the rope. (Application) (6 marks)

$T = m1a$ (2 marks)

$T = 8 \times 4.9$ (2 marks)

$T = 39.2\ N$ (1 mark for the correct answer, 1 mark for the unit)

12. In a game of tug-of-war, a rope is pulled by a force of 75 N to the left and by a force of 102 N to the right. **(12 marks)**

   a. What is the magnitude and direction of the net horizontal force on the rope? (Application) (6 marks)

F_{net} = F1 - F2 (2 mark)

F_{net} = 102 – 75 (2 mark)

F_{net} = 27 N, to the right (1 mark for the correct answer, 1 mark for the direction)

   b. What is the acceleration of the rope; consider the rope's mass is 1.0 kg? (Application) (6 marks)

$F_{net} = m\ a$ (2 marks)

$a = \frac{27}{1.0}$ (2 marks)

$a = 27\ m/s^2$ (1 mark for the correct answer, 1 mark for the unit)

III- Conceptual questions **(13 marks)**

13. A constant force applied to object A causes an acceleration of 5 m/s^2. The same force applied to object B causes an acceleration of 3 m/s^2. Applied to object C, it causes an acceleration of 8 m/s^2. (Comprehension)

   a. Which object has the largest mass? B (2 marks)

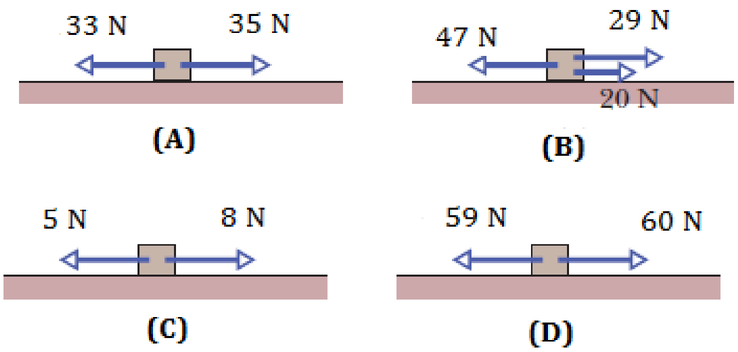
   b. Which object has the smallest mass? C (2 marks)

   c. What is the ratio of the mass of A to the mass of B? 3/5 (2 marks)

14. If an object is at rest, can you conclude that no forces are acting on it? Explain. (Analysis) (3 marks)

No (1 mark), the object's state of rest only tells about the net force or vector sum of forces, which must be zero (2 marks).

15. The figure below shows the same box in four situations where horizontal forces are applied. Rank the situations according to the magnitude of the box's acceleration, greatest first. (Analysis) (4 marks)



Greatest acceleration (C), then the acceleration of (A) = acceleration of (B), then the acceleration of (D)

1 mark for each correct answer

End of quiz

BIOLOGY: C3, P3, T4 AND C3, P3, T0

Comparison of the conducted exams during this study – Biology subject

Table 135 shows a description of the parts that were included in each exam for both lesson's, cellular respiration and photosynthesis. These lessons were conducted to check the impact factor while applying the C3, P3, T4 strategy in Biology. The first lesson, photosynthesis, was delivered using digital technology-based learning. The second lesson, cellular respiration, was delivered without using digital technology, nondigital technology-based learning.

Lesson Title	**Part number**	**Category**	**The weight of each part out of 100 %**	**The number of questions in each part**
Both lessons, cellular respiration and photosynthesis	I	Multiple choices questions	40 %	10
Both lessons, cellular respiration and photosynthesis	II	Figure's analysis	48 %	2
Both lessons, cellular respiration and photosynthesis	III	Conceptual questions	12 %	4

Table 135. The main parts of each exam

Table 136 and Table 137 show the cognitive level, Bloom's taxonomy stage, of the questions included in each part of the exams conducted.

Cognitive level / **Part number**	**Knowledge**	**Comprehension**	**Application**	**Analysis**	**Evaluation**	**Synthesis**
Part I	3 questions	4 questions	1 question			2 questions
Part II				1 question (several branches)		1 question (several branches)
Part III	2 questions	2 questions				

Table 136. The cognitive levels included in the photosynthesis exam

Cognitive level / **Part number**	**Knowledge**	**Comprehension**	**Application**	**Analysis**	**Evaluation**	**Synthesis**
Part I	3 questions	4 questions		2 questions		1 question
Part II				1 question (several branches)		1 question (several branches)
Part III	2 questions	2 questions				

Table 137. The cognitive levels included in the cellular respiration exam

Note: the cognitive level of each question is shown in the exams.

Table 136 and Table 137 show the included cognitive levels in each exam. Part I in both exams, comprises seven out of ten questions that focus on low order cognitive skills (LOCS), knowledge and comprehension, and three out of ten questions requiring high order cognitive skills (HOCS), application, analysis, and synthesis.

Part II in both exams comprises questions are deemed as high order cognitive skills (HOCS): analysis and synthesis. Part III in both exams focus on low order cognitive skills (LOCS): knowledge and comprehension. Being aware that the weight (out of 100%) of each part is equal in both exams. For instance, the total mark for the part I in both exams is 40 %, and so on for parts II and III, see Table 135.

As an overall view, in both exams approximately, 50 per cent of the questions required Low cognitive level, and the other 50 per cent needed a high cognitive level. Thus, the exams' level of complexity was described by the teacher as suitable for all students. Based on Table 136 and Table 137, it can be stated that both exams have approximately the same level of cognitive complexities.

Samples of the conducted exams during this study – Biology subject (both exams were conducted in term 2, academic year 2016/2017)

ATHS
ثانوية التكنولوجيا التطبيقية
Applied Technology High School

STS
المدرسة الثانوية الفنية
Secondary Technical School

Student's Sequence Number		**Subject**	**Biology**
Grade	**10**	**Lesson title**	**Photosynthesis**
Duration	**One hour**	**Learning strategy**	**Digital technology-based learning**
Date		**Mark**	**/ 100**

I- Choose the best answer. [40 marks, 4 each]

1. One of these statements describes how energy is released from ATP: (comprehension)

   A. The ribose sugar is utilized by cellular respiration process

   B. The bond between phosphate groups is reformed

   C. The bond between the phosphate group and ribose sugar is broken

   √ D. The bond linking two phosphate group is broken

2. ATP is considered the main usable form of energy in the human body. Which of these statements support this fact: (Comprehension)

   A. ATP has three phosphate groups

   B. Muscle contraction needs a lot of ATP

   C. Food is utilised to produce ATP

   √ D. B and C

3. Organism X produces ATP by utilising the self-produced organic material. Organism X is: (Synthesis)

A Heterotrophic organism

B Predator

C Herbivores

√ D Autotrophic organism

4. Photosynthesis is best described as: (Comprehension)

A. The process of releasing energy from self-produced food

B. The process of converting chemical energy into solar energy

√ C. The process of utilising solar energy to produce organic material

D. The process of utilising food to produce ATP

5. The ……….Photosynthetic stage acts as …………..for the ………… stage: (knowledge)

A. Second/source of inorganic material/first

B. First/source of inorganic material/second

C. Second/source of energy/first

√ D. First/source of energy/second

6. Water and carbon dioxide are reactants of the photosynthetic reaction. Water is …………..during the ……….. stage, and carbon dioxide is ………..during the …………stage: (Knowledge)

  - A. Reduced/light dependent/oxidized/light independent
  - B. Oxidized/light independent/reduced/light dependent
  - C. Oxidized/Calvin cycle/reduced/light independent stage
  - √ D. Oxidized/light dependent/reduced/Calvin cycle

7. Based on the photosynthetic reaction,………. Carbon dioxide molecules needed to produce three glucose molecules: (Application)

  - A. 12
  - B. 36
  - √ C. 18
  - D. 15

8. Calvin cycle utilises the energy produced by……………..to…………..carbon dioxide into sugar: (comprehension)

  - A Light independent stage/reduce
  - B Dark reaction stage/oxidize
  - C Light dependent stage/oxidize
  - √ D None of the above

9. Calvin cycle needs the following to start: (Knowledge)

	A	CO2/NADP+/ATP
	B	ATP/Sugar/NADPH
√	C	CO2/ATP/NADPH
	D	ATP/NADPH

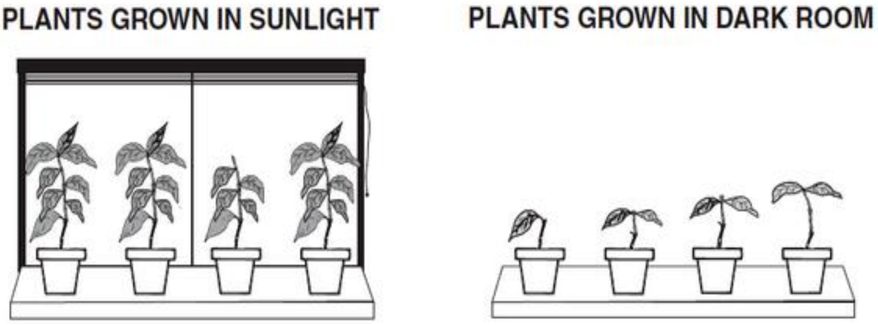
10. A student wanted to prove that oxygen is a waste product of photosynthesis. Which one of these steps is suitable to achieve that goal through a lab experiment: (Synthesis)

	A.	Put the plant in the dark during the experiment
	B.	Provide the plant with all photosynthesis needed material and use CO2 detector
√	C.	Provide the plant with all photosynthesis needed material and use O2 detector
	D.	All of the above

II. Figure Analysis

11. Refer to figure 1 and answer questions a-c. **[48 marks]**

Figure 1


PLANTS GROWN IN SUNLIGHT

PLANTS GROWN IN DARK ROOM

OBSERVATIONS

Plant Feature	Plants Grown in Sunlight	Plants Grown in Dark Room
Leaves	Dark green	Light yellow
Stem	Green and sturdy	Yellow and wilted
Average Plant Height	30 cm	18 cm

a. List two dependent variables? (Analysis) **[4 marks, 2 each]**

Colour of the leaves
Average plant height

b. What conclusion can be drawn from the above experiment? (Synthesis)

[4 marks]

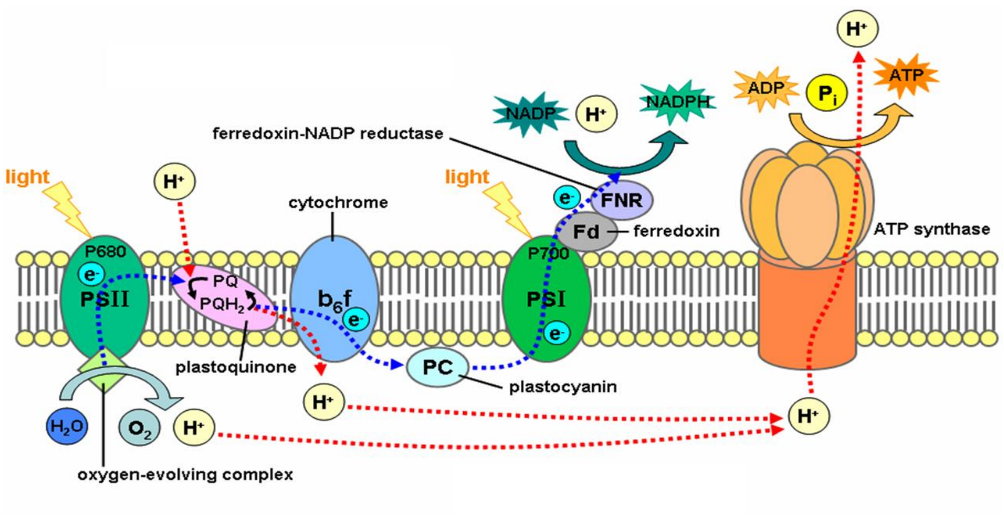
Energy from the sun is essential for plant growth.

c. Name two controlled variables and explain the importance of controlled variable for the experiment. (Synthesis/knowledge) **[6 marks, 2 each]**

Type of the soil
Type of the plant
The controlled variable is vital to make sure that the obtained results are due to the tested variable only.

12. Refer to figure 2 and answer questions a-f regarding photosynthesis.

Figure 2



a. Specify the photosynthetic stage represented in the figure? Justify your answer. (Analysis) **[4 marks, 2 each]**

The stage is light-dependent stage.
Justification: light is involved in the process.

b. Depending on your answer in part "a", determine which structure is represented in the figure. (Synthesis) **[4 marks]**

The structure represented is the thylakoid membrane.

c. Identify three roles of water according to the figure. (Analysis) **[6 marks, 2 each]**

Water provides electrons to the electron transport chain.
Water provides hydrogen ions.
Water is the source of oxygen.

d. What can you conclude about PS1 and PS2 represented in the figure? Justify your answer. (Analysis/Synthesis) **[6 marks, 3 each]**

PS1 and PS2 are sites of chlorophyll pigment.
Justification: light is being absorbed by these structures only.

e. Sequence the flow of electrons according to the figure. (Analysis).

[8 marks, 1 each]

PS2>>PQ>>b6f>>PC>>PS1>>Fd>>FNR>>NADP

f. Identify all the products of the above photosynthetic stage and specify their final fate. (Analysis/knowledge) **[6 marks]**

The product are: Oxygen, ATP, and NADPH [1 mark each]
Oxygen will be released outside the plant. [1 mark]
ATP and NADPH [2 marks, 1 each] will be used in the second photosynthetic stage (Calvin cycle) [1 mark]

III- Conceptual Questions **[12 marks]**

13. Write the overall balanced photosynthetic equation. (Knowledge)

[2 marks]

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

14. How is chloroplast well designed to accomplish its function? (Comprehension)

[4 marks]

The chloroplast is a plant cell organelle responsible for trapping solar energy (1 mark). It is structured with pigments located with the membrane of small sac-like structures called thylakoids (2 marks). These pigments absorb light waves with different wavelength and act as a generator for the whole process of photosynthesis (1 mark).

15. Light is one of the important factors needed for photosynthesis. Use your knowledge about the role of chloroplast during the light-dependent stage to describe the importance of light for the whole photosynthetic process. (Comprehension)

[4 marks]

During the light-dependent stage, chlorophyll pigment located within the thylakoid membrane absorbs the light and stimulate the electrons (in the reaction centre) within the pigment to move toward the electron carriers in the electron transport chain (1 mark). These electrons will be gained by the electron carrier NADP+ that will be converted into NADPH that is used during Calvin cycle (1 mark). In addition to that, light splits the water molecules into hydrogen ions, electrons, and oxygen. The hydrogen ions from a gradient used to add a phosphate group to the ADP molecule to produce ATP that will be used in Calvin cycle with NADPH (1 mark). Electrons from water will compensate those electrons being transferred from the PS2 and the process will repeat (1 mark).

16. Specify where each of the photosynthetic stages occurs? (Knowledge)

[2 marks, 1 each]

Light-dependent stage occurs in the thylakoid membrane.

Light independent stage occurs in the stroma of the chloroplast.

End of the Quiz

Student's Sequence Number		**Subject**	**Biology**
Grade	**10**	**Lesson title**	**Cellular respiration**
Duration	**One hour**	**Learning strategy**	**Nondigital technology-based learning**
Date		**Mark**	**/ 100**

I- Choose the best answer. **[40 marks, 4 each]**

1. Cellular respiration is best described as: (Comprehension)

   A. The process of oxidising ATP to get energy
   B. The process of utilising food to produce carbon dioxide
   √ C. The process of utilising energy in food to produce ATP
   D. The process of releasing water from food

2. Both cellular respiration and photosynthesis: (comprehension)

   A. Produce energy
   B. Use oxygen
   C. Have byproducts
   √ D. A and C

3. During the………… stage of cellular respiration, oxygen is used as……: (Knowledge)

   A First/source of electrons
   B Second/final electron acceptor
   C Third/source of electron
   √ D Third/final electron acceptor

4. Anaerobic respiration differs from aerobic respiration in: (comprehension)

A. The efficiency of producing energy

B. The way of using oxygen

C. Reactants needed in the overall equation

√ D. A and C

5. Ahmad had been running for 60 minutes before he felt that he has to stop to avoid any health problem. Which source of energy Ahmad was using a few minutes before he stopped running: (Synthesis)

A Aerobic cellular respiration

B Kreb's cycle

√ C Anaerobic cellular respiration

D Alcoholic fermentation

6. Which of the following is/are oxidised in the equation below? (Knowledge)

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

A Carbon dioxide

√ B Glucose

C Oxygen

D Water

E Water and glucose

7. A particular drug was found to block the action of NAD^+ in the cell. Which of the following is a correct direct consequence for the action of this drug? (Analysis)

√ A Glucose will not be oxidised in the cytoplasm

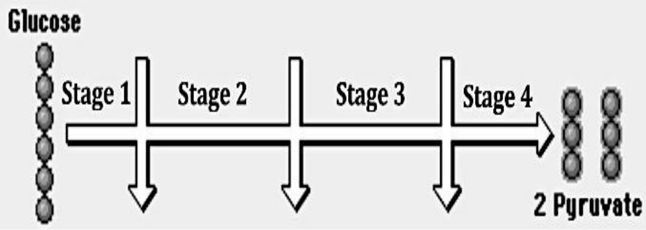
B Mitochondria will only perform the first stage of cellular respiration

C Oxygen will be converted directly to carbon dioxide

D Pyruvate will accumulate in the cytoplasm

E Water will split into hydrogen and hydroxide ions

8. Which process is shown in the diagram below? (comprehension)



A Fermentation

B Electron transport chain

√ C Glycolysis

D Oxidative phosphorylation

E Pyruvate reduction

9. Which of the following is correct about FAD? (Analysis)

A Acts as a reducing agent
B Used in the cytoplasmic reactions of cellular respiration
C Only required when oxygen is absent
√ D Has a role in the Krebs cycle
E Splits down to produce enzymes used in cellular respiration

10. Which of the following is produced during the electron transport chain? (knowledge)

A. ADP
B. Carbon dioxide
C. NADH
D. Oxygen
√ E. Water

II. Figure's Analysis [48 marks]

11. The apparatus shown below was used in a series of experiments to study aerobic respiration. Read the given and refer to figure 1 to answer questions a-c. In three different experiments, the reaction tube initially contained the following:

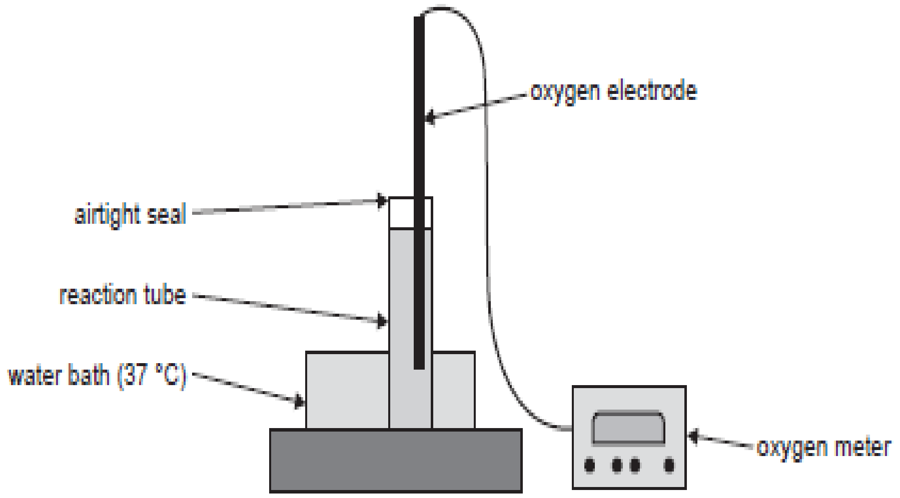
1. Suspension of mitochondria

2. The cytosol of cells from which the mitochondria had been removed

3. Suspension of mitochondria and cytosol of cells

In each experiment, a solution containing glucose was first added to the mixture in the reaction tube, and the oxygen concentration was measured for three minutes. Then, a pyruvate solution was added, and the oxygen concentration was measured again for three minutes. **(34 marks)**

Figure 1



a. Identify the dependent and independent variable in the experiment. (Analysis)

[6 marks, 3 each]

Independent variable: components of the solution in the reaction tube.
Dependent variable: the amount of oxygen being used.

b. Specify the result of each experiment. Justify your answer. (Analysis).

Experiment 1:

Adding glucose will not result in changing oxygen concentration since mitochondria use pyruvate as a starter reactant. **[3 marks]**

Adding pyruvate will result in reducing the oxygen amount since pyruvate is the starter reactant of the Kreb's cycle that occurs in the stroma of mitochondria. **[3 marks]**

Experiment 2:

Oxygen concentration will stay constant after adding glucose or pyruvate. After adding glucose, glycolysis will progress, but it does not need oxygen **[3 marks]**

while after adding pyruvate nothing will happen since there is no mitochondria for Kreb's cycle to occur. **[3 marks]**

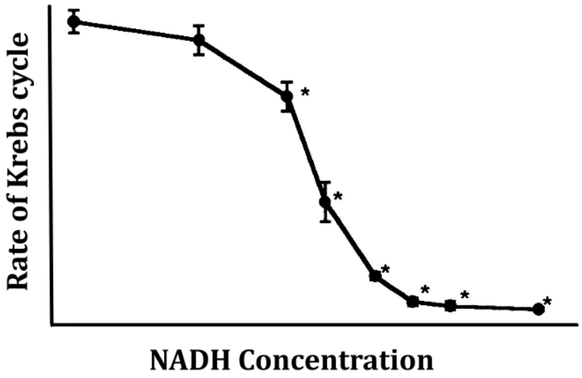
Experiment 3:
Oxygen concentration will decrease after adding glucose and after adding pyruvate **[4 marks]**.
Glucose will be utilised during glycolysis in the cytoplasm and will be converted into pyruvate that will be used during the Kreb's cycle in the stroma of mitochondria (Kreb's, ETC need oxygen)
[4 marks].

c. Identify all the products of the above photosynthetic stage and specify their final fate. (Analysis)

The product are: Oxygen, ATP, and NADPH **[4 marks]**
Oxygen will be released outside the plant. ATP and NADPH will be used in the second photosynthetic stage (Calvin cycle) **[4 marks]**

12. Use the graph below, which shows how the rate of Kreb's cycle changes with the NADH concentration values, to answer questions **a**-**c**.

[14 marks]



a. Describe **one** conclusion that can be drawn from the results shown by the graph. (Synthesise) **(5 marks)**

As the concentration of the NADH increases, as the rate of Kreb's cycle decreases in the cell.

b. Based on your knowledge of the Krebs cycle, explain the trend shown in the graph. (Analysis) **(4 marks)**

Kreb's cycle involves oxidation reactions that reduce NAD^+ into NADH (1 mark). As the concentration of NADH increases (1 mark), few NAD^+ will be available for the Krebs cycle reactions (1 mark). This leads to decrease in the rate of the Krebs cycle until an adequate amount of NAD^+ is available (1 mark).

c. Explain why during intensive exercises; the rate of Kreb's cycles remains relatively high (comprehension). **(5 marks)**

The demand for ATP is high during intensive exercises (1 mark). This means that the oxidation of NADH during the electron transport chain will be at a higher rate (1 mark) to produce more ATP (1 mark) and thus the NADH concentration decreases (1 mark). This decrease in NDAH concentration causes tie Kreb's cycle to remain at a high rate (1 mark).

III- Conceptual Questions **[12 marks]**

13. Cellular respiration overall reaction has two main reactants and three products. Specify the stage where each reactant is used and the stage where each product is produced. (Comprehension) **[5 marks]**

Reactants: [2 marks, 1 each]

Glucose is used during glycolysis

Oxygen is used during ETC as the final electron acceptor.

Products: [3 marks, 1 each]

Water is produced in ETC

Carbon dioxide produced during Kreb's cycle

ATP is produced during glycolysis, Kreb's and ETC.

14. Complete the table below by writing the role of each listed molecule in the process of photosynthesis. (knowledge) **[2 marks; 0.5 each]**

Molecule	Role in the process of photosynthesis
ATP	Provides energy to the light-independent reactions
Chlorophyll	Absorbs light energy to release required electrons
CO_2	Fixed in organic molecules
NADPH	Electron carrier for the light-independent reactions

15. Describe briefly what happens during ETC. (Comprehension) **[2 marks]**

All the reduced co-enzymes are oxidised (1 mark). The electrons move from the electron donor (NADH and FADH2) to electron acceptor (Oxygen) through a series of steps carried by the proteins in the inner mitochondrial membrane (1 mark).

16. Complete the table below by writing the name of the stage of cellular respiration that matches each description provided. (knowledge)

[3marks; 0.5 each]

Description	Stage of cellular respiration
Occurs in the cytosol of the eukaryotic cell	Glycolysis
Produces ATP through the process of chemiosmosis	Electron transport chain
Produces two molecules of NADH per one molecule of glucose	Glycolysis
$FADH_2$ is oxidised during this stage	Electron transport chain
Occurs in the matrix of the mitochondria	Krebs cycle
Requires oxygen as an electron acceptor	Electron transport chain

End of the Quiz

SOCIAL STUDIES: C1, P1, T1 AND C1, P1, T0

Comparison of the conducted exams during this study – Social Studies

This section shows the exams conducted after implementing each of the learning strategies for the Social studies lessons: “Key concepts of the universal culture” and “How UAE exhibits core values and beliefs of Universal culture”. Both lessons were conducted in order to calculate the impact factor that digital technology has on students’ attainment. The first lesson was implemented with digital technology-based learning C1, P1, T1; the second lesson used the nondigital technology-based learning C1, P1, T0.

Each exam was thirty minutes long and was conducted at the beginning of the lesson of the week following the studied lesson.

Table 138 shows the description of the parts that were included in both exams related to both lessons: Key concepts of universal culture (Key Concepts) and How UAE exhibits values of Universal culture (UAE Vision 2021).

Lesson Title	**Part number**	**Category**	**The weight of each part out of 100 %**	**The number of questions in each part**
Both lessons, Key concepts and UAE Vision 2021	I/section A	Multiple choices questions	35 %	7
Both lessons, Key concepts and UAE Vision 2021	I/section B	Matching	14%	1
Both lessons, Key concepts and UAE Vision 2021	I/section C	True/ False questions	10%	1
Both lessons, Key concepts and UAE Vision 2021	II	Situation Analysis	23 %	2
Both lessons, Key concepts and UAE Vision 2021	III	Conceptual questions	18 %	1

Table 138. The main parts included in each exam

Table 139 and Table 140 show the cognitive level, Bloom's taxonomy stage, of the included questions in each part of the conducted exams.

Cognitive level / **Number of questions in each part**	**Knowledge**	**Comprehension**	**Application**	**Analysis**	**Evaluation**	**Synthesis**
Number of questions in Part I. A	1 question	4 questions	1 question	1 question		
Number of questions in Part I. B		1 question				
Number of questions in Part I. C		3 branches (question 9 a, 9b, 9d)	2 branches (question 9c, 9e)			
Number of questions in Part II			2 branches (question 10a, 10b)	2 branches (question 10c, 10d, 11)	1 branch (question 10 e)	
Number of questions in Part III						1 question

Table 139. The cognitive levels included in the Key Concepts exam.

Note: the cognitive level of each question is shown in the provided exams at the end of this description.

Cognitive level / Number of questions in each part	Knowledge	Comprehension	Application	Analysis	Evaluation	Synthesis
Number of questions in part I. A	2 questions	3 questions	1 question	1 question		
Number of questions in part I. B		1 question				
Number of questions in part I. C		3 branches (question 9c, 9d, 9e)	1 branch (question 9a)	1 branch (question 9b)		
Number of questions in part II			1 branch (question 10a)	3 branches (question 10b, 10c, 10d)	1 question	
Number of questions in part III						1 question

Table 140. The cognitive levels included in UAE Vision 2021.

Note: the cognitive level of each question is shown in the provided exams at the end of this description.

Table 139 and Table 140 show the cognitive levels included in each exam. It can be seen that in both exams, Part I comprises six out of nine questions focus on Low Order Cognitive Skill (LOCS): Knowledge and Comprehension; while the remain three out of nine questions required High Order Cognitive Skills (HOCS): Application and Analysis.

Part II in both exams comprises questions are ranked as High Order Cognitive Skills (HOCS): Application, Analysis and Evaluation.

Part III in both exams includes questions that belong to both orders: High Order Cognitive Skills: Synthesis.

The weight (out of 100%) of each part, in both exams, is equal, i.e., the total mark for part I in both exams is 59 %, part II accounts for 23 % of the mark and part III for 18% (refer to Table 138). Based on Table 139 and Table 140, it can be stated that both exams have approximately the same level of cognitive complexities.

As an overall view, in both exams approximately, 50 per cent of the questions required Low cognitive level, and the other 50 per cent needed a high cognitive level. Thus, the exams' level of complexity was described by the teacher as suitable for all students.

Samples of the conducted exams during this study – Social Studies (both exams were conducted in Term 3, academic year 2016/2017)

Student's Sequence Number		**Subject**	**Social Studies**
Grade	**9**	**Lesson title**	**What are the key concepts of "Universal culture"?**
Duration	**Thirty (30) minutes**	**Learning strategy**	**Digital technology-based learning**
Date		**Mark**	**/ 100**

I. Recall and Understanding **[59 marks]**

I. A. Multiple choice questions **(35 marks/ 5 each)**

1. How can Culture be defined? (Comprehension)

A. Some aspects of a person's individual life

B. All the elements that makeup a society or civilisation

C. A particular segment that has interesting values

D. Languages are culture

2. Human culture is ______________________________. (Analysis)

A. Partly inherited genetically

B. Entirely learned

C. Limited to relatively rich societies

D. All of the above

3. Which of the following statements is true for the culture? (Comprehension)

   A. Languages are culture

   B. Archaeologist find culture in their excavations

   C. Culture is a powerful human tool for survival

   D. Culture is the same thing as a society.

4. Values, traditions and beliefs are examples of? (Knowledge)

   A. Customs

   B. Cultural relativism

   C. Popular culture

   D. Non-material culture

   E. Material culture

5. Which statement BEST explains WHY the family is a key feature of a culture's social organisation? (Application)

   A. In most cultures, the family chooses the leader of the government

   B. Nuclear families dominate extended families

   C. Through family, children learn their language

   D. The family teaches culture to each generation

6. Which of the following is not the example of language? (Comprehension)

   A. Reading

   B. Writing

   C. Speaking

   D. Gestures and body language

7. Believing that eating snails is disgusting or that in Britain people drive on the wrong side of the street are the examples of (Comprehension)

A. Cultural Universal

B. Ethnocentrisme

C. Melting pot

D. Cultural relativism

I. B. Matching question (14 marks/ 2 each)

8. Match the cultural universals to their examples (comprehension)

A	Government and Economy	D	Clothing, cooking, housing
B	Technology	F	Body adornment, folklore, funeral rites, religious ritual
C	Communication and Education	B	Medicine, toolmaking
D	Basic needs	A	Calendar, division of labour, law, property rights, trade, status differentiation
E	Arts and Leisure	G	Courtship, kinship groups, marriage
F	Beliefs	E	Athletic sports, dancing, decorative art, games, music
G	Family	C	Education, language, greetings

I. C. True/ False questions (10 marks/ 2 each)

9. Next to each statement write, is it T (true) or F (false)?

a) Values are used to decide what is good or bad, right or wrong

(comprehension) **T**

b) Symbols have the same meaning for people of different cultures (comprehension) **F**

c) No one can be entirely successful at practising cultural relativism (application) **T**

d) When all the immigrants coexist without giving up their own identity and culture is referred to as “Bowl of salad” (comprehension)

T

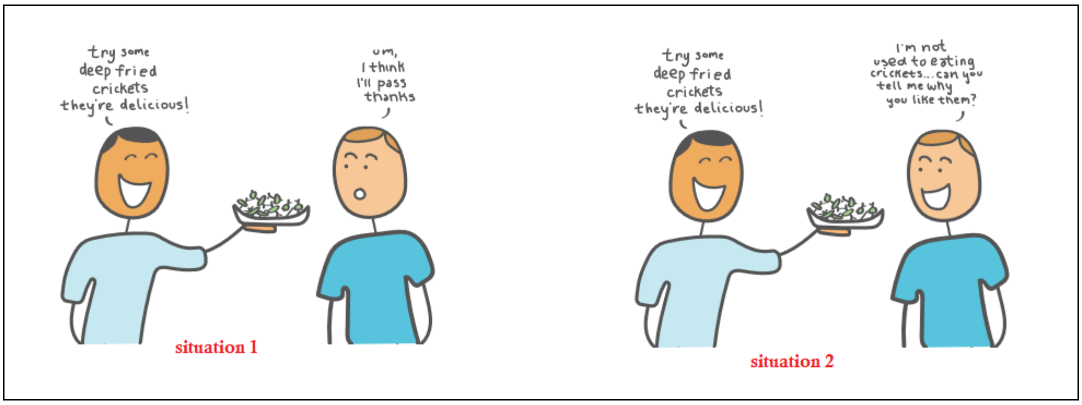
e) Objects that distinguish a group of people, such as their art, building weapons, utensils, machines, hairstyles, clothing, and jewellery are known as nonmaterial culture (application)

F

II. Basic Application of skills and concepts [23 marks]

10. Observe the images and answer the following questions a-e:

(17 marks)



a. Situation 1 represents what concept? (Application) (1.5 marks)

Ethnocentrism

b. Situation 2 represents what concept? (Application) (1.5 marks)

Cultural relativism

c. Which situation shows a judgmental attitude towards another culture. And how? (Analysis) (5 marks)

Situation 1, (1 mark)

Person sees the food they don't normally and refuses without even considering that this may be a choice of food for people in another culture.

(4 marks)

d. Explain how situation 2 is reflecting cultural relativism, use text in the image to support your answer. (analysis) (4 marks)

3 marks for giving their explanation similar to (Person acknowledges that different cultures can have different eating habits and wants to learn more about it)

1 mark for writing down the citation "can you tell me why you like them?"

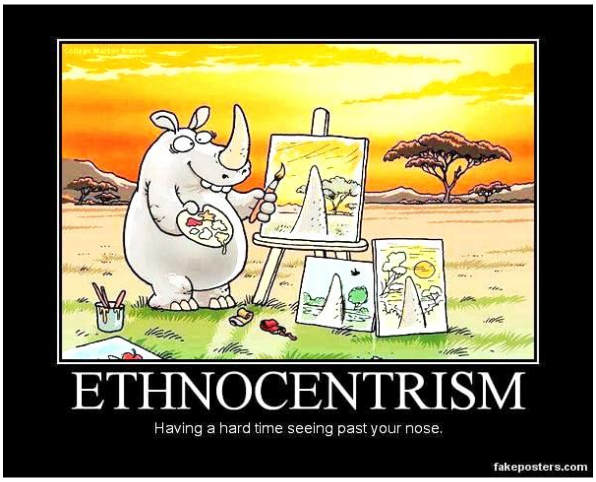
e. Give your own example when you faced ethnocentrism, or maybe you were ethnocentric (define your role: judging or being judged?)

(evaluation) (5 marks)

Giving their own example - 4 marks

Identifying their role in the situation (the one who is ethnocentric or judged by others) – 1 marks

11. Look at the image and explain the expression "having a hard time seeing past your nose." (Analysis) **(6 marks)**



4 marks for the explanation of ethnocentrism and cultural relativism, perspective of seing other cultures from your own point of view, etc.

2 marks for logical, coherent and well-structured sentences

III- Conceptual question [18 marks]

12. Should the UAE be a Melting pot or Bowl of salad? Write a short (minimum of 80 words essay) to give your opinion and justify it. Your essay should explain each concept, give negative and positive aspects to each. It should be written in coherent and complete sentences. (Synthesis)

3 marks for both descriptions (1.5 marks/ each) Melting pot and Bowl of salad

4 marks for giving at least 2 positive aspects

4 marks for giving at least 2 negative aspects

3 marks for choosing and justifying their choice

2 marks for logical, coherent and well-structured sentences

2 marks for respecting the given word limitation

End of the Quiz

Student's Sequence Number		**Subject**	**Social Studies**
Grade	**9**	**Lesson title**	**How does the UAE exhibit the core values and beliefs of "Universal culture"?**
Duration	**Thirty (30) minutes**	**Learning strategy**	**Nondigital technology-based learning**
Date		**Mark**	**/ 100**

I. Recall and Understanding [59 marks]

I. A. Multiple choice questions (35 marks/ 5 each)

1. How many are there Sustainable Development Goals (SGDs) that all the world's nations had agreed upon for the 2030 Agenda? (Knowledge)

   A. 10
   B. 17
   C. 20
   D. 12

2. In which year Vision 2021 was established? (Knowledge)
   A. 1998
   B. 2002
   C. 2017
   D. 2010

3. Which of the following is not part of the National Priorities? (Comprehension)

   A. Safe public and judiciary
   B. Competitive knowledge economy
   C. Equal and welcoming society
   D. First-rate education system

4. Under which key principle comes *cohesive society and Preserved identity*? (Comprehension)

   A. United in Responsibility
   B. United in Destiny
   C. United in Knowledge
   D. United in Prosperity

5. One of the targets for the First-rate education system is to achieve that ____ % of young Emiratis go to preschool? (Comprehension)

   A. 60 %
   B. 80 %
   C. 85 %
   D. 95 %

6. The vision *United in knowledge means*… (Analysis)

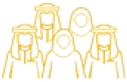
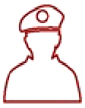
   A. it is economy driven by knowledge and Emiratis
   B. it is economy driven by knowledge and innovative leaders
   C. it is economy driven by knowledge and expats
   D. it is economy driven by knowledge

7. The purpose of UAE's National Agenda is to: (Application)

   A. Show that UAE is a safe place to live
   B. Compare UAE against global benchmarks
   C. Be identified as the top destination for immigration
   D. Implement Sustainable Development Goals set by UN

II. B. Matching question (14 marks/ 2 each)

8. Match the logos with exact National Priority (Comprehension)

A		D	First-rate Education System
B		F	Safe public and Fair Judiciary
C		A	Sustainable Environment and Infrastructure
D		G	Sustainable Cities and Communities
E		C	Competitive Knowledge-Economy
F		E	World-class Healthcare
G		B	Cohesive Society and Preserved Identity

II. C. True/ False questions (10 marks/ 2 each)

9. Next to each statement, write T (true) or F (false)?

a) Every national priority has a specific indicator(s) that show if the goal was achieved or not and show the progress (application)

______**T**______

b) UAE's targets are the same like SDGs (analysis)

______F______

c) Ensuring improvement in social-economic environment and the importance of family and community is to be United in Destiny (comprehension)______**F**______

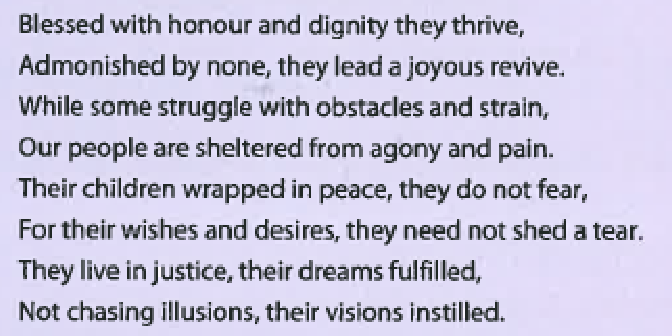
d) UAE wants to move away from the economy solely relying on the oil industry by developing renewable energy sources (comprehension)

T

e) The world-class healthcare system is not focused on medical research; its main goal is to provide medical service for all citizens and residents of UAE (comprehension) F

II. Basic Application of skills and concepts [23 marks]

10. Read a passage from the poem "Happiest Nation" by His Highness Sheikh Mohammed bin Rashed Al Maktoum and answer the following questions: **(15 marks)**



Blessed with honour and dignity they thrive,
Admonished by none, they lead a joyous revive.
While some struggle with obstacles and strain,
Our people are sheltered from agony and pain.
Their children wrapped in peace, they do not fear,
For their wishes and desires, they need not shed a tear.
They live in justice, their dreams fulfilled,
Not chasing illusions, their visions instilled.

a. Cite expression of safe public and fair judiciary? (Application)

(2 marks)

Admonished by none Their children wrap in peace,

they do not fear They live in justice

b. To which National priority you would attribute the following line, explain why? (4 marks)

Blesses with honor and dignity they thrive? (Analysis)

2 marks – united in destiny or reduce social and

economic gap between people

2 marks for giving the reasoning

c. Which National Priority is it referred to in the last line (justify your choice) (4 marks)

Not chasing illusions, their vision instilled (Analysis)

2 marks – united in knowledge or maximizing humain capital

2 marks for giving the reasoning (example: people are qualified and have the skills to achieve any goal, it's not any more an illusion, it's a reality)

d. In your own words, explain what the author meant by the following: (Analysis) (5 marks)

While some struggle with obstacles and strain,
Our people are sheltered from agony and pain.

To be used terms like: Responsibility, community, society, family, safety,

United in destiny, reducing the gap, safe public (3 marks for mentioning 2)

2 marks for coherent and logical sentences,

11. Compare and contrast SDG No. 16 and United in Responsibility (give at least 2 similarities and 2 differences between the two) (Evaluation) **(8 marks)**

2 marks for each of the similarities and differences mentioned (2*4 = 8)
similarities: promote peaceful society, supportive communities
differences: SDG speaks about government and institutions;
Vision 2021 focus mainly on family and active community
(charity, grass- roots initiatives, volunteering)

III- Conceptuel question **[18 marks]**

12. What are the SDGs that UAE is trying to achieve in its Vision 2021?

Write a short (minimum 50 words essay), name at least 4 SDGs and relate them to National priorities of Vision 2021, justify your choice. Your essay should be written in coherent and complete sentences. (Synthesis)

2 marks for each SDG chosen (2*4 = 8 points)

2 marks for each SDG connection to Vision 2021 (2*4=8 points)

2 marks for logical, coherent and well-structured sentences

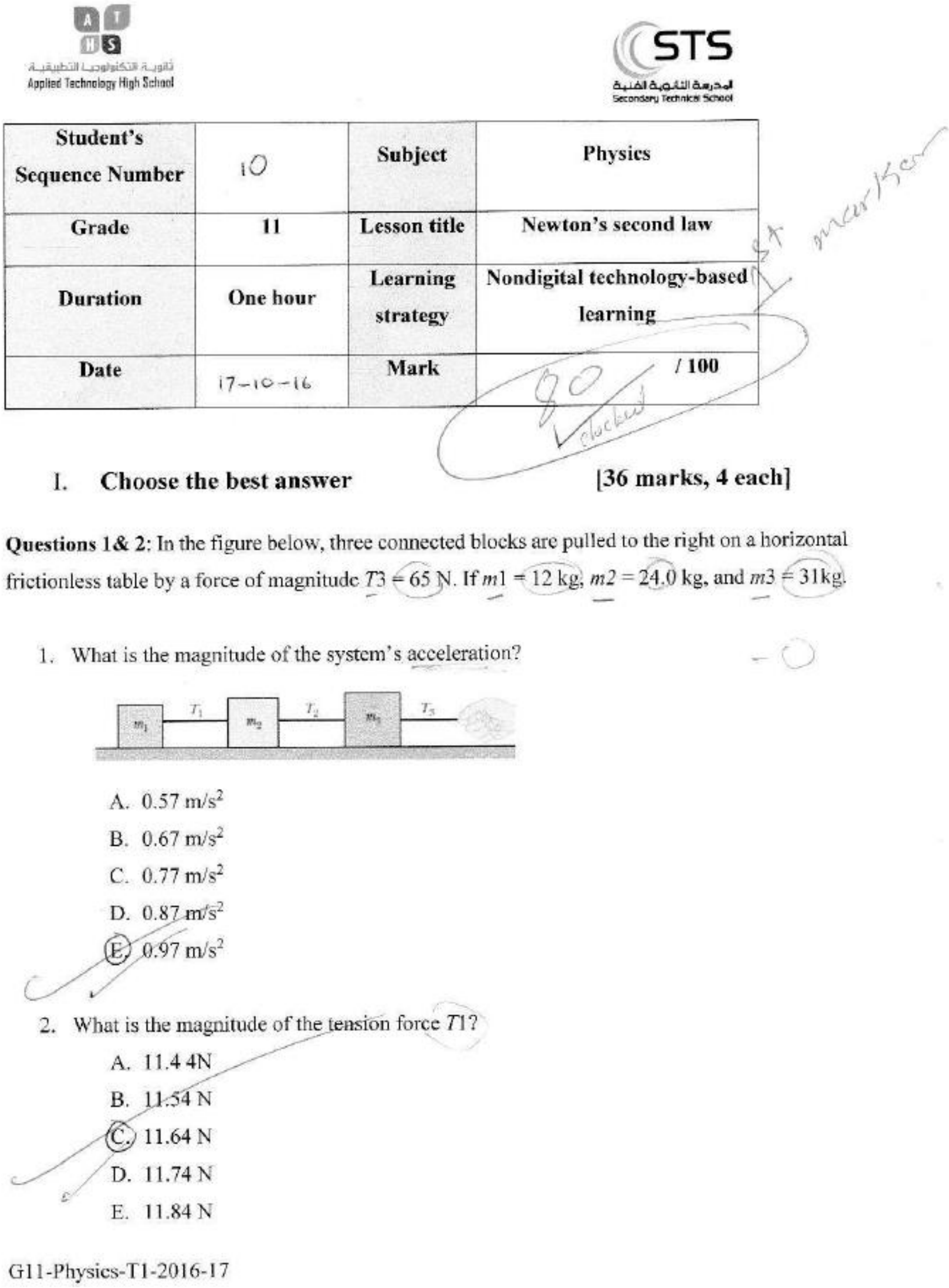
End of the Quiz

APPENDIX NINE

Samples of Marked Exams – Students' Responses

APPENDIX 9 – SAMPLES OF MARKED EXAMS – STUDENTS' RESPONSES

Example One: Nondigital Technology-based Learning



ثانوية التكنولوجيا التطبيقية
Applied Technology High School

STS
المدرسة الثانوية الفنية
Secondary Technical School

Student's Sequence Number	10	**Subject**	Physics
Grade	11	**Lesson title**	Newton's second law
Duration	One hour	**Learning strategy**	Nondigital technology-based learning
Date	17-10-16	**Mark**	90 / 100 checked

1st marker

I. **Choose the best answer** **[36 marks, 4 each]**

Questions 1& 2: In the figure below, three connected blocks are pulled to the right on a horizontal frictionless table by a force of magnitude $T3$ = 65 N. If $m1$ = 12 kg, $m2$ = 24.0 kg, and $m3$ = 31kg.

1. What is the magnitude of the system's acceleration? –0

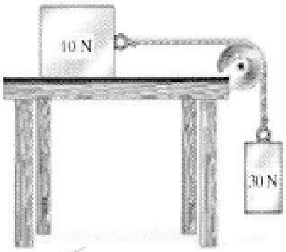
A. 0.57 m/s^2
B. 0.67 m/s^2
C. 0.77 m/s^2
D. 0.87 m/s^2
[✓ E. 0.97 m/s^2]

2. What is the magnitude of the tension force $T1$?

A. 11.4 4N
B. 11.54 N
[✓ C. 11.64 N]
D. 11.74 N
E. 11.84 N

G11-Physics-T1-2016-17

3. Two boxes are connected by a string, as shown in the figure below. The 10 N box moves without friction on the horizontal table surface. The pulley is ideal, and the string has negligible mass. What is true about the tension T in the string? (Application)



A. T = 30 N
B. T = 20 N
[✓ C.] T < 30 N
D. T = 10 N
E. T > 30 N

$\Sigma F = ma$

$30 - \cancel{F_T} = 3a$

$\Sigma F = ma$

$\cancel{F_T} - 10 = 1a$

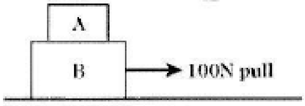
$20 = 4a$

$\boxed{a = 5 m/s^2}$

$F_T - 10 = 5$

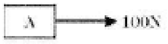
$\boxed{F_T = 15N}$

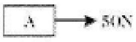
4. Two blocks, A and B, are being pulled to the right along a horizontal surface by a horizontal 100 N pull, as shown below. Both of them are moving together at a constant velocity of 2.0 m/s to the right, and both weigh the same. (comprehension)



Which of the figures below shows a correct free-body diagram of the horizontal forces acting on the upper block, A?

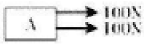
C

A


B


C


[✓ D]


E


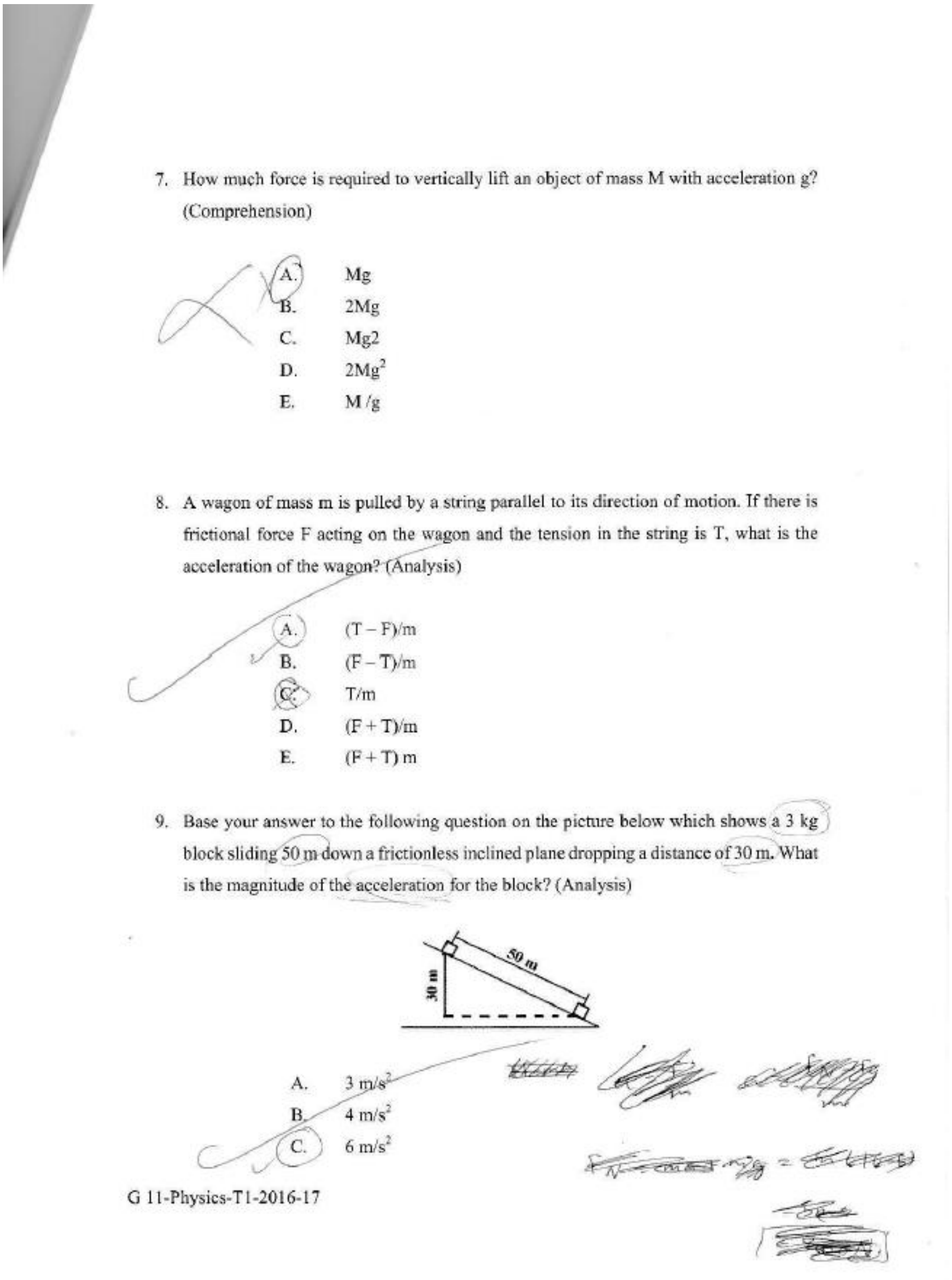
5. A dog that weighs 500 N at rest on the Earth's surface is standing on a scale on the floor of an elevator. The elevator is accelerating upward in the Earth's gravitational field at a rate of 9.8 m/s^2. What does the scale read? (Application)

A. 0 N
B. 250 N
C. 500 N
[✓ D.] 1000 N
E. 2000 N

6. A student that has a mass of 100 kg is standing on a scale in an elevator car. The elevator is accelerating downward at 5 m/s^2 in the Earth's gravitational field. The reading on the scale in the elevator is most nearly (Application)

A. 150 N
[✓ B.] 500 N
C. 1000 N
D. 1500 N
E. 50 N

$\Sigma F = ma$
$= 100 \times 5$
$\boxed{T = 500N}$



7. How much force is required to vertically lift an object of mass M with acceleration g? (Comprehension)

[✓ A.] Mg
B. 2Mg
C. Mg2
D. $2Mg^2$
E. M /g

8. A wagon of mass m is pulled by a string parallel to its direction of motion. If there is frictional force F acting on the wagon and the tension in the string is T, what is the acceleration of the wagon? (Analysis)

[✓ A.] (T – F)/m
B. (F – T)/m
C. T/m
D. (F + T)/m
E. (F + T) m

9. Base your answer to the following question on the picture below which shows a 3 kg block sliding 50 m down a frictionless inclined plane dropping a distance of 30 m. What is the magnitude of the acceleration for the block? (Analysis)

A. $3\ m/s^2$
B. $4\ m/s^2$
[✓ C.] $6\ m/s^2$

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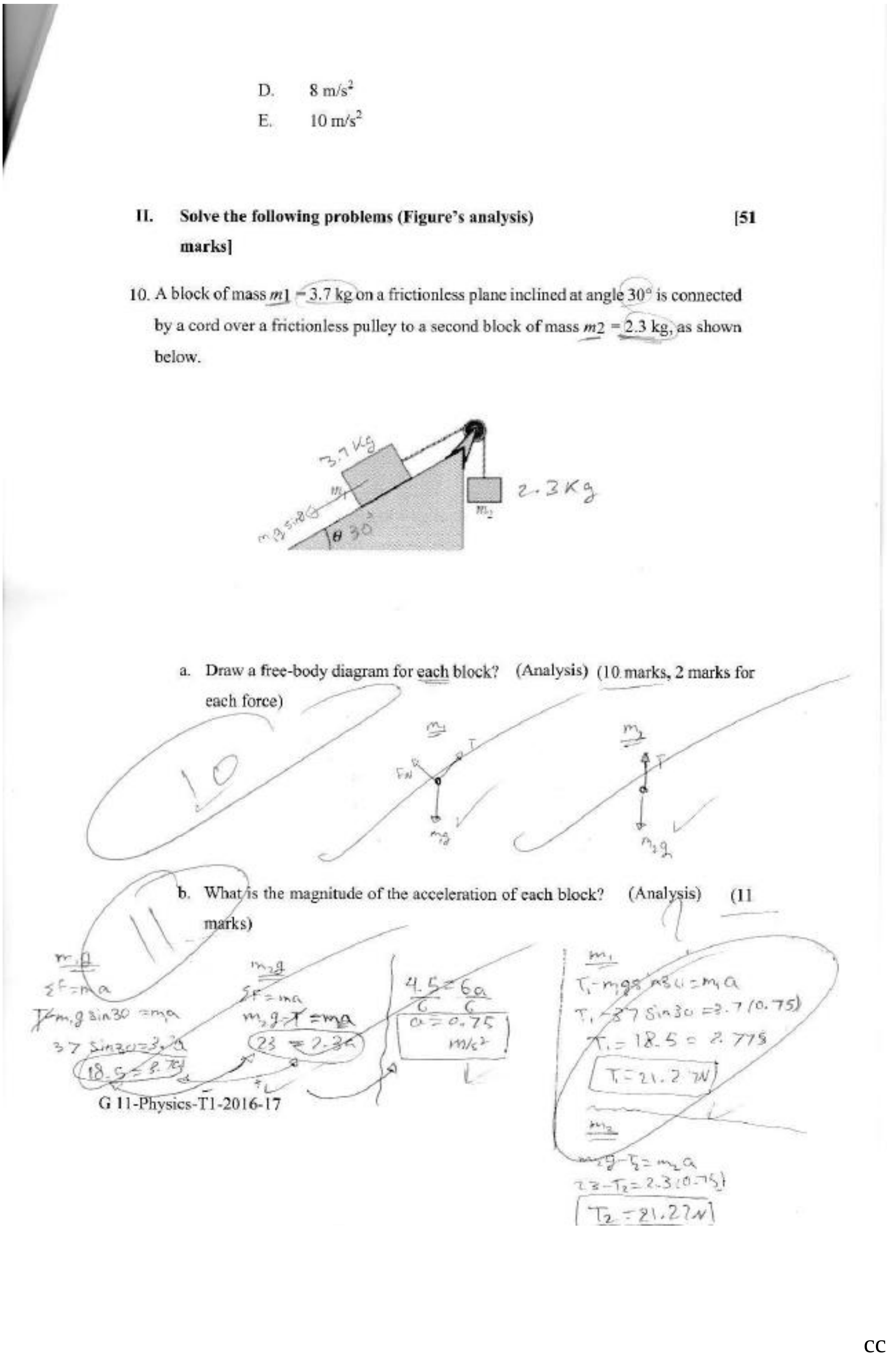

D. 8 m/s^2

E. 10 m/s^2

II. Solve the following problems (Figure's analysis) [51 marks]

10. A block of mass $m1$ = 3.7 kg on a frictionless plane inclined at angle 30° is connected by a cord over a frictionless pulley to a second block of mass $m2$ = 2.3 kg, as shown below.

a. Draw a free-body diagram for each block? (Analysis) (10 marks, 2 marks for each force)

10

b. What is the magnitude of the acceleration of each block? (Analysis) (11 marks)

11

m_1g

$\Sigma F = ma$

$~~T~~ - m_1g\sin30 = m_1a$

$37\sin30 = 3.7a$

$18.5 = 3.7a$

m_2g

$\Sigma F = ma$

$m_2g - ~~T~~ = ma$

$23 = 2.3a$

$\frac{4.5}{6} = \frac{6a}{6}$

$\boxed{a = 0.75\ m/s^2}$

m_1

$T_1 - m_1g\sin30 = m_1a$

$T_1 - 37\sin30 = 3.7(0.75)$

$T_1 - 18.5 = 2.775$

$\boxed{T_1 = 21.27N}$

m_2

$m_2g - T_2 = m_2a$

$23 - T_2 = 2.3(0.75)$

$\boxed{T_2 = 21.27N}$

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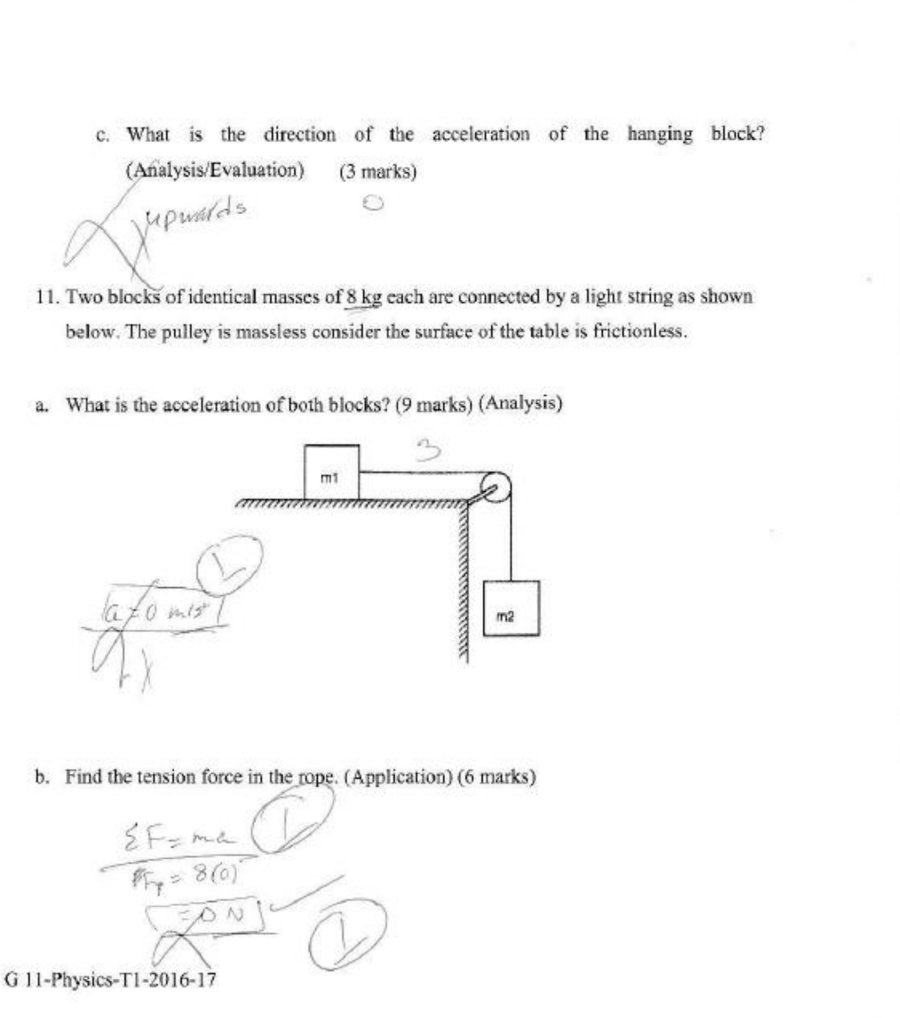

c. What is the direction of the acceleration of the hanging block? (Analysis/Evaluation) (3 marks)

upwards

0

11. Two blocks of identical masses of 8 kg each are connected by a light string as shown below. The pulley is massless consider the surface of the table is frictionless.

a. What is the acceleration of both blocks? (9 marks) (Analysis)

$a = 0$ m/s²

1

b. Find the tension force in the rope. (Application) (6 marks)

$\sum F = ma$

1

$F_T = 8(0)$

$= 0$ N

1

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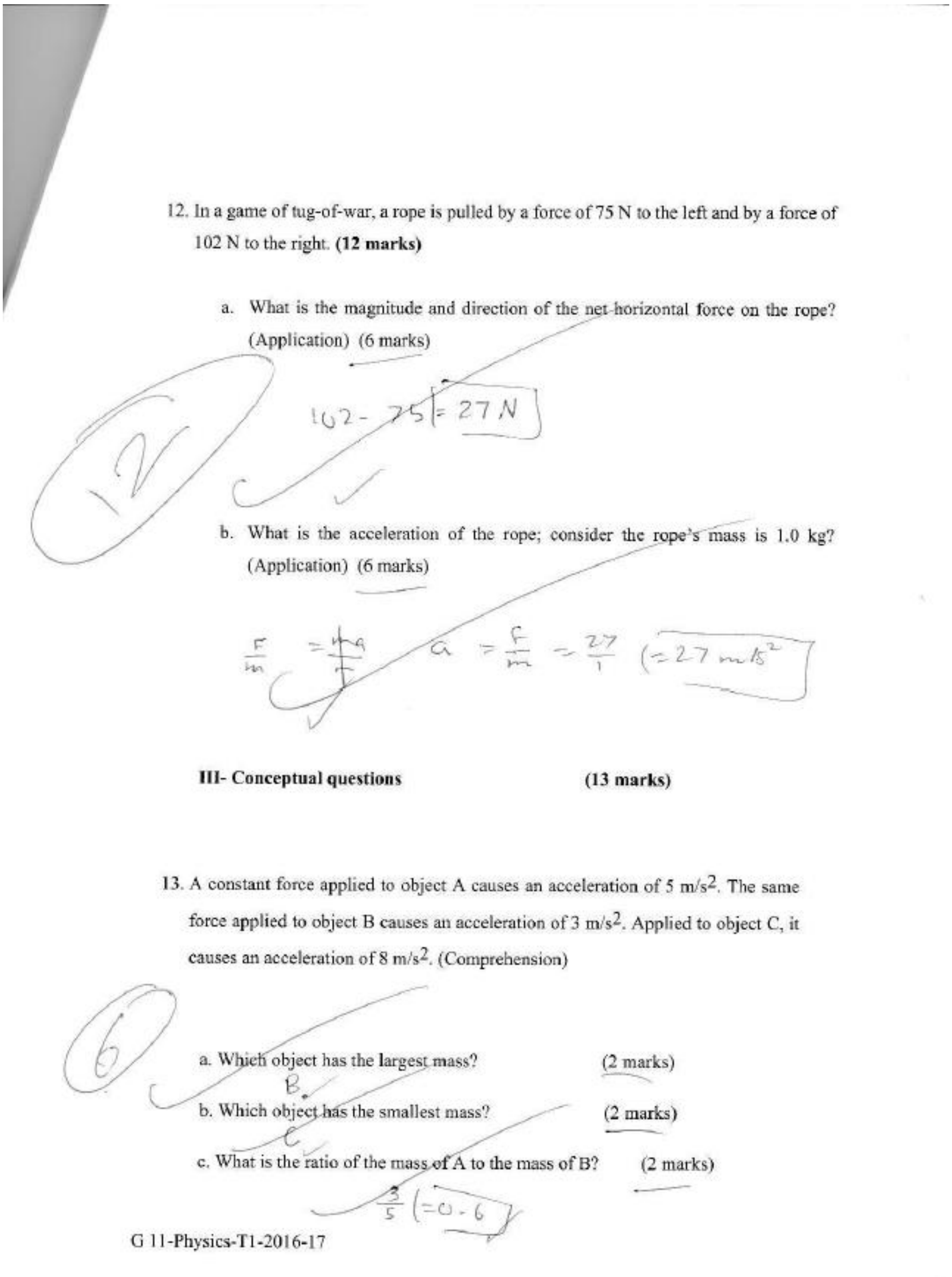


12. In a game of tug-of-war, a rope is pulled by a force of 75 N to the left and by a force of 102 N to the right. **(12 marks)**

a. What is the magnitude and direction of the net horizontal force on the rope? (Application) (6 marks)

102 - 75 $\boxed{= 27\ N}$

12

b. What is the acceleration of the rope; consider the rope's mass is 1.0 kg? (Application) (6 marks)

$\frac{F}{m} = \frac{ma}{F}$ $a = \frac{F}{m} = \frac{27}{1}$ $\boxed{(= 27\ m/s^2}$

III- Conceptual questions **(13 marks)**

13. A constant force applied to object A causes an acceleration of 5 m/s^2. The same force applied to object B causes an acceleration of 3 m/s^2. Applied to object C, it causes an acceleration of 8 m/s^2. (Comprehension)

6

a. Which object has the largest mass? (2 marks)

B.

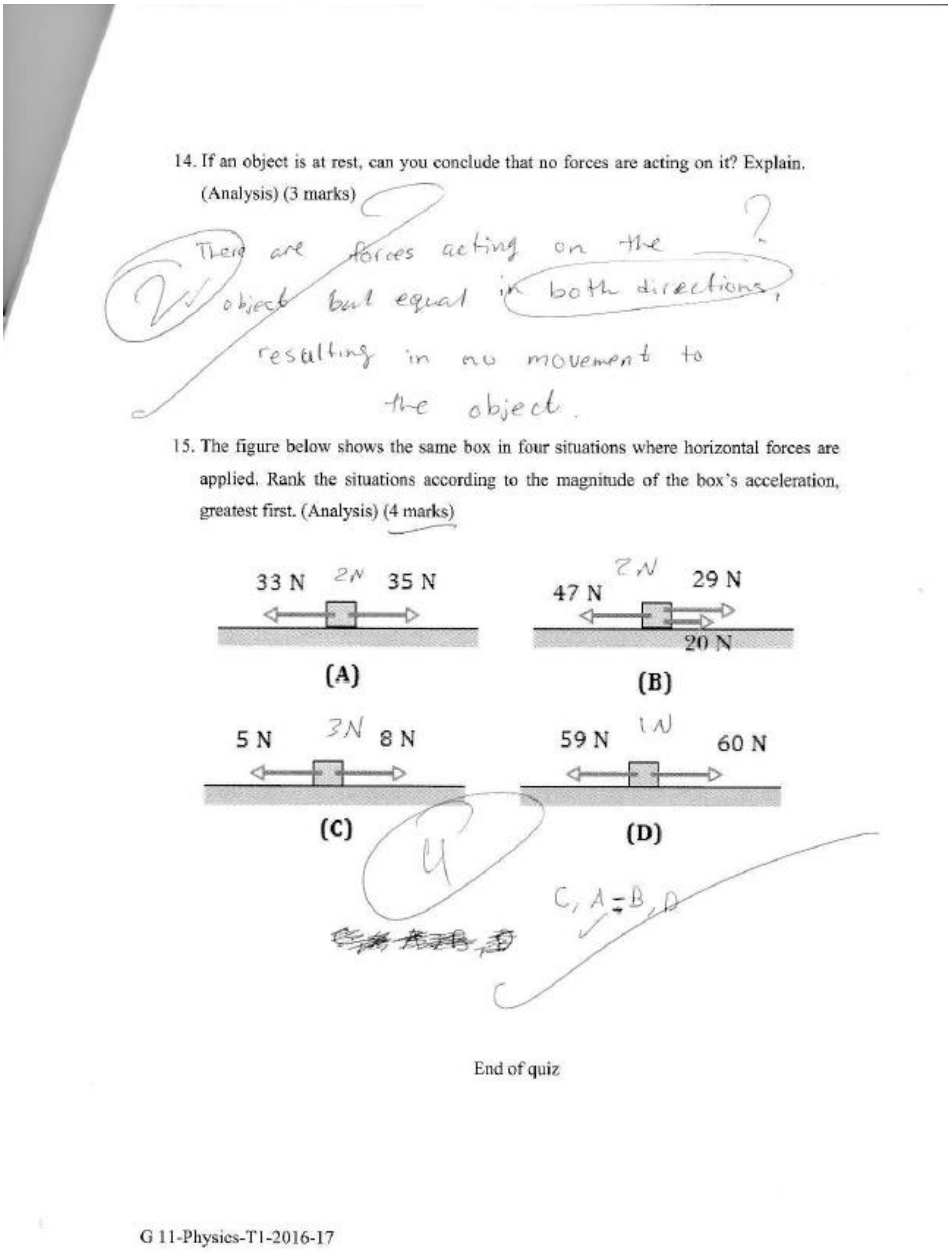
b. Which object has the smallest mass? (2 marks)

C

c. What is the ratio of the mass of A to the mass of B? (2 marks)

$\frac{3}{5}$ (= 0.6)

G 11-Physics-T1-2016-17



14. If an object is at rest, can you conclude that no forces are acting on it? Explain. (Analysis) (3 marks)

There are forces acting on the object but equal in both directions, resulting in no movement to the object.

?

2 ✓

15. The figure below shows the same box in four situations where horizontal forces are applied. Rank the situations according to the magnitude of the box's acceleration, greatest first. (Analysis) (4 marks)

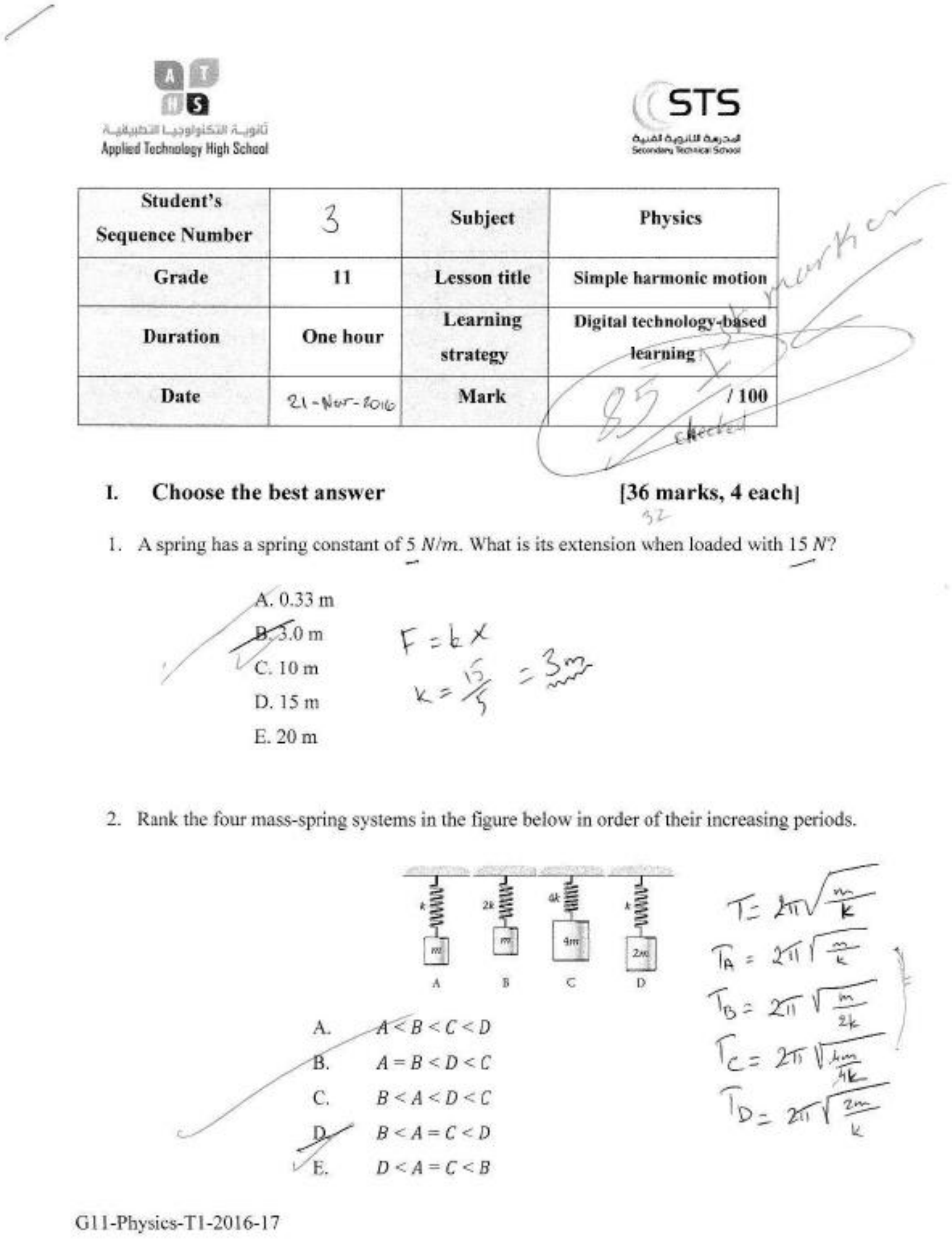
4

C, A = B, D ✓

End of quiz

G 11-Physics-T1-2016-17

Example Two: Digital Technology-based Learning



Applied Technology High School

STS
Secondary Technical School

Student's Sequence Number	3	**Subject**	**Physics**
Grade	**11**	**Lesson title**	**Simple harmonic motion**
Duration	**One hour**	**Learning strategy**	**Digital technology-based learning**
Date	21-Nov-2016	**Mark**	85 **/ 100**

marker

checked

I. Choose the best answer **[36 marks, 4 each]**

32

1. A spring has a spring constant of 5 N/m. What is its extension when loaded with 15 N?

A. 0.33 m

B. 3.0 m

C. 10 m

D. 15 m

E. 20 m

$F = kx$

$k = \frac{15}{5} = 3m$

2. Rank the four mass-spring systems in the figure below in order of their increasing periods.

A. $A < B < C < D$

B. $A = B < D < C$

C. $B < A < D < C$

D. $B < A = C < D$

E. $D < A = C < B$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T_A = 2\pi\sqrt{\frac{m}{k}}$

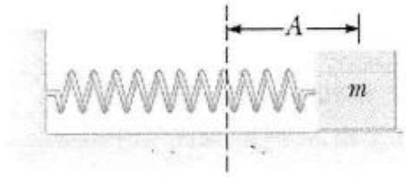
$T_B = 2\pi\sqrt{\frac{m}{2k}}$

$T_C = 2\pi\sqrt{\frac{4m}{4k}}$

$T_D = 2\pi\sqrt{\frac{2m}{k}}$

G11-Physics-T1-2016-17

3. A block on the end of a spring is pulled to position $x = A$ and released. Through what total distance does it travel in one full cycle of its motion?

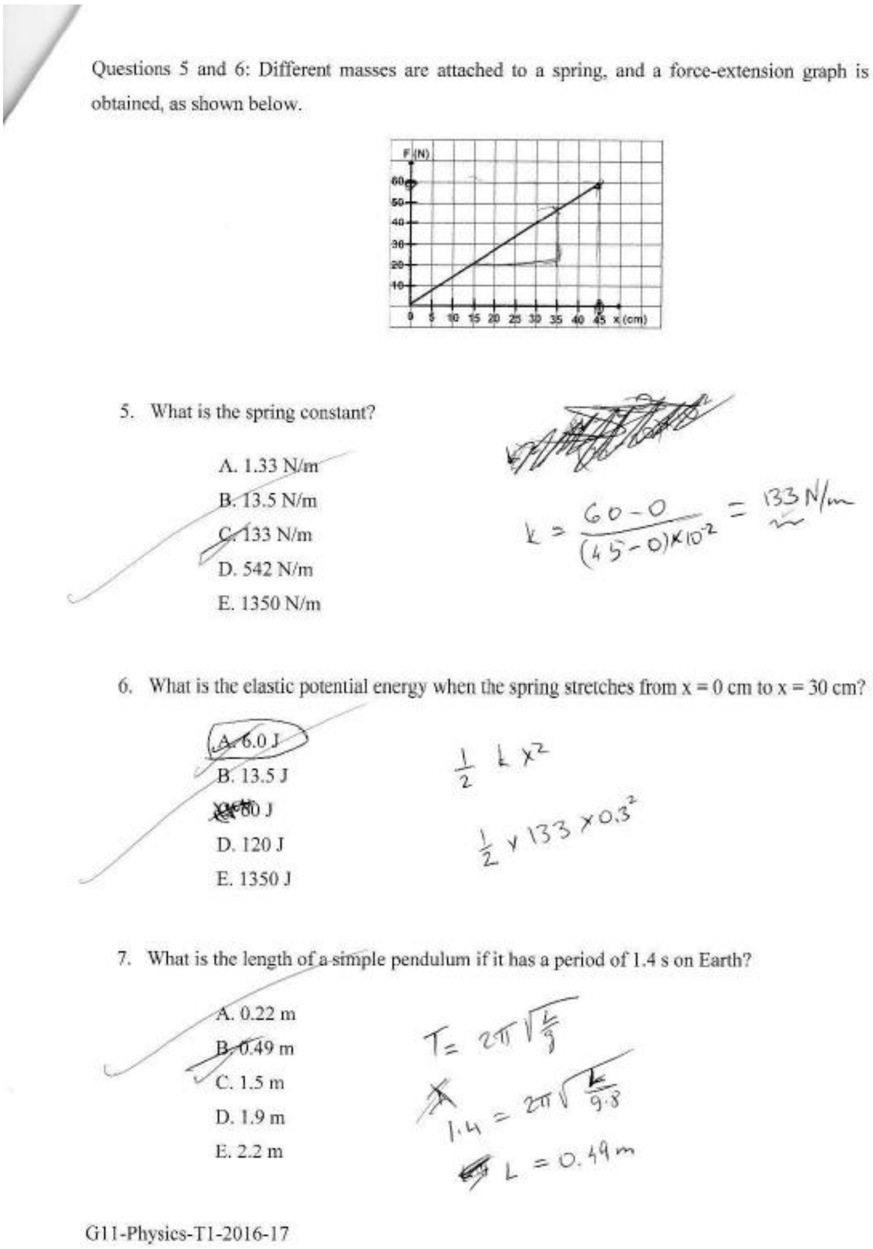


A. $A/4$
B. $A/2$
C. A
D. $2A$
[✓ E. $4A$]

4. An object of mass m is attached to a horizontal spring, stretched to a displacement A from equilibrium and released, undergoing harmonic oscillations on a frictionless surface with period T_0. The experiment is repeated with a mass of $4m$. What is the new period of oscillation?

A. $T_0/4$
B. $T_0/2$
C. T_0
D. $2T_0$
[✓ E. $4T_0$]

$$T_1 = 2\pi\sqrt{\frac{m}{k}}$$
$$T_2 = 2\pi\sqrt{\frac{4m}{k}}$$



Questions 5 and 6: Different masses are attached to a spring, and a force-extension graph is obtained, as shown below.

5. What is the spring constant?

A. 1.33 N/m

B. 13.5 N/m

[✓ C. 133 N/m]

D. 542 N/m

E. 1350 N/m

$k = \frac{60-0}{(45-0)\times10^{-2}} = 133$ N/m

6. What is the elastic potential energy when the spring stretches from x = 0 cm to x = 30 cm?

[✓ A. 6.0 J]

B. 13.5 J

C. 80 J

D. 120 J

E. 1350 J

$\frac{1}{2} k x^2$

$\frac{1}{2} \times 133 \times 0.3^2$

7. What is the length of a simple pendulum if it has a period of 1.4 s on Earth?

A. 0.22 m

[✓ B. 0.49 m]

C. 1.5 m

D. 1.9 m

E. 2.2 m

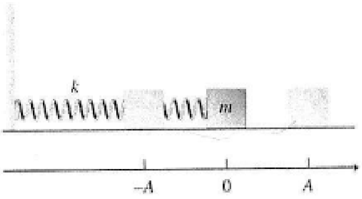
$T = 2\pi\sqrt{\frac{L}{g}}$

$1.4 = 2\pi\sqrt{\frac{L}{9.8}}$

$L = 0.49$ m

G11-Physics-T1-2016-17

8. Consider a block of mass m attached to a spring with force constant k, as shown in the figure below. The spring can be either stretched or compressed. The block slides on a frictionless horizontal surface. When the spring is relaxed, the block is located at x = 0. If the block is pulled to the right a distance A and then released, through what total distance does it travel in half a cycle of its motion?



A. A/4
B. A/2
C. A
~~D. 2A~~
E. 4A

9. In the previous question, if the oscillation has a frequency of (f). What is the new frequency if the mass is increased to 9m?

A. $f/9$
B. $f/3$
C. f
~~D. $3f$~~
E. $9f$

$T = 2\pi\sqrt{\frac{m}{k}}$

$f = \frac{1}{2\pi}\sqrt{\frac{m}{k}}$

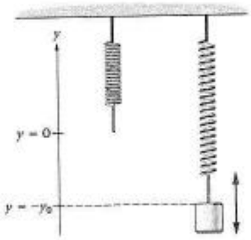
$f_2 \Rightarrow 9m$

$\sqrt{9} = \underline{3}$

II. Solve the following problems (figure's analysis) [51 marks]

43

10. A 0.260 kg mass is attached to a vertical spring which stretches to an equilibrium position of y = $-y_0$ as shown below. When the mass is put into motion, its period is 1.12 s.



a. Find the value of the spring constant? (9 marks)

$T = 2\pi\sqrt{\frac{m}{k}}$

$1.12^2 = 2\times3.14\times\sqrt{\frac{0.26}{k}}$

$= \sqrt{\frac{0.26}{k}} \times \frac{1.12^2}{2\times3.14} \Rightarrow k = 8.2$ N/m

9

b. How much does the mass stretch the spring when it is at rest in its equilibrium position y = $-y_0$? (9 marks)

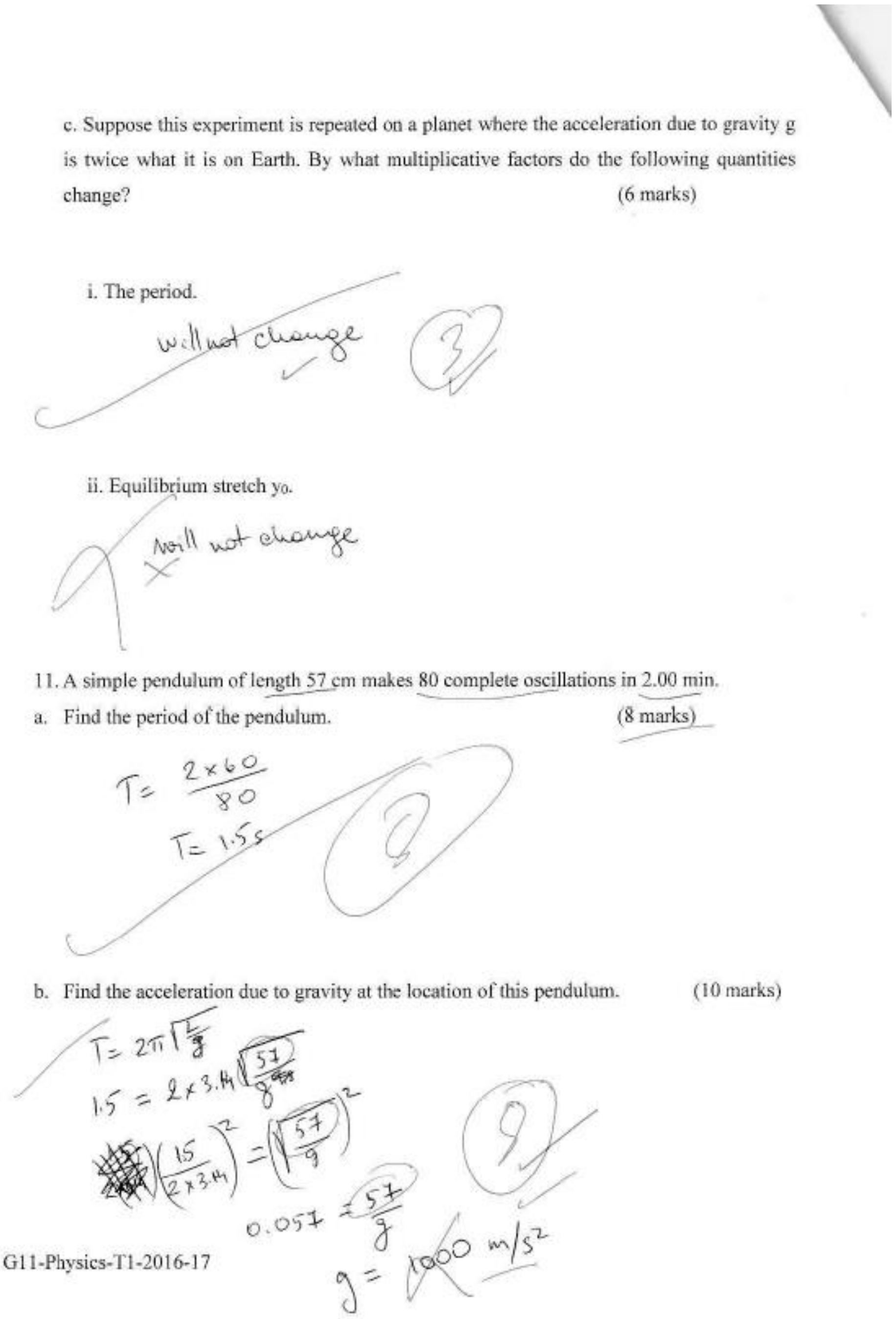
$mg = kx$

$x = \frac{mg}{k}$

$x = \frac{0.26\times9.8}{8.2}$

$x = 0.3$ m

8



c. Suppose this experiment is repeated on a planet where the acceleration due to gravity g is twice what it is on Earth. By what multiplicative factors do the following quantities change? (6 marks)

i. The period.

will not change ✓ ③

ii. Equilibrium stretch y_0.

will not change ✗

11. A simple pendulum of length 57 cm makes 80 complete oscillations in 2.00 min.

a. Find the period of the pendulum. (8 marks)

$T = \frac{2 \times 60}{80}$

$T = 1.5s$

②

b. Find the acceleration due to gravity at the location of this pendulum. (10 marks)

$T = 2\pi\sqrt{\frac{L}{g}}$

$1.5 = 2 \times 3.14\sqrt{\frac{57}{g}}$

$\left(\frac{15}{2 \times 3.14}\right)^2 = \left(\sqrt{\frac{57}{g}}\right)^2$

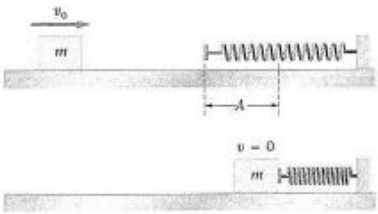
$0.057 = \frac{57}{g}$

$g = 1000 \ m/s^2$

⑨

12. *A* 0.980 kg block slides on a frictionless, horizontal surface with a speed of 1.32 m/s. The block encounters an unstretched spring with force constant of 245 N/m, as shown in the sketch. How far is the spring compressed before the block comes to rest?

(9 marks)



$\frac{1}{2} mv^2 = \frac{1}{2} kx^2$

$\frac{1}{2} \times 0.98 \times 1.32^2 = \frac{1}{2} \times 245 \times X^2$

x = 0.007m

7

III- Conceptual questions

[13 marks]

10

13. If a pendulum is suspended from a ceiling of a stationary elevator, and its period is recorded as 0.5 s. If the elevator now accelerates upward, will the period increase, decrease or remain the same? Explain. (5 marks)

weight ↑ □ ↑

$T = 2\pi \sqrt{\frac{L}{g}}$

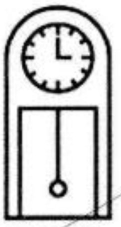
$T \propto \frac{1}{g}$

$g\uparrow \Rightarrow T\downarrow$

so T will decrease

5

14. A traditional clock contains a simple pendulum, as shown in the figure below. If the clock keeps perfect time on the surface of Earth, will it keep the same time when it is moved to the surface of the moon? Justify your answer. (4 marks)



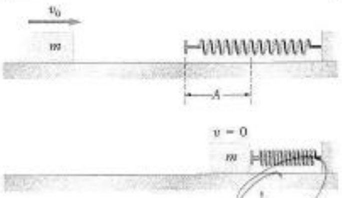
$T = 2\pi\sqrt{\frac{L}{g}}$

$g_{moon} \neq g_{earth}$

so $T_{moon} \neq T_{earth}$

4

15. In the following figure. If the initial speed of the mass is increased, how does the time required to bring the block to rest vary? Explain. (4 marks)



will increase

$T = 2\pi\sqrt{\frac{m}{k}}$

1

End of the Quiz

APPENDIX TEN

List of my Publications

APPENDIX 10 – LIST OF MY PUBLICATIONS

This work has been recognised by two publications, so that part of the findings are placed in the public domain:

1) ***Developing a predictive model for the enhanced learning outcomes by the use of technology*** - Mo'ath Farah1, Gren Ireson2 & Ruth Richards3

   Imperial Journal of Interdisciplinary Research (IJIR); Vol-2, Issue-5, 2016; ISSN: 2454-1362,

   http://www.onlinejournal.in/IJIRV2I5/213.pdf

2) ***A Content, Pedagogy, and Technology [CPT] Approach to TPACK*** - Mo'ath Farah1, Gren Ireson2 & Ruth Richards3

   Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-12, 2016 ISSN: 2454-1362,

   http://www.onlinejournal.in/IJIRV2I12/177.pdf