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Using Educational Applications on tablets to Support Science Learning Among First-Grade Saudi Primary School Children

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In the name of Allah the most

Merciful and Beneficent

DEDICATION

To my father and mother,

For their support, continuous prayer, unending inspiration, and dedication. For being my first teachers…

To my husband Saeed,

For your unconditional love and unflinching care. For inspiring me with your strength and motivating me with your kindness...

To my daughters Aseel and Farah,

For their eternal love; you are the force behind my success...

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ABSTRACT

Multi-touch tablets and educational apps provide young learners with opportunities to support science learning, rarely offered by traditional science teaching methods such as the chalk and talk method, which is heavily employed in Saudi schools. In many developed countries such as United States and Canada the use of tablets in classrooms has increased when compared with other mobile devices due to the educational advantages of tablets' unique affordances (Fritschi & Wolf, 2012). To date, research conducted on using tablets as educational tools and the potential of educational apps, especially with reference to science learning among children, is insufficient. The aim of this research therefore, was to explore the role of educational apps on tablets' potential to support science learning and engagement among first-grade Saudi children, as well as to investigate the challenges encountered in implementing mobile learning to support science education.

To fulfil this aim, I designed and carried out an interpretative study in a first-grade class in a private school in Riyadh, the capital city of the Kingdom of Saudi Arabia. I employed a qualitative approach to obtain deep and extensive understanding of mobile learning. I adopted social-constructivist theory to underpin my study. To collect data, I utilized semi-structured interviews, focus groups, and participant observation. The current study involved 17 female students between 6 and 7 years old. The data was examined by inductive thematic analysis.

The findings indicated that these young learners' experiences of learning using educational and gamified apps was both personally enjoyable and meaningful. It highly engaged them emotionally and cognitively. Furthermore, social interactions between peers regarding apps' contents and activities scaffolded their science learning and constructed their personal understanding. Also, these findings suggest that animations and multimodal apps provided children with unique learning experiences regarding abstract scientific concepts and assisted them in gaining new knowledge. Mobile apps afforded the children scaffolds and challenges in proper balance, which maintained their motivation, helped them solve problems, and promoted persistence and risk-taking.

The findings of this thesis will provide science teachers, policymakers, researchers, and app developers with an understanding of the potential impact of tablets' affordances and apps' educational advantages in supporting and facilitating science learning and their roles in encouraging engagement and scaffolding. Which might encourage science teachers to change

the traditional methods that they use in teaching science and employ mobile learning and other modern methods.

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CHAPTER ONE

INTRODUCTION

1.1. Introduction

Today's young learners are considered to be digital natives (Glassman & Glassman, 2015). Many children across the globe use mobile phones, tablets, and video games as part and parcel of their daily lives (Glassman & Glassman, 2015). The development and popularization of information technology requires teachers to reconsider their teaching methods and strategies (Wang, Ji, Dong, Chen, & Chang, 2011). Arellanes, Gallard, Strycker, & Walden, (2018) propose that teachers should provide young children with quality education that contributes to prepare tomorrow's citizens and assist them with discovering creative solutions for world problems. This can be achieved by taking into consideration the innovative and new means of technology that influence learners' engagement in science (Marino, Israel, Beecher, & Basham, 2013). Kapri (2017) argues to improve the productivity of education, educators should use new educational methods, while developing traditional techniques and mainstream technology with education. Nowadays, education and the world of technology are inseparable because of growth research that incorporates both mainstreams (Amerul et al., 2017).

Our world has been impacted by ubiquitous telecommunication technologies, an information explosion, and faster intercontinental transportation and schools and universities are also influenced by what occurs. Due to these changes, the new trends and approaches in education have been declared, such as mobile learning (Kumar, 2017). ICT is the latest advance regarding education (Taufiq, Amalia, Parmin, & Leviana, 2016). Mobile learning is defined as a learning process mediated by portable devices, tablets, computers, game consoles, and smart phones (Burden, Kearney, & Kearney, 2016). Mobile devices' potential affordances in education have been examined and explored in numerous studies. These studies' findings shed light on these devices' unique characteristics, multifunctionality, instant connectivity, portability, and small size (Butcher, 2014; Fisher, Lucas, & Galstyan, 2013; Merchant, 2015a; Pellerin, 2014; Cheon, Lee, Crooks, & Song, 2012). Furthermore, these findings highlight the limitations to mobile devices' physical and technical features, particularly their limited screen size, sudden shutdowns, and freezing, which might impact continuous learning (Park, 2011; Marsh et al. 2015). Nevertheless, the evolution of mobile and devices and tablets can resolve several technical issues that might influence learning.

Moreover, this new trend in learning offers new affordances to students, such as learning situations not being hindered by environmental and temporal constraints, in addition to contextualized and personalized learning (Crompton, Burke, Gregory, & Gra, 2016). Amerul et al., (2017) propose that students' learning styles have been influenced by the rapidly increased popularity of mobile devices. Choi, Land, & Zimmerman (2018) suggest that the ways in which science is conducted are influenced by technology. Much of scientific exploration would not be possible without technology (Bull & Bell, 2005). Using technology tools make complex and tacit thinking manageable and explicit and also engages students' agency and interest within a social and responsive physical environment. In addition, young learners advance their science knowledge and increase their inquiry capabilities when they learn in technology-rich environments (Song & Wen, 2018).

Morris, Croker, Zimmerman, Gill, & Romig (2013) believe that the needs of 21st-century learners can be filled and modern science education can be designed using mobile apps and serious games. Adopting mobile learning can lead to revelations in educational institutions, in which interactive classrooms can replace conventional classrooms. The application of this new trend in learning has the possibility to consolidate students' learning experiences due to mobile devices' features, which can afford different level of engagement (Ahmed & Parsons, 2013). Furthermore, this trend can provide young learners with an immersive experience of scientific system models to elucidate how the variables interact and make them completely comprehended (Zydney & Warner, 2016). Portable devices' playful applications can enhance and promote children's mental exercise, communication, creativity, and fantasy (Giannakos, Jones, Crompton, & Chrisochoides, 2014). Moreover, children's play experiences with digital devices help them to develop an understanding of the world around them and embrace their interests (Lee & Tu, 2016).

Marino et al., (2013) suggest that the intersection between traditional curricular materials and educational apps makes science learning more relevant to learners' lives and improves the accessibility of science content. Advanced mobile devices are embedded with thousands of free or low-cost apps. The availability of these apps affords science teachers new opportunities to explore how to use these resources to reinforce science learning (Falloon, 2017). Through the use of mobile devices, teachers are enabled to extend the context of learning far beyond the school schedule and the classroom walls (Huang, Lin, & Cheng, 2010). These devices have a power and ability that can revolutionize learning and teaching of science (Crompton et al., 2016).

Abundant studies have examined the efficacy of tablet usage by young learners in primary schools to support science learning and tablets' effects on their engagement and ability to obtain knowledge (Choi et al., 2018; Crawford, Holder, & Connor, 2017; Furman, Angelis, Prost, & Taylor, 2018; Herodotou, 2018; Wirawan & Arthana, 2018). Furthermore, these studies have clarified how mobile learning opens up opportunities for students to investigate life outside the classroom in diverse contexts, such as gardens, parks, forests, and museums as well as working in field sites (Menon & Steinhoff, 2017). Also, studies show how handheld devices facilitate the learning of scientific concepts and make them more accessible through multiple representations as well as modelling and visualization. Technology has allowed science learners to make predictions, explore data, and form conclusions (Bull & Bell, 2005). I explain this in further detail in the next chapter.

Firstly, I provide the problem statement for this research and the context of the study. Also, I provide a description of the education system in Saudi Arabia in general and of science education there, in particular.

1.2. Statement of the Problem

Numerous childhood researchers have suggested that science education should begin in the early years of children's schooling to build a basis for scientific understanding in the future (Watters, Diezmann, Grieshaber, & Davis, 2001). Science education provides children with scientific concepts and facts to help them understand natural phenomena, their surrounding environment, and the world (Eshach & Fried, 2005). The main purpose of teaching science to young learners is to assist them with obtaining knowledge, life skills, and ideas (Cholid, 2015). Some children view science as a difficult subject due to the theoretical nature of many scientific phenomena, processes, and concepts alongside its complex vocabulary (Marino, Becht, et al., 2014; Terrazas-Arellanes et al., 2018). Also, young learners find two aspects of dealing with dimensional scientific phenomena difficult: applying the knowledge and comprehending it (Anderson & Barnett, 2013).Generally, young learners encounter some difficulties in science learning, such as using high-order thinking skills, misunderstanding theoretical components, and lacking their own cognition system and the ability to generate concrete constructs in this context (Barak & Dori, 2011; Furman et al., 2018; Koseoglu & Efendioglu, 2015).

Children face difficulties in learning science because it requires them to use comprehension processes. These processes in learning science are not easily observed because they might be on too large a scale, too slow, and too small (Ekanayake & Wishart, 2014). Song & Wen (2018) believe that young learners might encounter challenges that are difficult to overcome in the process of inquiry learning, such as in conducting experiments, designing methods, exploring problems, and elucidating and presenting results. These reasons and factors may result in children developing negative attitudes towards science in the future as well as low achievement in science. Also, they can make young learners feel that science is boring. Many science teachers complain that there are declining attitudes toward science among learners. The factors that aggravate this problem include the adoption of traditional learning, with overreliance on memorization of scientific facts, instead of encouraging learners to engage with scientific investigations; concentrating on abstract concepts and vocabulary that are not connected to the learners' background knowledge; and stressing rigid interpretations of scientific methods, in a "cookbook lab" (Marino et al., 2013).

In developing countries such as Saudi Arabia (the context of the study), teachers' oral explanations are still the dominant learning approach used in classrooms. Also, proper learning environments that provide learners with a learning process mainly for science are rare (Koseoglu & Efendioglu, 2015). Teachers use fact memorization rather than scientific methods (DeWitt, Siraj, & Alias, 2013). The adoption of teacher-centered strategies and the ineffectiveness of conventional teaching methods can make students view science as a difficult subject (Karacop & Doymus, 2016). Traditional teaching does not help students to learn science concepts as expected; as a result, educators should consider unique alternative teaching methods (Karacop & Doymus, 2016). Direct instruction methods in traditional educational environments are not effective in teaching young learners. This requires science teachers to create fun, cooperative, meaningful, and worthwhile science learning experiences, such as by using play-based learning and mobile learning. Exposure to interesting, enjoyable, and positive science learning experiences increases learners' achievement later in school life as well as their engagement and comfort. This can allow learning to occur and contribute to helping children to acquire more complex skills as well as exploration, which can enable them to expand the boundaries of their learning and experimentation (Herodotou, 2018). Traditional learning creates passive learners who just sit and listen.

Trowbridge, Bybee, & Powell (2008) propose that using new technology tools such as tablets can assist children with acquiring scientific concepts and interpreting these abstract concepts in attractive, interesting, and interactive ways as well as help them enjoy learning science, if the pedagogical approach is appropriate. Handheld devices are very popular and, if used effectively, can facilitate analysis, process, data collection, communication, and collaboration, which may meet learners' needs, especially higher-order needs (Su & Cheng, 2013).

Mobile devices offer a host of affordances, including in knowledge construction, information sharing, multimedia access, connectivity, representation, reference, and analysis, which can help students to meet their science inquiry needs, share information, collect and search for data, and coordinate and discuss with peers (Song, 2014). Additionally, mobile learning may support a student-centred approach in learning science by providing learners with activities including problem-solving activities, independent learning activities, peer teaching, role-playing simulations, group discussions, experiential learning, inquiry-oriented approaches, concept mapping, hands-on activities, and cooperative learning (Karacop & Doymus, 2016). Current educational theories demand learning activities to be designed that maximize students' opportunities to develop higher thinking abilities and construct meaningful personal knowledge (Yu, Tsai, & Wu, 2013).

Due to some of the environmental circumstances, conditions, and educational learning systems in Saudi Arabia, teachers are compelled to teach scientific lessons in classroom contexts that need observation and outdoor practice to be understood deeply, which prevents children from applying their classroom knowledge. To resolve this limitation, having worked in this context, I began to see the potentials of mobile devices which can be seized to facilitate science learning in this situation and provide children with interactive, engaging, flexible learning experiences (Huang et al., 2010). Moreover, Yin, Song, Tabata, Ogata, & Hwang (2013) suggest that models of real-world settings provided by simulation apps can enable knowledge construction among learners through active participation. Also, such apps can afford opportunities for reflection. The utilization of technology means social media, and mobile apps are finding increased acceptance among Saudi children (Coyle, 2017). Yet, comprehension of the educational view of mobile devices among Saudi children is still absent (Abdullah, 2015). Utilizing tablets for enjoyable learning experiences in classroom may contribute to developing positive attitudes among children towards learning science. However, this is dependent on a number of factors, such as the quality of the apps used, and the pedagogical approaches used by the teachers.

1.3. Context of the Study

It is important to provide information about Saudi Arabia, the context of the study, which is different in many aspects (e.g., culturally, socioeconomically, educationally, geographically) compared with that of studies mentioned thus far in the literature review. Saudi Arabia is located in Southwest Asia. It is the largest country geographically in the Middle East. Its capital city is Riyadh. Its total population has reached 34 million people. Saudi Arabia is divided into five regions—South, West, East, North, and Najd—with 65 cities. The kingdom is a desert country with great temperature extremes. Desert life impacts every single aspect of education, the economy, and the environment. Saudi Arabia was a subsistence economy before discovering oil, which it now relies on, in addition to pilgrimages, pearl fishing, trading, and farming. Right now, the country depends on oil and is ranked as one of the top twenty world economies in the Arab world, which has led to great transformation and development in all fields.

1.4. Saudi Arabia's Education System

Compared to Western countries, the educational development of Saudi Arabia started very late. In 1927, the Saudi Directorate of Education was established. By establishing this directorate, schools and institutes were spearheaded throughout the kingdom. In 1954, its name was changed to the Ministry of Education (MOE) (Wiseman, Sadaawi, Alromi, 2008)

1.4.1. Administration

In Saudi Arabia, 42 districts are presided over by the Ministry of Education, which is considered to be the main provider of educational services (Saudi Arabian Cultural Mission, 2013), providing teacher selection, teacher recruitment, national examinations, curriculum plans, and educational resources. The ministry controls public education and private-sector standards. Education in Saudi Arabia is free and open to all citizens. The educational system in the kingdom consists of five stages: kindergarten, primary, intermediate, secondary, and higher education. The school year consists of two semesters (Dhir, Gahwaji, et al. 2013). Saudi Arabia's schools and universities are divided by gender. The Saudi educational system's objectives are to afford all Saudis basic education, educate students about the basic principles of Islam, and prepare Saudis for work (Al-Baadi et al., 2008, p. 3). In addition, it is very centralized, with uniform textbooks, syllabi, and national curricula (Alshumaimeri, 2008). The Ministry of Education oversees girls' and boys' education, higher education, and special education. Moreover, its members are responsible for the construction of schools and their maintenance as well as for providing schools with equipment, school supplies, and textbooks (Aljadidi, 2012). There is a specific department for curriculum in the Saudi Ministry of Education that is responsible for developing curricula and preparing textbook content. Each grade has specific textbooks for each subject. Teachers cannot play any role in curriculum development; they are required to use the specified publications and are not allowed to change the subjects and topics (Alquraini, 2011).

Primary school students are evaluated regularly during the school year through MOE assessments, and they do not need to achieve top performances on exams. In contrast, intermediate and secondary students must study their textbooks to pass their exams at the end of each semester. Teachers are not allowed to test students about any piece of information outside of the textbooks (Dhir, Gahwaji, et al. 2013).

The educational system of Saudi Arabia faces several challenges, such as high population growth, which has led to an increased number of students enrolled in schools. An addition challenge is in preparing university and secondary school students for the country's future social and economic needs, which needs greater emphasis on STEM education. The educational system in Saudi Arabia has been subject to some criticism. Most notably, critics have identified its perceived weaknesses in scientific and technical education, weaknesses in teacher training programs, a lack of modern technology being integrated into the learning process, preferences for traditional learning based on indoctrination, and teachers' lack of freedom to select their curriculum content according to their students' abilities and orientations (Howells, 2014). The ministry has put a lot of effort into changing the domination of traditional learning by developing the Tatweer project, which is aimed at employing mobile learning and digital learning in the same vein as other countries around the world (Saudi Arabia Ministry of Education, 2008). Recently, Saudi Arabia has adopted an approach for education development according to 2030 Vision, which includes the aims of promoting innovations and creativity, consolidating the quality of education outcomes, increasing the effectiveness of scientific research, affording educational opportunities for all within suitable learning atmospheres, offering students rehabilitation opportunities, developing public education, developing partnerships with the community, bridging the gap between labor market requirements and higher education outcomes, directing students to convenient professional options (Alhomairi, 2018).

1.4.2. Primary Schools

The participants in the current study were first-grade students from a primary school. Children enter primary school at age 6, and they spend six years in the primary program (Abdullah, 2015). The objectives of this stage of education are to develop students' basic skills, educate children about Islam and Saudi culture, and create a sense of responsibility within students (Al Omar, 2013). The subjects taught in primary school include Islamic studies, Arabic, English, mathematics, science, history, geography, and fine arts (Saudi Arabian Cultural Mission, 2013).

1.5. Science learning in Saudi Arabia

Science is a mandatory subject starting from first grade in primary school, and it continues through intermediate school to the first year of secondary school. After that, students have a choice in their second and third years of secondary school to select specific scientific studies and study science in an intensified and elaborated manner; they are required to study chemistry, physics, and biology or to select literary studies as an alternative track. Science learning in Saudi schools depends on text more than it does observation and interaction. Students take three 45-minute science sessions per week. The science learning objectives are to develop conceptual understandings and scientific knowledge; develop children's understanding through inquiries, to assist them with finding answers to their questions about the surrounding world; understand science's uses and implications; and build students' confidence through knowledge (Alhomairi, 2018).

1.5.1. First-Grade Science Curriculum

In the twenty-first century, the Saudi Ministry of Education's (MOE) main challenge has been to take action and develop science curricula so that scientific literacy becomes the core part of science education (Alarfaj, 2015). The MOE members have devised general plans specifically to serve that purpose (Ghamdi & Abduljawad, 2015). The science curriculum is derived from the curriculum taught in U.S. schools and adapted from the science textbooks of McGraw-Hill, which is an American publishing company. The curriculum committee at the Ministry of Education has modified and translated these textbooks into Arabic (Al-Shamrani & Mansour, 2015). In primary school, Science is taught as one subject that comprises physics, chemistry, and biology content (Kim & Alghamdi, 2019). The following are the objectives of science education in primary Saudi schools:

To:

- Reinforce children's faith towards god (Allah), recognise his creation, and realise the accuracy and coordination of the universe.
- Equip children with an appropriate amount of scientific facts and concepts that help them understand and interpret phenomena in order to realise that science facilitates their lives through the services it provides.
- Encourage children's use of scientific methods: search, observation, experience, inference, analysis, cross-checking, data examination, and inquiry.
- Help children become familiar with the environment, understand the related phenomena, take advantage of developmental science, and maintain safety.
- Expand the children's horizons by attracting their attention to their country's features, such as natural resources, so they can benefit from them and use them in the proper way.
- Provide children with suitable opportunities to conduct experiments and enable them to acquire manual skills and practical experiences.
- Familiarise children with healthy habits and the role of good health in people's lives.
- Increase children's understanding of Muslim scientists' roles in developing science and the role of their inventions and discoveries in offering welfare and human advancements.
- Develop children's use of scientific reading, references, and scientific writing, as well as their passion for science-related hobbies.
- Encourage children to obtain information about the history of science and global achievements in scientific fields (Alfehaidi, 2018).

The science curriculum for first-grade Saudi primary schools covers many topics of interest to children at this age, such as plants, animals, the Earth, weather, materials, power, and energy. It is designed to provide information to children about the environment in which they live, develop their ability to observe phenomena, encourage them to use their senses to explore their surrounding environment, satiate their curiosity to learn about natural and environmental phenomena, develop scientific skills, satisfy their curiosity and need for discovery, develop problem-solving and decision-making skills, increase their understanding of the nature and content of organisms, and increase their understanding of some chemical processes and simple physical phenomena. These topics are contained in the relevant textbook. Moreover, every chapter of the book has an accompanying pamphlet with activities that aim to help deepen children's scientific knowledge and give them the skills needed for scientific research and investigation. It also includes illustrations that reflect the content of each chapter (Alghamdi & Al-Salouli, 2013). The study reported in this thesis spanned four months during the first semester of the school year. Therefore, in Table 1.1, I have provided details of first-semester science book which includes three units: plants around us, animals and their environments, and our earth.

Table 1.1: First grade science book contents

Units		**Chapters**		**Lessons**
Unit One	Plants around us	**Chapter One**	Plants are living creatures	• Living creatures • Plants and their parts • Planting mangos • Revision
		Chapter Two	Plants grow and change	• Growing plants • Plants growing in many places • Different seeds • Revision
Unit Two	Animals and their environments	**Chapter One**	Animals around us	• Animals' types • Animals' needs • Animals' food • Revision
		Chapter Two	Animal living places	• Land habitats • Water habitats • Revision
Unit Three	Our earth	**Chapter one**	Earth resources	• Earth resources • Benefit from Earth resources • Maintain Earth resources • Recycling • Revision

Many teachers, however, have complained that the curriculum is too intense and includes some difficult new words that children do not understand. Some of the curriculum's content is not suitable for the Saudi environment due to there being different names for some plants and animals than those translated from the American curriculum. The curriculum's related activities have not been linked to children's reality, as the correlation is weak between the curriculum and Saudi society (Almazroa, Aloraini, Alshaye, 2015; Mursi, 2014). Furthermore, the curriculum's objectives concentrate on the cognitive domain and neglect the psychomotor and affective domains (Alarfaj, 2015). In addition, some activities require higher-level skills, such as extrapolation and investigation. Also, the curriculum is planned for an ideal classroom size of 25 students or fewer, but the class size in some Saudi public schools reaches 50 students. Furthermore, skills such as critical thinking, problem solving, independent learning, cooperative learning, and dealing with sources of information can be gained by conducting lab experiments; however, some public schools lack the means and tools for conducting the recommended experiments. Similarly, teachers complain about a lack of teaching tools, inadequate time for teaching science, and heavy workloads, which make teachers rely on lecture based teaching, which prevents children from interacting with real-life situations (Mansour & El-Deghaidy, 2015) and negatively affect students' acquisition of scientific skills (Alfehaidi, 2018). There is a heavy emphasis on rote learning and memorization. Official textbooks are the main source of information (Kim & Alghamdi, 2019).

1.6. Research Aims and Objectives

The overall aim of this thesis is to explore the role of educational applications on tablets to support science learning among first-grade children in a Saudi Arabian school. An additional aim of the study is to investigate the challenges encountered when implementing mobile learning to support science education. To fulfil these aims, I proposed the three following questions.

1.7. Research Questions

RQ1: What are children's responses to using educational science applications that support science learning in a Saudi Arabian Grade 1 class?

RQ2: How far do educational science applications support science learning in a Saudi Arabian Grade 1 class?

RQ3: What are the issues and challenges related to implementing mobile learning in a science class in a primary school?

To answer these three questions. I conducted an interpretative study, which enabled me to design a mobile learning environment to examine and explore the effects of apps on first-grade children's science learning and engagement. The study was carried out in a Saudi primary school. The children were provided with tablets equipped with a selection of different types of apps, including gamified, puzzle, coloring, and problem-solving apps. The study spanned four months during the first semester of the school year. The apps were selected according to the science curriculum's skills, topics, and perspectives. I adopted the qualitative approach and collected data by living the experience with children in the classroom through participant observation, focus groups, and interviews. Thematic analysis was used to analyse the extracted data according to social constructivism theory. The findings of this thesis will offer science teachers insight about the educational potential of tablets and their apps to support science learning among young learners as well as provide them with clear understanding about their roles in engaging students cognitively and emotionally to learn science. In addition, the study provides explanations regarding scaffolding of science learning through mobile learning environments and the function of this strategy in assisting children with science learning. Lastly, the study's findings will afford recommendations for policy makers and app developers.

1.8. Structure and Outline of the Chapters

Chapter One: Introduction

This chapter includes the statement of the research problem and research questions; the aims and context are also explained.

Chapter Two: Literature review

This chapter includes existing literature on mobile learning and its role in supporting science learning. Furthermore, it offers a review on mobile learning's educational affordances and limitations. I provide discussion regarding its potential in education in general and science education in particular as well as its design characteristics. Also, I review the drawbacks and concerns that occurred as a result of adopting this type of learning. Finally, the chapter contains examples of some app types that can be useful in assisting with science learning.

Chapter Three: Theoretical framework

This chapter includes an explanation of social constructivism theory and the framework that guides the present study.

Chapter Four: Methodological framework

This chapter includes a rationalization and outline of the research paradigm, the data-gathering means, and the data-analysis procedure.

Chapter Five: Findings

This chapter includes a discussion about the data extracted from the study to provide answers to the research questions.

Chapter Seven: Conclusion and recommendations

This chapter includes a summary of the current study's key findings, recommendations, implications, limitations, and contributions.

1.9. Chapter Summary

Today, there is exponential and accelerating growth in technology interest among learners from all levels (Wang et al., 2011). Such learners are interested in using portable devices due to their characteristics and their apps' affordances, and the apps harness learners' enjoyment and the devices' popularity and possibilities. Technology can provide opportunities for children to learn science through mobile learning rather than traditional learning as it allows learners to learn without being restricted by time and place (Huang et al., 2010). However, such use needs to be guided by appropriate pedagogical practices and the use of high-quality resources if it is to be beneficial. In the following chapter, I discuss literature related to other studies' findings and outline the key theoretical arguments in order to identify my study's novel contribution.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This chapter reviews existing literature on mobile learning and its role in supporting science learning. Furthermore, the chapter offers a review of mobile learning's educational affordances and limitations. I provide a discussion of research focused on the potential of mobile learning in education in general and science education in particular as well as on its design characteristics. Also, I provide drawbacks and concerns regarding the adoption of this type of learning. Finally, I provide examples of some app types that are useful in assisting with science learning.

2.2. Definitions of Mobile Learning

Mobile learning refers to a situation when teachers and/or learners take advantage of opportunities offered by portable devices, such as smartphones, laptops, and tablets, to enhance the learning process. It is based on interactions between two elements—ubiquitous handheld devices and their utilization for learning purposes (Su & Cheng, 2013)—which make students show higher levels of confidence, relevance, and motivation (Hwang, Chiang, & Yang, 2016). Mobile learning is characterized by authenticity, which highlights opportunities for situated, participatory, and contextualized learning (Burden et al., 2016). It contextualizes the knowledge in conditions and styles that are unobtainable in conventional classrooms (Marino et al., 2013) and has the ability to enhance formal education within classrooms and informal education outside of schools, with the latter happening in a variety of physical and temporal arenas (Hockly, 2013). Meaningful learning can occur by using handheld device applications, due to the unique capabilities of the hardware, which combine visual presentations and animation to provide instant feedback, and has the potential to attract the attention of students at all educational stages (Clements, 2002; Falloon, 2013). Additionally, such devices are characterized by low weight and small sizes, so students can avoid carrying heavy bags full of papers, folders, and textbooks by using touchscreens. Furthermore, some mobile devices include touchscreens, which are easier to deal with than a mouse and keyboard and provide the best sensory experience for elementary children in the United States, using direct touch (Zhang, Trussell, & Gallegos, 2015).

2.3. Mobile learning educational affordances

Mobile learning has gained widespread popularity in the field of teaching and learning because it offers vision-enabled learning at any time and any place using any handheld devices to enhance and expand the learning experience. Moreover, technology has become central to the lives of students due to its unique features and capacity to help students perform their daily tasks and duties (Martin & Ertzberger, 2013). The most prominent advantages of mobile learning are as follows.

2.3.1. Flexibility

Field (2005) believes that Efficiency cannot be achieved in learning except through flexibility, when students are determining the conditions of their learning. Mobile learning can help teachers to accomplish this aim. A mobile learning environment allows students to determine their own objectives, goals, and aims and to select their own paths within the learning process (Gerger, 2014). In fact, mobile learning offers students the opportunity to learn without considering the limits of time and space. Moreover, children engage with multimedia content because of its flexibility; children can choose from a wide range of media options that accommodate individual differences in learning style preferences, allowing the children to learn at their own pace. By contrast, textbooks do not offer children these choices to help them stay interested and enjoy learning (Oludare, Moradeke, & Kolawole, 2012). Mobile technologies have tremendous educational potential in serving today's generation. These advancements have allowed students to process information outside classroom boundaries, thus encouraging learning within the context of the real world. However, students' excessive reliance on handheld devices instead of attending classes, especially if they can access learning materials online anywhere and at any time, contributes to them missing out useful activities and important discussions in the classroom, which will affect students' learning. Actively involving students in classroom activities makes learning and teaching more effective (Shonola & Joy, 2014).

2.3.2. Engagement

Engagement refers to the ability of learners to remain on-task and not be distracted (Hirsh-Pasek et al., 2015). Effective learning takes place when students are cognitively and emotionally engaged. Mobile learning provides learning experiences with a low degree of formality, which engages students and reluctant learners. Tablets and other handheld devices have proven to be effective at engaging learners and at helping them recognize ways to present their learning (Dunleavy, Dede, & Mitchell, 2009). Furthermore, using handheld device applications and games can engage young learners who may have lost interest in education. Perry (2003) demonstrated that students' participation and enthusiasm increased within mobile educational milieus. The active learning experiences that mobile learning has created can improve course retention, improve engagement, satisfy curiosity, deliver needed information, and increase motivation (Su & Cheng, 2013). Handheld devices can provide children with easy access to multimedia resources, stimulate children's senses, and improve children's engagement and learning outcomes in the right circumstances. Tabuenca et al. (2016) indicated that direct manipulation of tablets promotes higher engagement among children because they can control the digital objects that appear on the screen. Furthermore, tablet screens' designs, colors, and visual elements as well as the apps' audio can influence students' emotions and moods. In addition, Byun & Loh (2015) propose that tablets keep students emotionally and behaviorally engaged during the learning process. By contrast, Selwyn argues that young people's use of digital technology might lead to increased alienation from activities and formal institutions, disenchantment, and disengagement, as a result of them utilising the Internet on technological devices used more for self-promotion and self-expression than for learning purposes (Selwyn, 2009: 368).

2.3.3. Motivation

Motivation is a vital and essential aspect of learning (Su & Cheng, 2013). It contributes to deep learning occurring (Ward, Finley, Keil, & Clay, 2013). Motivated learners are more likely to overcome obstacles in understanding, put in more effort for comprehension, and engage in the task or lesson (Parong & Mayer, 2018). Apps' multimodal features have led to an increase in children's motivation in some projects by providing an assorted selection of apps for expression and enabling them to make decisions (Fatina & Quniebi, 2016). Sung and Hwang (2013) found that employing collaborative games promotes students' learning attitudes and motivation and improves their self-efficacy.

2.3.4. Communication

Mobile learning offers communication channels to teachers and students, which reduce the barriers between them. Divitini, Haugalokken, and Norevik (2002) showed that using mobile applications in an educational context improved communication and cooperation. In addition, using portable device applications has become a part of everyday life, and most people are accustomed to using such applications to communicate (Corbeil & Valder Corbeil, 2007). Mobile technologies are able to provide learners with liberty from their classroom's physical boundaries and allow students to interact, communicate, and work with experts and peers beyond the school context to negotiate shared meanings and articulate their ideas (Burden et al., 2016; Sun, Looi, Wu, & Xie, 2016). For example, using nQuire-it on mobile devices enables learners to communicate and interact with their classmates and teachers anywhere and at any time, and to investigate both authentic and virtual scientific phenomena (Sun & Looi, 2018). Morris, Lambe, Morris, & Lambe (2017) suggest that Mobile devices' intelligent user interfaces and ubiquitous communication can be harnessed to support learning. Moreover, the novel tools that technological innovations provide offer educators opportunities to communicate and connect with students. These implemented tools can contribute to positive transformation in traditional perceptions of pedagogies such as lecture-based learning (Ward et al., 2013).

2.3.5. Lifelong, informal learning

School is only part of the learning process and cannot provide people with all knowledge and skills. The Internet enables learners to obtain a rich variety of opportunities to learn informally through use of their mobile devices to read books, watch videos, and participate in discussion forums (Ozdamli & Cavus, 2011). Learning is a continuous process, as it is not restricted by a specific time, place, or age. Handheld may devices enable learning to continue outside the classroom and to take place naturally (Zydney & Warner, 2016).

2.3.6. Game playing

Play is a process that promotes positive development and facilitates mental growth (Herodotou, 2018). Children naturally engage in all forms of play. Handheld devices create experiences for play in a modern form (Herodotou, 2018). Learning does not only mean accessing knowledge from traditional resources. Educational mobile and video games offer a vital source of learning opportunities, thereby integrating learning with entertainment (Jones, Larson, Weaver, & Caliph, 2005). Gaming elements such as scores, time limits, operations, and competition can attract students and motivate them to learn (Giannakos et al., 2014). Serious games can afford learners contexts characterized by a high degree of competence and control regarding their actions (Morris et al., 2013). Furthermore, several mobile games are available that develop intelligence and language skills. Mobile games have earned attention as tools with which to promote thinking and creativity (Becta, 2001). Furthermore, serious games can be employed to support education, meet the current generation's preferences, and provide them with various strategies that are fully appropriate for learning 21st-century skills (Miller, Chang, Wang, Beier, & Klisch, 2011).

2.3.7. Collaborative and active learning

Collaborative learning is an effective strategy for constructing knowledge (Dewitt, Alias, & Siraj, 2018) and plays an important role in providing students with a supportive environment and in crafting their communication skills (Amerul et al., 2017). Learning is more effective when learners talk with each other and share their understandings of the world. Discussions between peers within their groups allow for debate, argument, and reflection, thereby reinforcing critical thinking (DeWitt et al., 2013) and positively impacting their learning retention (Amerul et al., 2017). Handheld devices enable learners to share information easily by sharing documents and exchanging ideas with classmates or students outside of class (Barker et al., 2005). Meaningful learning requires educators to expose children to activities that encourage the exchange of opinions and communication with one another (Amerul et al., 2017). Schuler, Winters, and West (2012) found that utilizing tablets in the classroom assisted with creating a collaborative learning environment among students in which they could exchange information efficiently.

Employing educational applications can help children as a potential method of learning, by increasing their strategic thinking, collaboration, and learning performance (Sung & Hwang, 2013). Within mobile learning games, collaborative problem solving can be scaffolded by differentiated roles, with every student in the group individually receiving specific information about their own role. Sharing this information and findings with group members can contribute to solving game problems collaboratively (Bressler & Bodzin, 2013). In contrast, Friesen and Lowe (2011) believe that employing mobile apps in the educational process is ineffective because they emphasise agreement and thus might negatively impact significant learning strategies that encourage dissent and disagreement, confrontation, and critical inquiry. Moreover, educational dialogue—a central process of collaborative learning—may be threatened by adopting some apps, which do not foster dialogue. Furthermore, the educational quality of some educational institutions can be degraded by the threat that collaborative pedagogical and learning through mobile technology use will be limited (Criollo-c et al., 2020).

2.3.8. Individualisation

Not all children are alike. Every child has individual learning needs and abilities. Teachers and students have found that mobile learning helps to individualize the learning process and improves students' educational experiences (Thomas, 2005) because students can select learning materials, resources, and styles that match their learning preferences (Panjaburee & Srisawasdi, 2016). Moreover, modern technology tools offer forms of individualized instruction for students within their learning group, who are likely very diverse in their strengths in and preferences for learning (Kamarainen et al., 2013). Mobile learning environments are used to adapt instructions to young learners' specific needs (Basu, Biswas, & Kinnebrew, 2017).

2.3.9. Personalized learning

Personalized learning refers to learners' access to a variety of learning resources based on their needs as individuals (Sun et al., 2016). Technology provides individuals suitable methods to acquire information and interact with other people via applications and the Internet. Also, through technology, learners are able to organize their learning processes when they choose a method to achieve a particular goal (Selwyn, 2016). Learners can use different mobile devices as a tool to adopt different learning pathways (Looi et al., 2011). Handheld devices can enhance personalized learning, as the facilitated learning that occurs is distinctive from other learning forms (Sun et al., 2016). An appropriately designed mobile learning experience that affords learners a high level of personalization allows them to enjoy a greater degree of agency (Burden et al., 2016). However, a major challenge for teachers and educators is to find ways to ensure that mobile learning is highly situated, long-term, collaborative, and personal—in other words, truly learner-centred learning (Muyinda, Mugisa, & Lynch, 2006).

2.3.10. Autonomous self-directed learning

Autonomy is children's ability to control their own learning, motivation, behaviors, and metacognition to achieve desired learning outcomes. Mobile devices can offer children a sense of ownership of their own learning; as a result, they take responsibility for their own learning. Also, these portable devices demolish the perspectives that require learners to connect a specific activity to a time or place (Hoban & Nielsen, 2014). When learners take responsibility for their learning, they become more active (Sun et al., 2016). Self-directed learning can be encouraged using handheld devices' apps and various in-built functions and features (Menon & Steinhoff, 2017). Children taking ownership of their own learning contributes to a richer and deeper knowledge structure, which leads to the introduction of new situations (Akcay & Akcay, 2015). Mobile learning promotes greater control by allowing learners to process information regarding their interests, as well as analyze, organize, and choose (Devolder & Braak, 2012). A high level of control and choice lead to high learner engagement (Jones, Scanlon, & Clough, 2013). Furthermore, it is important to provide children control and agency on an appropriate level, depending on their experience and age, so as to contribute to their sustained interest and to enable them to progress at their own pace (Hirsh-Pasek et al., 2015). However, giving children a great deal of freedom can cause difficulty integrating, selecting, and organising relevant information (Suárez, Specht, Prinsen, Kalz, & Ternier, 2018). Also giving them the main control in a mobile learning context might quickly overwhelm the learners if a situation demands quick reactions, or if no coach is online. Thus, they might sometimes receive too little guidance (Frohberg et al., 2009).

With regard to control in the gaming environment, when children can control their interactions with avatars, they pay more attention, learn more, and experience a higher level of arousal (Hirsh-Pasek et al., 2015). Motivation can be enhanced when students control what they choose to view and interact with mobile objects (Fokides, 2017), as well as control the game characters, setting, and environment (Israel, Wang, & Marino, 2016). Nouri (2014) proposes that gamified apps make learners responsible for implementing actions drawn by task instructions, and they are allowed to freely construct their own actions. Many mobile learning activities provide learners the freedom to make choices related to how they compose, solve, sequence, and plan their given tasks. Within this freedom comes the responsibility for testing and constructing potential solutions, applying information, interpreting, reflecting on relevant cognitive processes, evaluating, monitoring, coordinating, and managing (Basu et al., 2017). Increasing students' voice and choice has enabled them to control their learning and to make decisions (Looi et al., 2015).

2.3.11. Enjoyable learning experience

Effective learning takes place when students are engaged cognitively and emotionally. Children's positive learning perceptions can be increased if they are provided with interesting learning activities (Panjaburee & Srisawasdi, 2016). Employing mobile devices in the classroom can offer a seemingly personalized learning experience and spark learners' interest (Ward et al., 2013). Educational apps produced for both learning and entertainment can attract children's attention through their playful designs (Israel et al., 2016; Noorhidawati, Ghalebandi, & Hajar, 2015). The enjoyment that children experience when they play or interact with app contents may create positive feelings that can be facilitate knowledge acquisition (Fokides, 2017; Morris et al., 2017). The entertainment value of game apps motivates some children and influences their persistence to master the game (Riconscente, 2013). When learners are interested and value the materials, they work harder (Parong & Mayer, 2018). An interesting learning process and interactive multimedia can spare learners from boredom caused by teachers who are less communicative in delivering materials (Raditya, Eryanto, & Prestiliano, 2017). In previous research, using multimedia increased memorability, enhanced understanding, and increased the level of interest. Additionally, teachers found that students greatly enjoyed using an iPad in the classroom context, as the activities provided by the apps increased students' understanding of core concepts, and immersive tablet-based activities enhanced their engagement (Kapri, 2017).

2.3.12. Multisensory learning experience

Young learners are sensory dependent; because of this, any object beyond their immediate world such as abstract thought and intangibles is vague and unreal (Paek & Fulton, 2016). Multisensory learning experiences allow learners to structure their knowledge and improve their learning satisfaction (Hwang et al., 2016). Multisensory techniques are effective for children's learning, as they allow them to best mimic the world's real settings. Moreover, learning situations that demonstrate information in multiple sensory modalities increase brain function and optimal learning. Textbooks do not afford children multisensory learning experiences, and this generates disharmony between their life experiences and these books.

Most handheld devices, regardless of their type, are equipped with sensors. These sensors offer children realistic feelings and enable them to perform learning activities in an interactive and sensational way (Tarng, Ou, Yu, Liou, & Liou, 2015). Ciampa (2013) and Pellerin (2014) argued that apps using multimedia in all forms (e.g., videos, images, and audio) triggered children's interests and sensory curiosity. Multimedia content affords children multisensory learning experiences by stimulating more than one of their senses at the same time. Multimedia includes a number of elements: still pictures, animation, graphics, music, sounds, spoken words, and texts. These elements provide different stimuli that support learners' different senses in the learning process (Kapri, 2017). Virtual reality and augmented reality applications encourage learners to engage in deeper learning by offering them a fully sensory-immersive experience in any conceivable place (Parong & Mayer, 2018).

2.4. Integrating Mobile Learning into Education

Technological developments have caused many educational institutions to think seriously about how to improve their strategies and policies by integrating and using handheld devices in the education process (Bidin & Ziden, 2013). As suggested previously, mobile learning allows learners to learn without being restricted by time and place (Huang et al., 2010), and it helps learners share their knowledge and create social interactions (Suanpang, 2012). Additionally, mobile learning stimulates students and attracts their attention while helping them solve problems, improve their memory, and develop reading and writing skills (Taleb, Ahmadi, & Musavi, 2015). Mobile learning can help students organize their own learning and thus makes it more flexible and smoother (Lim & Churchill, 2016), as students have instant access to the Internet, photography, and e-mail, and they can use technology to write notes, record sounds, and exchange experiences with students from all over the world (Montrieux, Vanderlinde, Schellens, & Marez, 2015). It could also be said that mobile learning provides students the chance to develop their learning environments because it combines the real world and the digital world. Because of their engagement with devices, students acquire many skills through mobile learning without necessarily feeling like they are in the process of learning (Prensky, 2007). However, conducting mobile learning is not easy. It requires tremendous effort to build harmonious relationships among components related to users (students and teachers), educational context components, and technological components (software and hardware) for successful implementation (Francisco, Gabriel, Marina, Oliveira, & Manuel (2018)). Moreover, not all activities and learning content are appropriate to conduct through mobile learning (Miangah & Nezarat, 2012).

Integrating technology with education can support a democratic education in which technology provides students with many methods and educational forms that can facilitate access and participation in learning. In other words, individuals are capable of learning easily in online courses if the courses are designed well and appropriate for their needs. Technology assists individuals in overcoming some of the circumstances that have deprived them of their right to education such as disability, age, and family responsibilities (Selwyn, 2016). For technology to support and improve the educational process, all forms of technology must be integrated so that everyone is interested instead of being controlled by trade and profit (Selwyn, 2016). A transformation from traditional classes to mobile learning classes requires some conditions to be fulfilled. For example, feedback and peer learning must be optimised; students (and not the teacher) must be in "control" of learning, multiple opportunities for learning must exist (e.g. increasing time on task, deliberative practice); pre-training must be given on the use of mobile technology as a learning and teaching tool; and diverse teaching strategies are needed in order to apply this kind of learning effectively (Montrieux, Vanderlinde, Schellens, & Marez, 2015). Teachers need to acquire new pedagogical and technological skills in order to successfully integrate innovative technology into classroom practices, but implementing them is not easy. Some teachers do not integrate technology to enhance learner-centred approaches, but only to provide content digitally (Montrieux et al., 2015).

Adopting mobile learning requires alignment and modification of the school curriculum to accommodate it (Shonola & Joy, 2014). Traditional classroom contexts differ from the mobile learning context, which requires educators to create learning contexts for students through their interactions with handheld devices (Asabere, 2013). Also, educators should design mobile learning environments that encourage collaboration, cooperation, communication, and deep reflection among students (Aguayo, Cochrane, & Narayan, 2017). The challenge of designing a successful mobile learning environment is how to enrich learning conversations to boost learners' experiences (Sharples, Arnedillo-s, & Milrad, 2009). which might introduce a burden in the adoption of mobile learning. All of these requirements, alongside inadequate funding, might contribute to some teachers and educators being unwilling to employ mobile learning if it adds to their workload, particularly if they have little motivation and are given additional responsibilities in preparing for mobile learning beyond teaching tasks in the classroom (Shonola & Joy, 2014).

2.5. Mobile learning – disadvantages and limitations

There is no doubt that mobile learning contributes significantly to improving the teaching and learning processes. However, there are some disadvantages and limitations in this kind of learning, such as the costs and charges. For students to participate in mobile learning, they need portable devices. Some students from low-income families are unable to afford such devices. In addition, monthly data charges burden some students (Barker, Krull, & Mallinson, 2005). Further, in some isolated and rural areas, poor or absent network signals lead to difficulty accessing online content, thus negatively affecting mobile learning (Bryan, 2004). Other technological issues include battery life. Smartphones and tablets quickly lose their charge, especially when running certain applications. A continuous learning process is impacted by the sudden loss of battery life in these devices (Barker et al., 2005; Marsh et al. 2015). The lesson flow is disrupted if Internet or technical problems occur, such as an application crashing or a website not opening (Montrieux et al., 2015).

Also, some mobile learners spend long hours performing their tasks and reading, and this may strain their eyes and therefore affect their vision (Aderinoye, Ojokheta, & Olojeda, 2007). There may also be social disbenefits. In addition, it has been suggested that computer games may have a potentially negative impact on children’s and teenagers’ behaviors. These games may lead to violence, aggression, and addictive use (Mitchell et al., 2004). Also, when mobile learning students are completing assignments and assessments, some resort to cheating by asking for assistance from friends or using a search engine (Katz, 2005). Some teachers find that evaluating and managing assessments of learning outcomes and processes, tracking learning progress and determining the final outcomes of the learning process are difficult and challenging tasks in mobile learning mediums (Asabere, 2013). In fact, mobile learning might lead to substantial problems for evaluation because mobile learning supports education across contexts and life transitions. Evaluating learners is difficult in this context for many reasons, such as ethical issues related to monitoring activities outside the classroom; learning being spread across locations and times; a potential lack of a prescribed curriculum; the learning activity being interleaved with other activities; or learning involving a variety of personal, public, and institutional technologies, so there may be no fixed point at which to locate an observer (Sharples, 2013).

Implementing mobile learning faces some cultural norms and social concerns and challenges, such as accessibility, resistance to change, cyber-bullying, data security, privacy issues, and increased workload (Alhajri, 2016). Using mobile devices in classrooms may lead to teachers losing control, as these devices can take the learning process out of the classroom and school boundaries, beyond teachers’ reach (Shonola & Joy, 2014). Retention of classroom material might become poorer due to a lack of non-restrictive classroom policies on mobile device usage (Francisco et al., 2018). A non-restrictive classroom policy of mobile device usage and non-academic use of those devices contributes to poorer retention of classroom material and decreases learning performance. Students lose valuable cognitive resources when they are distracted by these devices (Aaron & Lipton, 2018). Despite the aforementioned obstacles, technology is constantly developing. A new release in the market might contribute to overcoming some of these obstacles and challenges in the future. In addition, it is beneficial to consider the potential use of mobile devices in education while also considering the disadvantages.

2.6. Relevant studies on the effects of mobile learning in education

Widespread use of mobile devices has led to the existence of a large number of applications that students can use to support their learning process; for example, Martin and Ertzberger (2013) developed a new type of learning called “here and now mobile learning” to explore the effects of using mobile devices in students’ educational achievement. When students have access to information at any time through the Internet, as well as handheld devices to perform activities in the context of learning, they can obtain information linked to what they are seeing and experiencing in their lives. The authors indicated that students enjoyed participating in a learning environment that allowed them to use mobile devices to access information. Similarly, Falloon (2013) sought to discover interactions between children and mobile applications to improve the educational possibilities of these applications. His study included 5-year-old children. Teachers with expertise carefully chose the applications from the Apple Store to enhance the children’s literacy, numeracy, and ability to solve problems. Before the teachers chose the applications, they evaluated them on the basis of several criteria: each application’s rating in the Apple Store, the cost of downloading the application to the devices of all children participating in the study, user feedback on the application from the Internet, and how the application would support the objectives of the educational process. Forty-five applications were selected to develop the children’s skills within the curriculum’s framework. Fallon (2013) clarified the value of applications in supporting children’s learning process. Mobile education has a positive impact in stimulating students to learn mathematics and actively participate in related activities. According to Zhang, Trussell, and Gallegos (2015), using smartphone applications to enhance students’ understanding of mathematics leads to improved mathematics learning and reduces the gap between good students and struggling students. The researchers explored the importance of these applications through their exploratory study of fourth-grade students who used mobile phone applications to support their learning of decimals and multiplication. Recently, Calder and Campell (2016) examined students' beliefs and attitudes toward the use of mobile applications in numeracy. The researchers reported that utilizing applications enhanced students' participation of in mathematical tasks and promoted positive attitudes and enthusiasm toward learning math. Furthermore, mobile devices helped students understand and explain mathematical problems when working with a large amount of information and numbers. On the other hand, Lawrence, Ching, & Abdullah (2019) studied the strengths and weaknesses of an education 4.0 program that aimed at promoting technology use in the teaching and learning contexts. They found that the education 4.0 program disconnected students from the real world, limited educators' engagement and involvement towards their learners, and limited the face-to-face communication between students and teachers. What seems to be important is the appropriateness of the use of mobile technology in specific contexts, the quality of the resources used, and the teacher input.

Applications enhance educational experiences and increase motivation, enthusiasm, attention, engagement in the educational process, and creativity; finally, learning becomes more attractive and effective. That is also what Montrieux (2015) found when he explored the possible advantages of using smart devices. A great deal of research has provided evidence for the effectiveness of using an application called Our Story (OS) and other applications to engage children in the educational process. Kucirkova, Messer, Sheehy, and Fernandez (2014) participated in designing the OS application. It supports children's learning by creating stories and activities, and the researchers noted the children's interactions with the OS application compared to other applications they chose for use in this study. OS provides students the opportunity to design their own story by creating an audio-visual digital text and by adding images, sounds, and text. After children complete the design, the story can be printed or shared with other users on the Internet. Researchers have demonstrated the benefits of using the OS application to encourage children to use questions and enhance their problem-solving skills.

The use of mobile devices in education benefits students in many ways, as reported in previous studies. However, some researchers have found that portable devices are ineffective tools and that there is no difference between the use of such devices and traditional methods in education. For example, Brown's (2008) comparative study aimed to compare students' vocabulary comprehension when they were assisted by mobile devices versus traditional methods. After analysis, the data indicated no difference between the two methods. Additionally, in their comparative study, Price, Jewitt, and Crescenzi (2015) found that preschool children's use of tablets deprived them of sensory experiences—such as painting or playing with Play-Doh and sand—which prepare them for literacy skills at the school stage. In addition, when children painted or drew in tablet applications, they only used one or two fingers, which prevented the other fingers from interacting with the tablets. There has been exponential growth in utilizing mobile learning in education (Crompton et al., 2016). Furthermore, some studies addressed the disadvantages of mobile learning. Furthermore, Fatina (2016) found that 8th, 9th, and 10th graders who used iPads in the classroom for learning purposes were preoccupied with irrelevant topics which distracted them. Furthermore, the teachers indicated that using iPads led to bad handwriting and weakened students' writing abilities. Petko (2016) conducted an empirical study of 74 primary school children to evaluate serious games and found that these games had no effects on the tested learning games.

Many mobile learning projects fail due to many reasons, such as a lack of integration between technology tools' affordances in the course's delivery or assessment, lack of the learning community's support beyond face-to-face class time, some communication tools proving to be ineffectual and unreliable for class interaction, inappropriate choice of supporting technologies due to teachers' false presuppositions about learners' technology ownership, unforeseen limited Wi-Fi connectivity, unsuitable choice of mobile devices for the learners' demographics, and a lack of flexible and appropriate learning spaces to bridge formal and informal learning (Cochrane, 2012). As suggested previously, this emphasises the importance of the pedagogical strategies used, and the quality of the resources, in digital learning.

2.7. Mobile learning supports science learning

2.7.1. The importance of learning science among children

Science is a mainstream process of gaining knowledge and a body of knowledge (Knight & Davies, 2016). Children must develop high-level science literacy and capability due to its crucial role in achieving population, social, economic, well-being, and environmental goals (Falloon, 2017). Scientific literacy includes understanding the process of scientific inquiry, important scientific concepts, the attitudes toward more active engagement, and regular information consumption (Aristeidou & Spyropoulou, 2015). Young learners should learn science due to its importance in their cognitive development (e.g., hypothesizing, predicting, reasoning, and inquiring); social development (e.g., working in groups, playing, sharing, negotiating, cooperating, and becoming a valuable part of the community); language development (e.g., using science terms and communicating ideas in different ways); physical development (e.g., using large and small motor skills in science work); and affective development (e.g., having fun, caring about living creations, and following their interests).

2.7.2. Incorporation mobile learning to assist science learning

2.7.2.1. Mobile learning's educational benefits for science learners

Some students view natural science as difficult to understand when passively learning materials from a textbook. Children should be taught science to assist them in grasping concepts and applying them logically in other situations related to their life experiences (Hendajani, Hakim, Lusita, Saputra, & Ramadhana, 2018). Primary school students have encountered difficulties understanding some natural process theories such as condensation and rainfall. Usually, first-, second-, and third-grade students face conceptual difficulty, and utilizing traditional methods that adopt an expository approach in teaching these concepts does not help them understand, as they experience difficulties imagining what is being taught (Hendajani et al., 2018). Imagery is a crucial element in understanding scientific concepts (Bull & Bell, 2005).

Su & Cheng (2013) believe that engage children should be engaged in meaningful, authentic activities and to solve complex problems using handheld devices that act as powerful cognitive tools. Representing complex scientific content through simulation, games, non-textually mediated representations (Anderson & Barnett, 2013), and tangible experience might encourage reluctant students to learn science. Furthermore, multimedia is valuable for science learners because it affords them access to levels of abstraction (Anderson & Barnett, 2013). This can lead to basic understanding through simplified scientific strategies (Kapri, 2017). The inefficiencies in cost and time in science education can be overcome using various digital multimedia (Dewi, Kannapiran, & Wibowo, 2018), and multimedia offers tools that can enrich and extend children's science learning and teachers' instructional strategies (Kapri, 2017). Numerous scientific phenomena cannot be directly observed, are impossible to see, and are unavailable due to several reasons such as limited observation time and the size of phenomena such as galaxies and atoms (Nielsen, Brandt, & Swensen, 2016). Furthermore, simple observation is not enough to see the details and understand many abstract scientific concepts (Israel et al., 2016). Multiple representations of information animation, visualization, and sound afford students opportunities to experience infeasible phenomena (Nielsen et al., 2016).

Mobile technologies are convenient in supporting inquiry-based science learning, which is an effective approach to reinforce children's motivation and curiosity (Suárez et al., 2018), whereas curiosity leads to exploratory behaviour that is important for scientific thinking (Morris et al., 2013). Accessibility and availability via handheld devices encourage scientific enquiry (Menon & Steinhoff, 2017) and can make them agentic learners and critical thinkers capable of working in complex environments (Suárez et al., 2018). Students' engagement in mobile learning, experimentation, and exploration in science inquiry investigations may guide them in interpreting data and promoting deeper understanding (Ahmed, Parsons, & Mentis, 2012).

A playful atmosphere is substantial in promoting learners to seek answers for scientific questions and encouraging work with science. Young learners' interests and inquiries regarding science occur in play. Gamified apps may help struggling children better understand science by increasing their engagement. Also, they can act as useful instructional platforms that contribute to increased interest in science, content knowledge, and problem-solving (Israel et al., 2016); for example, Kao, Chiang, and Sun (2017) found that game-based science learning is an effective approach in facilitating science learners' learning outcomes by increasing their interest. In addition, Ward et al. (2013) found that using games to collect scientific data highly engaged students in learning about basic science concepts.

Virtual reality and augmented reality support science learning through three inherent advantages: vision-haptic visualization, real-world annotation, and contextual visualization (Tarng, Ou, Lu, Shih, & Liou, 2018). Specifically, augmented reality can assist the experimental approach and research, as well as provide better understanding of physical phenomena through better visualization. It is a precious tool that associates the real world with the virtual world (Cieutat, Hugues, & Ghouaiel, 2012). Additionally, tablets are embedded with functions, such as download resources, note-taking recording, and cameras, that can be utilized in field trips that support testing in new situations, abstract conceptualization, reflective observation, and concrete experience (Looi et al., 2015). Mobile devices help students collect data in the field trips and document their experiences through photographs and videos (Wallace & Witus, 2013). Handheld devices prove their efficiency in supporting outdoor learning near streams, lakes, woodlands, and parks, for example (Choi et al., 2018). Moreover, educational apps prove their efficacy in connecting children with nature, and this is important in increasing emotional well-being and physical activity; for example, Crawford et al. (2017) developed the

Agent Of Nature app to engage children with their natural environment. Use of this app promotes children's pro-environmental attitudes and increases place attachment by fostering the surrounding nature connections.

Various studies have expanded mobile devices' educational value by exploring well-designed apps and tapping into their affordances (Sun et al., 2016); for example, Aini, Majid, and Husain (2014) found that the iSain app assisted Malaysian young learners in obtaining knowledge about day and night. Engaging learners in an authentic laboratory experience through an app is now possible; for example, the Stickleback Evolution Virtual Lab app allows learners to perform statistical analysis, classify organisms, and prepare samples (Mills, Seligman, & Ketelhut, 2017). The Human Respiration System App assists students in understanding lung functions through realistic visualization (Nielsen et al., 2016). The Playground Physics app allows learners to explore their own bodies' energy and forces. The app records their movements, and this allows them to trace a path of motion (Mills et al., 2017). The Habitat Tracker app engages fifth-grade students in hands-on activities and data collection (Marty et al., 2013).

Students are able to explore the science of sound using the Sound Uncovered app, which offers the opportunity to construct explanations by providing relevant scientific information (Mills et al., 2017). The Dichotomous Key app helps fifth-grade students improve their scientific observation skills and identify living things (Knight & Davies, 2016). Observation is an essential part of the scientific process. To learn science, children are required to practice observation to systemically gather information and knowledge, as well as use various methods, including experimentation, to verify this information (Lee & Tu, 2016). In one study, students found that mobilized science lessons made science more engaging, deep, and personal (Looi et al., 2011). Mobilized science curriculum 5E improves students' work quality and increases their participation and engagement in learning activities (Looi et al., 2015). Utilizing mobile devices' varied affordances assists children in advancing their knowledge about fish anatomy beyond textbook knowledge (Song, 2014). Using tablet-based activities to learn about food chain dynamics enhances students' concept building and engagement (Ward et al., 2013). Learners' interactions with MLE components and e-order assisted them in understanding plant and animal life cycles (Looi et al., 2015). Utilizing tablets' possibilities can promote the understanding of challenging scientific concepts such as astronomical scales (Furman et al., 2018). Using tablets to enhance preschool children's science learning increased their interaction, motivation, independence, collaboration, and autonomy (Furman, De Angelis, Dominguez Prost, & Taylor, 2018). Linking science learning with technology assists learners in becoming successful problem solvers by conducting their obtained knowledge in real-world contexts (Kumar, 2017). On the other hand, Asabere (2013) believed that practical hands-on lessons cannot be augmented by mobile learning. In addition, this kind of learning might create a feeling of being out-of-the-loop or isolation among students and teachers who may not always have mobile connectivity. Furthermore, mobile learning may give students with high technical skills an advantage, in terms of device usage and systems, over students with low technical skills. Additionally, Frohberg, Göth, and Schwabe (2009) found in their critical analysis of mobile learning projects that many of them with physical contexts do not support cooperation or knowledge application, and do not implement elements that support deep reflection.

In addition, authentic technologies provide advantages such as simulation, animation, and virtual reality so as to offer unlimited solutions for problems that occur due to the following circumstances: phenomena that require a longer duration of time to observe or record (e.g., the observation of some scientific situations such as astronomical phenomena is restricted by topographical conditions, time, and weather) (Tarng et al., 2018); conducting dangerous experiments and operations; excessively abstract concepts; difficulty conducting reliable and accurate observation because of remote locations; technological limits; and high cost (Yen, Tsai, & Wu, 2013).

2.7.3. Relevant Studies on the Effects of Mobile Learning in Science Education

Handheld devices and digital technology can support science learning in many different ways. For example, digital tools can be used to conduct research, facilitate communication, and create presentations (DeGennaro, 2012). Mobile learning has earned great attention among science teachers due to its ability to offer appropriate assistance when required and to enhance learning experiences (Aubusson & Schuck, 2013). Utilizing mobile learning in science education may lead to improved student learning in science. Sun, Looi, Wu, and Xie (2016) designed a mobile science curriculum entitled “5E.” They found that the adoption of mobile learning makes learning science more flexible and attractive to children. In addition, Song (2014) relied on the bring your own device (BYOD) strategy, which allowed students to form positive attitudes toward science and to gain a better understanding of science topics related to fish when they used their own devices to search for information. To determine the effects of mobile devices on learning science, Jones, Scanlon, and Clough (2013) compared two case studies. One focused on the use of mobile devices for learning science in informal settings, and the other focused on the use of mobile devices for learning science in classrooms. The participants used their own devices. The researchers were able to observe how students used devices and how mobile devices support learning science. Jones et al. (2013) found that mobile devices help students choose interesting topics in science and find answers to their inquiries without adults' help, as the students were able to access resources and information using mobile devices in both formal and informal settings.

Another interesting outcome was identified in relation to a project named The Thin Learn application. This project was developed to provide an effective environment for students to conduct practical training activities and to engage in scientific research practices. Ahmed and Parsons (2013) designed Thin Learn. Through this application, students can gain a deeper understanding of the transfer of thermal energy. The researchers noted that the Thin Learn application contributed to strengthening the students' positive attitudes toward school learning and improved their science learning in terms of generating hypotheses. In the same vein, Marty et al. (2013) designed a project aimed at developing science skills using the Habitat Tracker application. Habitat Tracker provides a link between formal and informal contexts in science education. It links classrooms to science museums and wildlife centers and allows students to acquire information about different environments outside of the school's boundaries. This helps students better understand scientific concepts related to animals, plants, and space. Furthermore, Integrating animated movies in apps within the science curriculum can help promote positive attitudes toward science and change the erroneous images formed in some students' minds about science. Likewise, animations can help students develop scientific concepts indirectly, become passionate about reconnaissance, and discover new scientific concepts (Barak & Dori, 2011). Tarng et al. (2018) found that mobile learning is an effective tool in learning about the sun path. Choi et al. (2018) found that tablet-based problem-solving activities increased children's engagement and use of procedural strategies to solve problems about the tree life cycle. Utilizing tablets to learn science increased collaboration, autonomy, interaction, and independence in children (Furman et al., 2018).

Researchers in the previous studies have proven that mobile device use has had a positive impact on students' learning of science. However, some researchers reported that mobile devices did not affect students' science learning or help them. Nouri, Cerratto, Pargman, Rossitto, and Ramberg's (2014) quasi-experimental study aimed to compare the performances of students' science activities during school field trips when they were assisted by technology versus the performances of the same activities through traditional methods. In fact, researchers found that technology did not support the students in performing these activities. The traditional methods and the technology-assisted method led to the same results. In the same vein, in another study, researchers found that students' use of a water cycle application on their phones did not help them. Furio, Juan, Seguit, and Vivo (2015) found there was no difference in students' learning outcomes between the group that used the application and the other group that learned through traditional methods. The children learned similar knowledge regardless of the method used. This may have been because the use of technology did not make best uses of the affordances of the devices.

In conclusion, these studies indicate that portable devices and mobile education may open new horizons in the field of education if used in an appropriate manner. Such devices exist in the current culture and in the daily lives of students and teachers alike. Likewise, as this overview of key literature has suggested, applications can be used as an effective and powerful tool to teach children, but there is evidence suggesting that such applications should be adequately chosen and suited to children's needs if they are to be effective.

2.7.4. Challenges of Mobile Learning Incorporation into Science Education

There are challenges and limitations related to mobile applications, as explained previously: In a virtual world, numerous outstanding legal issues should be considered when planning and designing mobile learning programs, such as potential virtual assault, sexual harassment, and virtual violence (Aristeidou & Spyropoulou, 2015). Furthermore, some poorly designed apps may impede learning compared with traditional methods (Parong & Mayer, 2018). Sometimes students engage in non-educational activities (movies, music, and pictures) (Wallace & Witus, 2013). Heavy use of mobile devices might prevent children from enjoying a sense of play (Coyle, 2017). There are also some limitations regarding conducting mobile learning in science in particular; for example, in some situations, the efficacy of dynamic visualisation is reduced because students are prevented from re-inspecting information (Virk, Clark, & Sengupta, 2015). Moreover, the information provided by animation might be difficult to process and fleeting, especially among children (Karacop & Doymus, 2016), as they cannot control the animation's presentational pacing (Thomas & Israel, 2014).

Concerning serious games, some children concentrate on how to win the game rather than practicing and learning concepts (Magana, 2014). Furthermore, battery life is considered a limitation in some situations, such as in extended use of handheld devices to perform outdoor activities (Huang et al., 2010). Utilising mobile devices in outdoor learning is negatively influenced by lost GPS signals, lost networks, and technical problems that reduce learners' enjoyment in utilising the tool (Zydney & Warner, 2016). Also, sunlight glare on the tablet screen can lead to difficulty seeing, and a noisy outdoor environment may lead to difficulty hearing audio (Zydney & Warner, 2016). In addition, there is a high cost in developing high-quality and well-designed educational applications, training teachers on how to integrate these apps into their teaching practices, human resources, planning introduction activities designed to prepare learners, and following up on activities (Ward et al., 2013). In mobile learning environments, it would be helpful if every student could own his or her tablet, or at least treat it as if he or she owns it. Tablet ownership helps to encourage students' ownership over their learning. This means students must be allowed to use devices any time they wish and have the freedom to customise and upgrade them (Sharples, 2013). However, some schools that lack sufficient resources cannot afford tablets or laptops for students due to the very high expenses (Dumancic, 2016).

2.7.5. Challenges of Mobile Learning Applications in the Science Curriculum within Saudi Primary Schools

Mobile learning in Saudi Arabia is still in its infancy despite its necessity and recognition of its importance, as demonstrated in the studies outlined above. The MOE members strive to activate and integrate technology in all subjects, especially science (Saqlain, Al-qarni, & Ghadi, 2013). However, mobile learning in Saudi schools occurs in a basic form, and many challenges hinder its application in educational environments (A. Islam, Al-shihi, Al-khanjari, & Sarrab, 2015). At the forefront of these challenges is the fact that the curriculum is designed for traditional education methods rather than for mobile education. Some teachers and educators stick to traditional education methods due to heavy workloads and a lack of incentives to change (Ghamdi & Abduljawad, 2015). Saudi educational environments also lack the infrastructure for mobile learning, in that public schools and rental schools lack adequate networking and high-speed Internet connections. The large number of students in classrooms also affects mobile learning's applicability (Ghamdi & Abduljawad, 2015).

2.7.6. Features and Design Characteristics of Tablets

2.7.6.1. Easy to use

The current generation has been immersed in mobile technology since birth, as it is highly prevalent. Learners become familiar with innovative technologies even younger (Ward et al., 2013). Today, young learners are familiar with technology's various forms due to growing up in a digital age (Giannakos et al., 2014). Their daily lives become increasingly interconnected with mobile devices (Ward et al., 2013). Tablets do not need fully developed literacy skills to use; they can be used intuitively. Naturally, young learners just starting school have a limited ability to read and write, but they can easily navigate tablets without reading instructions by recognizing icons instead (Furman et al., 2018). Positive and increased motivation via ease of use and enjoyment can increase cognitive engagement (Kartiko, Kavakli, & Cheng, 2010). Personal attitudes toward use mobile devices for learning are influenced by ease of use. A user-friendly interface design attracts students to use the app (Alqahtani & Mohammad, 2017).

2.7.6.2. Touch screen

Modern tablets have screens small enough to carry around and large enough for sharing in group settings (Choi et al., 2018). Tablets' touch screens provide young learners intuitive interaction, which makes the content of apps potentially accessible (Hirsh-Pasek et al., 2015). Using natural hand gestures to manipulate virtual objects is considered to stimulate experiences that contribute to powerful learning (Furman et al., 2018). Young learners interact with tablets through a series of swipes, pinch-zooms, and taps (Mckenzie et al., 2018). Furthermore, touch screens enable children to interact with objects of interest via physical touch, which can be delightful for them (Giannakos et al., 2014). The large size of tablets' touch screens promotes interaction and viewing and conveys more realistic images (Giannakos et al., 2014). On-screen cuing, object design, object placement, and colour are initial interactions that play important roles in focusing young learners' attention (Podolefsky, Moore, & Perkins, 2010). However, Francisco et al. (2018) argued that handheld devices are a source of distraction and cognitive overload. The movement and lighting of text, low-battery warnings, instant messages, pop-ups, and the orientation and visual nature of laptops can make these devices distracting.

Using children's sense of touch to perform tasks satisfied their desire to touch and may develop some skills, as indicated by Noorhidawati, Ghalebandi, and Siti Hajar (2015), who found that perception and manipulation of digital objects encouraged children's recognition skills and cognitive growth. Children engage with touch screens due to the contingent interactions that apps provide. The immediate response from each swipe or touch creates a feeling of control in children, which promotes continued interaction and maintains their focus (Hirsh-Pasek et al., 2015). Modern tablets enable learners to narrate, write, and draw for diverse learning processes. This feature overcomes input device limitations, like keyboards and computer mice (Chang, Liu, & Tsai, 2016). Writing on tablets was productive and efficient comparing with using paper and a pencil (Paek & Fulton, 2016). Active learning involves minds and physical activities, and children's interactions with tablets take multiple forms, such as touch, movement, sight, speech, and hearing. Touch also takes multiple forms, including tapping, swiping, writing, and drawing on the touch screen. Additionally, children can move the device by tilting and shaking it (Hirsh-Pasek et al., 2015). Touching a tablet's surface to select objects can stimulate additional exploration (Giannakos et al., 2014).

2.7.6.3. Portability and connectivity

Tablets are powerful tools for extending learning activities outside classroom boundaries. No longer limited to school, learning can occur at any time by using any device from anywhere (Tarng et al., 2018). They afford more portability and mobility because they are smaller and lighter than laptops (Menon & Steinhoff, 2017). Mobile devices' portability enables learners to utilize them in any context (Jones et al., 2013) and makes learning in real world, science's natural space, possible (Crompton et al., 2016; Laru, Järvelä, & Clariana, 2012; Sun & Looi, 2018). The portability of handheld devices is quite suitable for learning science on the move and for assisting in location-based learning (Burden et al., 2016). Learners can also use these devices out of classrooms to gathering needed data (Marty et al., 2013). Additionally, the flow of learning science between informal and formal settings can be mediated by mobile devices' portability (Burden et al., 2016). Portable devices facilitate the learning process by leveraging unique characteristics, such as immediacy, mobility, context sensitivity, and individuality (Looi et al., 2015). Regarding connectivity, wireless networks for mobile tools can afford various opportunities to bridge diverse learning contexts and contents (Looi et al., 2015). However, the poor cellular network coverage in rural areas leads to low usability of mobile devices (Criollo-c et al., 2020). Also, The significant challenges when conducting mobile learning include evaluating learning that takes place across locations and outdoors, creating new forms of informal learning assisted by personal handheld devices, and improving the usability of mobile learning technology (Sharples, 2013).

2.7.6.4. Digital scaffolding

Digital scaffolding assist learners in managing cognitive loads, accessing and saving notes, locating and finding resources, and visualizing and externalizing their understanding (Kim & Hannafin, 2011). Technical scaffolding strategies include hints, visualization, concept mapping, promoting questions, feedback, and expert modelling (Kim, Belland, & Walker, 2018). Gamified app scaffolds are used to explore games' strategies, explain games' rules, and familiarize children with skills needed to accomplish their goals (Kao et al., 2017). Completing a game's action offers children surprising responses, which increases their enjoyment and engagement (Giannakos et al., 2014). Praising young learners for their hard work and effort motivates them to persist through difficulties and helps them understand that learning is not instantaneous (Hirsh-Pasek et al., 2015). Even errors and failures during gameplay are seen as feedback that helps learners achieve goals, rather than being seen as negative external evaluations (Morris et al., 2013).

Feedback plays a significant role in reducing frustration and increasing engagement (Basu et al., 2017), and it helps learners obtain information about their performance and find correct solutions. Learners need critical, informative, and timely feedback to amend their mistakes and misconceptions (Hui-Ling, Hsiao-Ian, & Hsiao-Ching, 2016), which assists them in discovering learning problems and enables them to concentrate on learning (Gwo-jen, Po-Han, & Hui-Ru, 2011) and guide their learning and observation and assist in thematic knowledge construction (Wu & Anderson, 2015). Feedback benefits motivation and learning achievement and engages learners in reflective thinking (Hwang, Wu, & Ke, 2011). it can be delivered in two ways: auditory or visual feedback (Dirksen, 2009; Snell-siddle, 2013). Feedback can include access to additional content, badges, points, parasocial displays, motivational messages, and labels (Hirsh-Pasek et al., 2015; Marsh et al., 2015). Formative feedback scaffolding in mobile learning environments improves skill and knowledge acquisition (Basu et al., 2017).

Receiving explanatory feedback encourages learning (Virk et al., 2015). Furthermore, conceptual sense can be supported by dynamic immediate feedback (Podolefsky et al., 2010). Learners can optimize their performance via external and internal evaluation of current performance, which is called feedback (Bradley, Steve, Corinne, Devin, 2013), and their self-esteem is enhanced by positive feedback, which is significant for successful learning (Pirker & Gütl, 2015). Instant and readily interpretable feedback retains concentration on conceptual understanding and allows seamless interactions for students while highlighting casual relationships and important concepts (Podolefsky et al., 2010). Feedback also provides children with opportunities to identify their weaknesses, become more independent, and construct knowledge without relying on the teacher, which enhancing their autonomy in learning (Van Nuland, Roach, Wilson, & Belliveau, 2015).

Hints help learners improve self-regulation skills and metacognition, develop effective and efficient strategies for solving problems, and identify and correct errors and misconceptions (Basu et al., 2017). Providing learners with instants hints and guidance contributes to interpreting complex learning tasks. This support should be provided to learners in time to prevent them from losing interest (Hwang et al., 2011). Students can progress through hints such as suggestions and clues (Kim et al., 2018). Mobile devices afford sequential and timely instructions that provide clear guidance and reduce the risk of confusion, (Nouri, 2014) which acts as a type of scaffold. Where learners enabled to access these instructions and materials related subject Via handheld devices (Taufiq et al., 2016).

2.7.6.5. Productivity tools

Tablets can be described as a learning hub that combines self-created artefacts, resources, and personal learning tools in one site (Sun & Looi, 2018). Tablets are powerful tools that provide learners with assorted advantages over desktops and laptops. They are portable, lightweight, affordable, and have wireless network capacity, which can be used to quickly install educational applications (Santos, Hechter, Tysinger, & Chassereau, 2014). Smart devices and modern tablets are becoming increasingly powerful in sophisticated digital content delivery, storage capabilities, memory, and processing (Mckenzie et al., 2018). Modern technological devices can boost science learning, make science practices readily accessible, and demonstrate scientific concepts in multiple ways (Mills et al., 2017). Mobile devices' cameras have allowed learners to record observations by capturing images and documenting experiments' stages (Ekanayake & Wishart, 2014). Utilizing video and images captured by mobile devices has enabled instructors to correct learners' misconceptions, assess their learning, deliver instructions, and bring the outside world into science classrooms (Ekanayake & Wishart, 2014). However, modern mobile devices with great possibilities, which are very expensive for many students, quickly become out of date, and frequent changes in these devices might lead to cost issues (Hashemi, Azizinezhad, Najafi, & Nesari, 2011).

2.8. Educational apps

The power of educational apps is growing (Anderson & Barnett, 2013). Mobile applications provide a digital doorway between the rapidly growing digital cloud and the physical world that young learners live in (Hirsh-Pasek et al., 2015). Using apps and mobile devices are popular activities among children (Herodotou, 2018; Marsh, Yamada-rice, Bishop, Lahmar, & Scott, 2015; Merchant, 2015). Children enjoy using educational and gamified apps for many reasons; they provide children with a sense of control over actions and with effortless and deep concentration. They also offer activities with immediate feedback and clear goals and, finally, afford them a chance to complete tasks (Pirker & Gütl, 2015). Tablet-based learning's viability grows with the development of educational applications (Ward et al., 2013). Many educational apps consolidate multisensory input characteristics that allow learners to interact with many forms of content: visual, auditory, and tactile. This feature is powerful in supporting science learning (Santos et al., 2014). Mobile apps developed to support science learning afford many features, such as differentiating roles, digital mechanisms, knowledge sharing, digital tools for constructing knowledge, location-aware functionality, and technology-based scaffolding (Zydney & Warner, 2016). Taking advantages of these apps' benefits can enhance science learning online or in a classroom setting (Song & Wen, 2018). However, adopting mobile learning still poses challenges and problems with evaluating the quality of mobile learning applications because of a lack of methods to observe specific quality aspects of these applications; additionally, existing quality evaluation methods are overly generic (Soad & Barbosa, 2016).

Educational apps have some common problems, such as: assistance and manual mechanisms are not always provided; sometimes there is no blockage when a user repeatedly tries to use an incorrect password to authenticate; collaboration is not always encouraged; in some cases, apps do not allow use in offline mode; the keyboard is sometimes not adjustable in accordance with the content context; the apps do not always support use in portrait mode; buttons can have confusing features; some apps cannot be modified according to the learners' needs; the security level is not sufficient when apps do not require a password; some features do not have demonstrations of use in a number of apps, and there are sometimes no mechanisms to report offensive messages (Soad & Barbosa, 2016).

2.8.1. Gamified apps

Gamified apps are games designed for tablets and smart phones (Glassman & Glassman, 2015). Games are defined as an enjoyable, voluntary, and immersive activity where the player attempts to accomplish a challenging goal that concurs with agreed-upon rules (Sung & Hwang, 2013). One innovative use of technology is assimilation in gamified apps. Serious games aim to combine the fun aspects of digital games with serious aspects, such as communication, teaching, and learning (Cieutat et al., 2012). These game apps enable learners to focus on goal-oriented experiences (Atwood-blaine & Huffman, 2017). Playing serious digital games helps children learn by encouraging them to focus on aims, realize the game's problems, find proper solutions, reason, and relate cause and effect (Bulu, 2010). Some abilities, such as naming, classifying, remembering, memorizing, and matching, can develop via playing games. In addition, children learn to communicate with other people, win, lose, and obey rules (Bulu, 2010).

Many powerful gamified apps are designed according to efficient learning paradigms, such as cooperation, self-efficacy, inquiry-based learning, experimental learning, continuous feedback, goal setting, cognitive modelling, and tailored instructions (Pirker & Gütl, 2015). Furthermore, this type of app can boost the social and cognitive accessibility of a science curriculum's materials (Marino, Gotch, et al., 2014). Providing young learners with serious games triggers their motivation and offers interactive experiences (Sung & Hwang, 2013) while engaging them via mastery approaches, levelling up, extended time-on tasks, promoting behavioral persistence, and suppressing the fear of failure (Morris et al., 2013). The gamified learning approach creates a mindset characterized by no fear of failure and attempting new things (Su & Cheng, 2013). It also allows collaboration and rewards that can promote students' engagement (Giannakos et al., 2014). Moreover, Serious games can bridge the gap between passive learning and experiential learning needs. This learning allows learners to receive feedback, discover, and explore (Ormsby, Daniel, & Ormsby, 2011), and it enables them to demonstrate what they have learned by dealing with serious games' authentic contexts (Morris et al., 2013). Metacognition, cognition, and motivation can be enhanced via the key features of serious games (Morris et al., 2013). Even in failure, children use the game to learn the consequence of their actions and choices. The game helps children to make good choices via instant feedback and correction of fundamental misconceptions (Marino, Becht, et al., 2014). Games also help them make sense of their world (Anderson & Barnett, 2013). If learners lose their interest in science subjects in school because they cannot connect their everyday life with science (Aristeidou & Spyropoulou, 2015), using gamified apps can allow them to manipulate the processes and materials that are fundamental for science learning (Lee & Tu, 2016). Young learners' enthusiasm and engagement with gamified and educational apps can motivate science learning and raise interest in science (Herodotou, 2018).

2.9. The type of apps that assist science learning

2.9.1. Role-playing games

Dale (1969) believed that children's learning experiences should be concrete, including contrived experiences (interactive model), dramatic participation (role play), and real-life direct experiences, instead of learning through abstract thinking (Giannakos et al., 2014) Experiences that allow learners to play roles can be described as virtual apprenticeships (Beier, Miller, & Wang, 2012), which offer learners situated learning or apprenticeships that might inaccessible in real world. This enables them to think and work authentically in specific roles. Children are attracted to games where they can control everything or to games that enable children to act as adults; pretend play provides children with a natural experience to develop their cognitive skills. Role-playing games help learners think about real-world problems (Beier et al., 2012). This kind of game helps children foster more imagination in their play. In addition, imaginary play, which occurs when children play fictitious roles, is considered key for cognitive, emotional, and social development (Sukstrienwong, 2018; Verenikina I.a Herrington, 2010). Vygotsky believed that imaginative play significantly contributes to the developing children's ability to think, forms the basis for children's awareness of the world and enhances their cognition of reality (Vygotsky, 1967). From a cultural-historical lens, role-playing games enable children to manage their emotions and learn about adults' rules and roles (Verenikina & Kervin, 2011).

"A child's greatest achievements are possible in play, achievements that tomorrow will become her basic level of real action." (Vygotsky, 1978, p. 100)

Role-playing games enable children to work through scenarios through viewpoints of other characters or people (Glassman & Glassman, 2015). Learners take on unique identities within role-playing games, such as doctor, public health expert, and technician. These roles promote their engagement in the learning process (Marino et al., 2013) and engage learners in making decisions about virtual worlds and thinking in educationally valuable ways (Atwood-blaine &

Huffman, 2017). The environment of role-playing games allowed learners to engage in careers that other peers at same age group may not prefer and to take risks without serious effects (Beier et al., 2012). They also afford learning opportunities for exposure to professional roles. Some of these roles cannot be encountered in school contexts. This exposure allowed learners create projective identities, inhabit the roles, and commit to them (Beier et al., 2012). Playing various roles enhances students' conceptual knowledge understanding (Yin et al., 2013). Playing such these games can influence learners' interest, competence, agency, and self-efficacy (Beier et al., 2012). Furthermore, Children's engagement in role-playing games provides opportunities for experimentation, exploration, and manipulation, which are considered essential for constructing knowledge (Verenikina, Kervin, Rivera, & Lidbetter, 2016) and for learning science. Via role-playing games, learners might develop an interest in science by experiencing authentic events in a concrete way (Beier et al., 2012). They can also explore difficult concepts with this type of game. That enables students to form abstract concepts, observe, experience, test suggested solutions, and reflect (Yin et al., 2013). Exposing children to role-playing games affects their attitudes toward science (Beier et al., 2012). For example, Citizen Science is role-playing game that requires students to solve problems by using scientific thinking. This game positively impacted collaborative learning and engaged students with scientific content (Schwartz, 2012).

In Apple Store and Google Play, many role playing games support science learning. Mad City, a mystery game, offers learners three roles to play: government officials, environmental specialists, and medical doctors. The game requires members to cooperate to solve the mystery of a character's death. Playing as a team, each member selects a role (Zydney & Warner, 2016). The Monster Guard app requires children to play monster guard trainees and obtain important information about various emergencies, including wild fires, home fires, earthquakes, hurricanes, and tornadoes (Glassman & Glassman, 2015). Environmental Detectives allows learners to play scientist roles, which helps them understand chemical spills via discussions, questions, and data collection and evaluation (Morris et al., 2013). The epidemiology game about an outbreak enables children to play a disease detective role. They investigate disease outbreaks, including legionnaires' disease, rift valley fever, and west Nile virus (Glassman & Glassman, 2015). The ToxInvaders game helps children learn about environmental health and explore health topics by carrying out multiple-choice tasks (Glassman & Glassman, 2015). Ubig bio is a role-playing game that requires children to run a pet shop, where they breed beetles (Zydney & Warner, 2016).

2.9.2. Adventure games

They are interactive games that require children to play a fantasy role driven by puzzles and exploration in episodic adventure stories. For example, the popular game Minecraft positively impacted students' science learning performance. They showed enthusiasm, excitement, and engagement with learning tasks (Wang et al., 2016). Scape is adventure game that requires students to solve problems by utilizing observed physical and chemical properties, which supports students' comprehension of natural changes in matter (Campbell et al., 2013).

2.9.3. Simulation games

Learners can experience active immersion in realistic scientific roles via simulation and visualization (Burden et al., 2016). Simulation gaming's immersive nature affords learners experiences that allow them to utilize developed intuitive knowledge through play, explicate complex scientific problems, and draw upon thinking about scientific concepts (Anderson & Barnett, 2013). Simulation can boost a jointly constructed understanding of the world (Aristeidou & Spyropoulou, 2015). In addition, Simulation apps combine reality and virtual reality, which improves the level of interaction (Yen et al., 2013). In fact, simulations can highlight items that cannot be seen by simple observation or by the naked eye. It can also highlight intangible items (Cieutat et al., 2012). This technique presents abstract concepts in authentic, interactive, and intuitive ways to enhance students' concentration and motivation (Yen et al., 2013). For example, Yen et al. (2013) found that simulation and interactive 3-D models facilitate students' comprehension of spatial concepts. Moreover, using 3-D simulations on iPads helps students learn about the universe (Furman et al., 2018).

A simulation is a powerful tool that enables students to conduct impossible experiments easily. Stretching time and space also makes invisible effects visible. It also allows science learners to virtually conduct dangerous and expensive experiments and provide them an opportunity to observe various phenomena. Some real-life situations are difficult to recreate, such as planet motion and brain discerption. However, simulation techniques can act as alternatives to actual situations (Aristeidou & Spyropoulou, 2015). Simulated models of real-world settings enable learners to construct knowledge through active participation. They also afford opportunities for reflection (Yin et al., 2013). Simulation can provide science learners with access to high-quality learning environments, engage them in real world problems, and address science education's critical weaknesses by meeting advanced and low-achieving students' learning needs (Muehrer, Jenson, & Friedberg, 2012). Simulation can also promote inquiry and active learning based on students asking questions at their own pace (Chang, 2017). Augmented reality and virtual reality can help students directly learn content's essence and modify their native knowledge (Yen et al., 2013). Issues of insufficient engagement and motivation can be overcome via simulation games. An example of a simulation game and its role in supporting science learning is Energy Skate Park, designed to help students learn about energy concepts. This game encourages students' productive exploration (Podolefsky et al., 2010). Supercharged helps middle school students learn about electromagnetism (Anderson & Barnett, 2013). River City allows students to conduct investigations. This game enhances their engagement with science with fewer disruptions and better attendance (Morris et al., 2013). The Hereafter app promotes physics via a model-building tool that contributes to a deeper understanding of conceptual information (Menon & Steinhoff, 2017). A floor planer app enables learners to create 3-D models by designing a house or garden, which requires critical thinking and measurement skills (Mills et al., 2017).

2.9.4. Problem-solving apps

Active learning requires students to play active roles in their learning process by confronting problems, and it challenges them to solve those problems and construct knowledge (Cieutat et al., 2012). Problem solving is crucial for learning science (Kim & Hannafin, 2011). it indicates learners' engagement in cognitive processes to realize, comprehend, and resolve problems where the strategies to solve the problems are not promptly attainable (Choi et al., 2018). Deep learning can be achieved by engaging students in authentic and well-structured problems. It also offers social support scaffolds and tools to enable them to manage complex problems (Choi et al., 2018). Learners can engage in deep learning because problem solving helps them internalize and transfer their problem-solving process and outcomes in diverse contexts (Choi et al., 2018).

During problem solving, mobile devices and their apps can supplant and augment inquiry. The technological possibilities of these devices might guide learners to concentrate on critical aspects of problem solving, such as justifications, construction of solutions, identification of evidence, and observation of phenomena (Kim & Hannafin, 2011).

This kind of app is prominent due to their function in promoting students' thinking (Kumar, 2017). They come in different types, such as board games, memory games, puzzles, classifying and grouping activities, and tic-tac-toe. These games' power lies in their ability to elicit learners' misconceptions and, after, offer a context for thinking about problems (Anderson & Barnett, 2013). Puzzles challenge children to solve activities with clear goals (Pirker & Gütl, 2015) and require high-level thinking tasks that require synthesis, analysis, and evaluation (Karacop & Doymus, 2016). Puzzles afford learners an opportunity to recognize inconsistencies in their knowledge and increase their motivation to explore (Podolefsky et al., 2010). The interactive play experiences that problem solving apps provide can encourage learning and higher-order thinking (Anderson & Barnett, 2013). For example, the Tree Investigator app requires children to perform problem-solving activities and identify trees in various stages. Using this app helps children use various strategies, which are procedural, real-time decision-making, and tactical strategies about trees' life cycle. It also engages children in deep learning (Choi et al., 2018). The Thinknlearn app helps students exploit their critical thinking skills and generate hypotheses by engaging them in experiments and exploration in real environments (Ahmed & Parsons, 2013). The Solve the Outbreak app requires children to progress through outbreak investigations. Children perform many activities by answering multiple-choice questions, which support analysis of relevant data (Glassman & Glassman, 2015). The Biome Viewer app helps students learn about bio-diversity, climate, and biomes by enabling them to formulate questions and search for accurate answers (Mills et al., 2017). The Chem Crafter app enables children to recognize chemical reactions that result from mixing virtual chemicals with salt, acid, and water. These reactions are represented in shattered lab equipment, fire, smoke, and color changes. This game required children to gain access to new lab equipment and more chemicals and unlock new experiments by applying effective strategies (Glassman & Glassman, 2015). The popular Angry Birds casual puzzle game helps students learn the basic principles of physics, such as making observations of velocity and speed. Children's interaction with the game's elements develops their knowledge about projectile motion (Herodotou, 2018). This same game also helps middle school students explore the dynamics and kinematics of projectile motion (Rodrigues, Carvalho, 2013). Portal is a scientific game the requires learners to create portals to transmit objects and characters to solve puzzles (Morris et al., 2013). Alchemist Knight is a chemistry board game that helps students improve their critical thinking skills and enhances the mystery of alkane concepts derived from compound materials (Wardani, Lindawati, & Kusuma, 2017). The Ocean Quest game promotes students' critical thinking and problem-solving skills and helps them learn about fish species (Ormsby et al., 2011). The Great Stem Caper game is designed to encourage 5^{th} and 8^{th} graders' engagement in science. It requires them to solve challenges collaboratively to earn badges and points (Atwood-blaine & Huffman, 2017). The Evoke game requires children to engage with some problems related to energy and food to promote their thinking about real-world problems (Morris et al., 2013). The Crayon Physics Deluxe app includes puzzle activities that encourage students to make connections between new and existing experiences (Kao et al., 2017). The Fold It games help students solve real-world problems (Pirker & Gütl, 2015).

2.9.5. Multimedia and animation apps

Multimedia present and process information in a more understandable and structured manner by utilizing various media: video, audio (Kumar, 2017), icons, avatars, images, tables, animation, graphs, and texts (Virk et al., 2015). Multimedia learning refers to creating mental models from spoken and printed words or from dynamic or static pictures to construct knowledge (Magana, 2014). Interactive multimedia can make learning experiences more realistic, which helps learners acquire theoretical knowledge (Cholid, 2015) and can create authentic learning environments that support meaningful learning (Kumar, 2017). Exposing learners to multimedia facilitates sense-making and the multiscale and multimodal presentation of information (Magana, 2014). Cooperative multimedia components offer young learners greater understanding, repetition, and conclusions (Wardijono & Hendajani, 2018). Involving science-learning environments with multiple information representations helps students make sense of relationships and complex models (Virk et al., 2015). Providing young science learners with audio-visual aids helps them communicate ideas and concepts (Thomas & Israel, 2014). Using multimedia to learn science concepts also produces long-term memory and improved retention of materials in learners (Kumar, 2017). For example, Hautala et al., (2018) found that using multimedia lessons to teach 1st-grade children about animals increased their interest in science and enhanced their science learning significantly.

Animation is defined as a series of pictures moving quickly to appear live (Raditya et al., 2017). It is considered a promising learning strategy. Animation affords motion and trajectory, two attributes that still pictures in textbooks cannot provide (Karacop & Doymus, 2016). It is a powerful vehicle for science education due to its ability to depict dynamic real-world phenomena better than static graphics (Wu, Wu, Chen, Kao, & Lin, 2012). This technique can bring to life scientific phenomena (Thomas & Israel, 2013). Dynamic visualization represented in animation and simulation can provide learners with more details than static visualization (Koseoglu & Efendioglu, 2015). Furthermore, it involves the senses of hearing and sight, which can make science learning more permanent and meaningful (Thomas & Israel, 2014). Learners who use animations to study science were able to connect science to their daily life, which developed their self-efficacy, interest, and enjoyment (Barak & Dori, 2011). Animation triggers students' explanatory ability and enhances their conceptual understanding (Barak & Dori, 2011) For example, Raditya et al., (2017) found that animation and virtual reality are very helpful in attracting learners' attention; thus, they deeply understand a solar system lesson. Utilizing animation techniques can help students understand chemical bonding (Karacop & Doymus, 2016). The AKSES app's activities encourage children's interest in learning science, therefore improving their observation skills (Amerul et al., 2017).

2.9.6. Drawing and colouring apps

Drawing apps allow learners to sketch phenomena and objects by directly utilizing fingers on a touch screen (Chang et al., 2016). Drawing helps young learners' competencies and interactions with orientations, relation, interpretation, and spatial visualization. Regarding science, drawing supports young learners' transformation of spontaneous and everyday concepts into scientific ones. When young learners are encouraged to discuss, revise, and revisit their drawing, they can explore and represent more complex ideas. Young learners' thinking becomes visible through their drawings and sketches (Sun et al., 2016). Using drawing apps in science class allowed children to construct scientific reasoning and portray their understanding of scientific questions (Chang et al., 2016).

Scientific explanation can be supported by narrative and by drawing on tablets. Moreover, drawing is an important tool that can enhance scientific conceptual understanding (Chang et al., 2016). Using drawing apps to generate personal representations can help learners acquire new understanding by consolidating existing and new knowledge (Chang et al., 2016). There are thousands of narrative and drawing apps in Google Play and Apple Store available to support science learning via drawing activities (Chang et al., 2016). For example, Song and Wen (2018) found five apps that primary school children can utilize (Edmodo, Evernote, Skitch, Camera, and Recording) in the BYOD model to support science learning and help them obtain a better sense of ownership in learning and improve their scientific knowledge. The Sketchy app allows students to draw their experience of field trip after observing a butterfly cycle and compose a Sketchy composition (Looi et al., 2015). Using the Hereafter app for writing and drawing saves time and increases efficiency (Menon & Steinhoff, 2017). The Plotly app enabled learners to visualize data by creating and sharing interactive graphs (Mills et al., 2017). Animating and drawing on Sketchy fosters students' thinking and demonstrates their understanding (Looi et al., 2011).

2.10. Standards of selecting apps and mobile games to support science learning

Using apps and digital mobile games to facilitate children's science learning without proper game design will negatively impact their learning, which might lead to poor outcomes. One such outcome is rearing children with self-alienating behaviors (Sung & Hwang, 2013). Another negative outcome is that children may lose interest in the games and thus become distracted from their learning (Wang & Towey, 2013). Children's use of handheld devices should be incorporated into the classroom with a focus on the quality of the digital games and mobile technologies used. The adoption of mobile learning and new technologies in the classroom requires that administrators and educators work together to assess various learning approaches and find the proper one (Ward et al., 2013). The apps to be used for learning in the classroom should be selected according to two important factors: The apps should facilitate a high level of engagement, and they should be efficient in helping learners to accomplish their desired learning outcomes (Mckenzie et al., 2018). In addition, consider the learner-centered approach in the selection process (Marty et al., 2013). Based on this approach, the apps should be easy to use and useful, support creativity, be collaborative, and enrich communication and concentration. They should also include interactive and visual elements to help learners to enjoy the interactive learning experience. Furthermore, the structure and content should be crafted to fulfil young learners' desires and needs; for example, the apps should come with rewarding, immediate, and clear feedback in two forms: visual and oral (Herodotou, 2018). In addition, the landing page should include large buttons and bright colors, which highly engage children, and interface distractors should be minimized (Mckenzie et al., 2018). The apps' interfaces should also be functional, systematic, and intuitive (Marty et al., 2013). Furthermore, the absence of advertisement should carry the most weight in the pedagogical app selection process (Santos et al., 2014).

Creating engaging gaming experiences requires that teachers also consider game characteristics such as how challenging the games are, their goals, and the rules (Kao et al., 2017). Moreover, educators should avoid selecting apps that require children to perform overly complex tasks that can cause disappointment and frustration. In addition, the apps should feature minimal written content, as too many written words on a screen can easily overwhelm children (Giannakos et al., 2014). Furthermore, children should be able to complete each level of a game within two minutes maximum because children become restless if they spend too much time on one level (Giannakos et al., 2014). A game's challenge levels should also match children's zones of proximal development (Marino et al., 2014). Select games that act as guides that direct children's attention to specific topics, with each level or stage concentrating on a particular concept or skill (Giannakos et al., 2014). It is also important to select games that encourage cooperation and competition among children and that allow for sharing resources (Giannakos et al., 2014). Furthermore, it is important that teachers guide children and provide them with support when they use educational mobile games. They must maintain a balance among the four aspects of ability, learning, challenge, and gaming (Sung & Hwang, 2013). Also, game and app content should be relevant to the school curriculum (Giannakos et al., 2014). In fact, there is a problem when some applications are without guides or frameworks and do not have used usability tests. This might generate problems affecting users' understanding and interactions with these applications, especially for those not familiar with mobile technology. Students with limited technical skills might have negative expectations about mobile learning, whereby they may feel that mastering these skills will require additional efforts (Criollo-c et al., 2020).

2.11. Conclusion

The research literature related to the use of mobile devices in the science classroom, demonstrates that the unique capabilities of modern technology can support science learning by helping students to do the following:

- Direct their scientific exploration by preserving a sense of agency with the mobile learning approach.
- View science as enjoyable and accessible; students demonstrate more interest in science and engage in authentic scientific practice.
- Make connections between formal science and the experiences of everyday life, which will assist students in perceiving the role of science in understanding the world.
- Develop a conceptual understanding that will enable them to coordinate together across multiple representations, notice cause-effect relationships, and comprehend expert models.

- Engage in scientific exploration; students have opportunities to reflect and monitor their own understanding, build upon their previous knowledge, use evidence to support their ideas, make predictions, design experiments, and pose their own questions.

In the following chapter, I present and discuss the theoretical framework that underpinned my conceptualisation and analysis of the data obtained during the study. As my aim was to determine how different aspects and affordances of tablets and their apps engage and support first grade children science learning. I based my research on social constructivism theory which will be outlined and discussed in the next chapter.

CHAPTER THREE

THEORETICAL FRAMEWORK

3.1. Introduction

This chapter includes an explanation of social constructivism theory, its principles, and its framework, which guide the present study.

3.2. Brief summary of the theory

"Learning is more than the acquisition of the ability to think; it is the acquisition of many specialized abilities for thinking about a variety of things."—Lev S. Vygotsky, Mind in Society, 1978

Social constructivism developed from constructivist theory. Vygotsky is one of its pioneers. The social construction of reality is a theory of knowledge regarding sociology and communication that examines the development of a jointly constructed understanding of the world (McMahon, 1997). Vygotsky strongly believed that knowledge is socially and culturally constructed rather than individually. Moreover, Vygotsky's theory pertains to cooperative learning and focuses on relationships and on the individual's role in the social construction of reality. It involves the investigation of social influences on both group and individual life, as well as the individual learning that occurs due to group interactions (Oke, 2006). Vygotsky placed great emphasis on a number of areas, including how individuals learn; the ways in which individuals construct meaning through interaction with social environment experiences; the role of society in individuals' development; individuals' interactions with teachers, parents, and peers to gain knowledge; and the importance of utilizing tools, such as computers and language, to build knowledge (Jonassen, 1992). This theory places considerable emphasis on using tools such as laptops and mobile devices in the learning process due to their role in assisting learners in constructing knowledge (Mifsud, 2003). As a researcher who is interested in mobile learning, I was motivated by Vygotsky's emphasis on the use of tools, so I selected his theory to guide my research.

3.3. Principles of social constructivism

Many principles underpin social constructivism: How and what we think are affected by the social context, the fundamental factor of children's development is interaction, through whichknowledge is co-constructed (Lantolf, 2000). In addition, cognitive development requires social interaction. According to this theory, social learning is important because individuals learn in a positive manner in groups. Social learning helps with constructing knowledge. Social constructivism regards individuals as parts of cultural, political, and historical evolutions (Andrews, 2012). Vygotsky believed that meaningful learning takes place when children interact with knowledgeable peers or teachers, as this interaction can offer guidance and provide a model for solving problems (Lee & Tu, 2016). Social communication is especially important for young science learners. Their interactions and debating of issues related to science, enable them to link existing knowledge with newly acquired knowledge (DeWitt et al., 2013).

"Human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them." —Lev S. Vygotsky, Mind in Society, 1978

DeWitt et al., (2013) mention that Vygotsky saw discussion as a vehicle for learning and thinking. Students' discussions in the science classroom provide them with opportunities to listen to their peers' perspectives, refine their ideas, evaluate, and declare their beliefs (DeWitt et al., 2013). According to social constructivism theory, learning occurs through interaction and dialogue. Based on another of the tenets of social constructivism, dynamic social processes are represented in dialogue among teachers, learners, and classmates. Learners' prior knowledge is a fundamental component of the ability to engage in meaningful learning. Prior information and beliefs play a pivotal role in the learning process. In addition, individuals learn to build meaning through the social interactions and experiences they have undergone within the environment (Schwandt, 2003). Knowledge is also influenced by culture, which includes language, and culture is influenced by beliefs and skills, such as communication, cooperation, and technology skills (Holzman, 2010). Changes in people's realities depend on a number of variables, such as social interaction, culture, and language (Powell & Kalina, 2009). Gauvain (2008) propose that, From a social constructivist perspective, intellectual development is social rather than biological in nature as Piaget suggested. Learning is a factor that encourages intellectual development. Social and cultural contexts influence learners' cognitive development, and language is used as a tool for speaking and thinking (Powell & Kalina, 2004).

"The specifically human capacity for language enables children to provide for auxiliary tools in the solution of difficult tasks, to overcome impulsive action, to plan a solution to a problem

prior to its execution, and to master their own behaviour.” —Lev S. Vygotsky, Mind in Society, 1978

Through social interaction with more experienced individuals (e.g., teachers, parents, and friends), learners’ knowledge is built based on a shared understanding via linguistic communication and the use of writing (Oke, 2006). According to Vygotsky, learners’ educational experiences are divided into three patterns; first, historical experiences, or knowledge acquired via individuals through generations; second, social experiences, which include knowledge that individuals acquire as a result of their contact with others; and third, experiences of adaptation, or knowledge that individuals acquire as a result of close contact with the surrounding environment (Oke, 2006).

Thompson (2013) points out, the social constructivism approach in learning emphasizes the importance of psychological tools, including language, concepts, drawing, oral dialogue, symbols, ideas, and beliefs. Moreover, physical tools, such as books, computers, and devices, are used in the learning process, where these tools mediate children’s learning. Mediation refers to humans not directly interacting with the environment, where their interactions are mediated by signs and tools instead. These tools facilitate knowledge construction, helping learners to achieve the objectives of learning, perceiving, and engaging.

From Vygotsky’s perspective, cultural tools can be information-seeking strategies that increase human cognition. In addition, these tools can be concrete or conceptual (Morris et al., 2013). Science is social and individual activity that creates and uses cultural tools. Morris et al., (2013) suggest that Educational and cultural tools play an important role in the development of scaffolded scientific thinking skills, which are not routinely developed but are necessary for the practice and development of scientific thinking.

Mobile devices act as cognitive tools that can support learners’ cognition, monitor their progress, promote collaboration and sharing, and develop their critical-thinking skills (Sun et al., 2016). Digital games in particular have the potential to support three basic components of scientific literacy: understanding the nature of science, process skills, and content knowledge. For this reason, these games are seen as types of cultural tools that provide metacognitive scaffolds, cognitive scaffolds, and motivational scaffolds (Morris et al., 2013). Vygotsky heavily stressed scaffolding, which means having teachers or more knowledgeable peers provide learners with assistance to help them to solve problems (Kao et al., 2017; Yu et al., 2013). Vygotsky believed that children advance their learning within their zones of proximal development by using temporary guidance (Kao et al., 2017). A zone of proximal development refers to the distance between two situations of children's performance: when they are assisted and when they are unassisted.

"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).

All types of scaffolds assist students in bridging the gap between potential and actual performance (Fallon, 2017). The various scaffolding types include motivational scaffolding, strategic scaffolding, metacognitive scaffolding, and conceptual scaffolding (Kim et al., 2018). The objectives of scaffolding are to assist learners in achieving what they are unable to achieve because they go beyond their current abilities and improve engagement in learning (Kim et al., 2018). Scaffolding supports learners' sense of empowerment and agency, which encourages exploration (Podolefsky et al., 2010). Additionally, it can increase learning motivation and build learners' confidence (Kao et al., 2017). Learning becomes more tractable with scaffolding, as scaffolding makes difficult and complex tasks more manageable and accessible (Laru et al., 2012). The temporary support of scaffolds assists learners in becoming more comfortable and adept. In addition, it helps them to avoid frustration and floundering, and it assists them in coping with difficulties (Yu et al., 2013). For example, with scaffolding, students learn about respiration, plants, and the nervous system, which helps them to make hypotheses, draw conclusions, and develop high reasoning skills (Wu, Weng, & She, 2016).
Scaffolding can clarify incomplete knowledge as well as a conceptual or procedural misunderstanding. It can also minimize learners' working memory when they deal with new knowledge (Yu et al., 2013). A range of educational goals encompassing content, process, and affect can be supported via scaffolding (Podolefsky et al., 2010). Supportive scaffolding concentrates on giving learners the support and advice they need to achieve a task by modeling, guiding, and coaching (Yu et al., 2013). Discovery and exploration without scaffolding and guidance might not offer support for learning (Hirsh-Pasek et al., 2015).

In the mobile learning environment, children actively build their learning with teachers and peers. Digital scaffolds provide the necessary support rather than being passive (Lee & Tu,

2016). Children can attain cognitive benefits while playing games if this experience is mediated by teachers or knowledgeable individuals (Herodotou, 2018).
Multiple forms of scaffolding that cater to learners' needs can improve their cognitive learning achievement (Song, 2014). The three forms of scaffolding that exist include teacher-based scaffolding, peer-based scaffolding, and digital scaffolding.

3.3.1. Teacher-based scaffolding

Science teachers play a key role in making young children's education more effective by scaffolding their science learning while they play. They do this by creating alternatives, provoking inquiry, arranging the learning environment, and asking questions. Teacher-based scaffolding forms include strategy naming, element identifications, assisted modelling (Alake & Ogunseemi, 2013), elaborative promotion, corrective feedback, and teacher-led consolidation (Yu et al., 2013). It also includes providing an introduction to an activity, guidelines, comments on progress, and task or tool familiarity. Instructions in the form of scaffolding enable learners to gain information about activities' learning goals, available resources to use, how and where to find them, and how to complete the activities (Aristeidou & Spyropoulou, 2015).

Young learners often need instructional support when they engage in complex scientific activities (Wu et al., 2016). They may have difficulty with developing the scientific concepts and obtaining necessary knowledge if timely and proper support from teacher scaffolding is lacking (Tarng et al., 2018). Teacher scaffolding helps learners to investigate evidence, refine strategies, remain on task, revise answers, and monitor their progress (Kim & Hannafin, 2011).

3.3.2. Peer-based scaffolding

As explained previously, the social constructivism view is that constructing knowledge occurs in active social processes. These processes can be represented in the areas of collaboration, negotiation, and interaction through discussion, dialogue, and conversation with others (Ward et al., 2013). Vygotsky's association of the social and the cognitive offers opportunities to explore and realize young learners' social experiences. Peer interactions within a group enhance understanding of concepts and principles; thus, they lead to fewer errors and help to improve memory (DeWitt et al., 2013). In addition, communicating in science class helps students to share ideas, promote critical thinking, and engage in planning (DeWitt et al., 2013). Peer scaffolding assists learners in sharing perspectives, challenging one another, encouraging

further thinking, reconciling with one another, and confirming answers (Kim & Hannafin, 2011).
This form of scaffolding involves multiple patterns, such as checking and confirming answers, tool familiarity, variable manipulation, and navigation (Kim & Hannafin, 2011).

Peer scaffolding is not always effective due to the spreading of disorganized and incomplete knowledge, as well as misconceptions among learners (Nouri, 2014).The adoption of a collaborative approach within science learning encourages the use of scientific language among learners, with the acquisition of scientific language enabling them to build scientific knowledge (DeWitt et al., 2013). Brainstorming, discussing, asking, and arguing in collaborative learning groups provide children with helpful information for creating new ideas to perform tasks properly (Sung & Hwang, 2013).

3.3.3. Digital scaffolding

Mobile devices have a variety of features that are used to scaffold learners' exploratory activities and that can accompany them on field trips, such as those to museums, or as they study natural phenomena outside of the classroom. These devices facilitate taking pictures, recording audios, taking notes, and using digital resources (Ruchter, Klar, & Geiger, 2010). Kim & Hannafin (2011) suggest that Digital scaffolding helps learners to manage their cognitive loads, access and save notes, locate and find resources, and visualize and externalize their understanding. Mobile devices can provide just-in-time-resources and access to experts (Zydney & Warner, 2016), visualization and modeling (Kim & Hannafin, 2011), and sequential and timely instructions that offer clear guidance and reduce the risk of confusion (Nouri, 2014). They also offer access to quick reference tips (Menon & Steinhoff, 2017).

Technical scaffolding strategies include providing hints, concept mapping, questions, feedback, and expert modeling (Kim et al., 2018). They also include facilitating online discussions, explanations, reasoning, scientific thinking, content trees, and reflection (Yu et al., 2013). The goal is to provide learners with guidance, such as hints or feedback, and to assist them in re-organizing their scientific observations (Hwang et al., 2011). The digital scaffolds that gamified apps provide are used to bridge the gap between the skills that learners need to be successful and their current skills (Kao et al., 2017) They also have the potential to assist in the gaming process and to facilitate learning effects (Kao et al., 2017). These scaffolds can be used to explore games' strategies, explain games' rules, and familiarize children with the skills they need to accomplish their goals (Kao et al., 2017). Implicit scaffolding can reduce teachers' role as a source of knowledge. It can also increase their use of modes that assist in developing the scientific process, as well as increase the use of pedagogical practices (Podolefsky et al., 2010). Even though digital scaffolds provide rich support for learners, their potential cannot be achieved in the absence of peer interaction and teacher mediation (Palincsar, Fitzgerald, Marcum, & Sherwood, 2018).

3.4. A social constructivist view of teaching

According to social constructivism in the mobile learning environment, science teachers' roles are flexible where they should be—in the roles of evaluator, facilitator, mediator, collaborator, and designer (Sun et al., 2016). These teachers are required to verify students' knowledge; evaluate conceptual scaffolds in terms of their students' capabilities and learning characteristics; critically review apps that students use, taking into account accessibility; closely monitor conceptual learning with their students' apps; and select appropriate apps that align with assessment, pedagogical, and curriculum design (Ormsby et al., 2011). Science teachers should create legitimate spaces for experimentation by guiding students' learning toward intended outcomes. In addition, they must act as facilitators of their creativity (Abdullah, 2015). Teacher-learner interactions while using apps or games enable teachers to detect misconceptions and then correct and eliminate them, which assists learners in building their own understanding and detecting their learning processes (Sun et al., 2016).

"The teacher must adopt the role of facilitator not content provider." —Lev S. Vygotsky, 1985

Science teachers as facilitators help students to plan and carry out investigation analyses, as well as to interpret data, brainstorm ideas, gather information, generate questions for explanations, and collect data (Yin et al., 2013). They must scaffold students' learning, interact with them, conduct mobile activities, ask questions, and create situations that enable learners to seek explanations for events and objects, as well as explore concepts (Looi et al., 2015). Facilitating conceptual knowledge construction requires science teachers to support learners' thinking, assist them in further challenging or elaborating and articulating their comprehension, and ask questions to elicit learners' ideas (Sun et al., 2016). Teachers' questioning and structuring can help young science learners to practice inquiry (Kim & Hannafin, 2011). Asking exploratory questions helps teachers to understand learners' reasoning processes and to encourage learners to produce their own explanations (Sun et al., 2016).

According to the socio-constructivist approach, science teachers should provide students with authentic learning activities that induce reasoning skills and higher-order thinking rather than fact memorization (Laru et al., 2012). They should reinforce learners' reflections and interpretations instead of mirroring fixed structures and representations of the external world (Yu et al., 2013). In addition, they are responsible for giving students inspiration and support, encouraging them to discover the world around them. Teachers should identify and determine what learners are able to accomplish both with guidance and independently (Ed & Ed, 2013). They can determine the assistance that learners need by monitoring children's learning statuses (Tarng et al., 2015).

Within a social constructivism theoretical framework, teaching consolidates and activates learners' understanding. It also assists learners in generating new knowledge and new meaning during collaborative work in the social context. In addition, teachers are responsible for creating learning environments that enable learners to learn independently through exploration and experience as they acquire their own knowledge and skills (Marshall, 1996). The most important condition for the provision of a successful learning environment is to provide support and to challenge learners' thinking (Di Vesta, 1987). In addition, it is important to create an environment that can help learners to arrive at their own conclusions (Rhodes & Belly, 1999). The role of teachers in classrooms that operate within the theory of social constructivism is related to the organization of the learning environment and the provision of guidance and counseling to students. Teachers are considered to be just one conduit of information, not the main source. Furthermore, teachers are in charge of the link between technology and education, which brings learners into greater harmony with what occurs in society—be it developments or changes (Koole, 2009). Additionally, attributes of the social constructivist teacher encourage a spirit of inquiry and discussion between learners. Such attributes are characterized by the appropriate selection of learning activities that can stimulate discovery in learners (Koole, 2009). Science teachers can support learners by creating socio-cognitive learning that exceeds what games and apps can provide (Anderson & Barnett, 2013).

Many social constructivists strongly criticize traditional approaches in education, which use a didactic teaching style (Mifsud, 2003). In contrast, social constructivists suggest that learning takes place when students are actively involved with their colleagues, instead of receiving information from teachers, and when the learning process occurs in a framework of cooperation and social interaction, instead of being based solely on the process of memorization (Bauersfeld, 1995). Many models and strategies reflect the theoretical foundations of social constructivism, such as reciprocal teaching, a community of learners model, a cognitive apprenticeship model, and a generative learning model (Shunk, 2000). Adopting these models and strategies leads to an indirect teaching style and encourages learning based on solving problems, collaborative work, and contemplative thinking.

3.5. A social constructivist view of learners

Social constructivism considers students to be active learners when they are highly engaged and involved in their learning processes. They are able to construct their knowledge and collaborate with teachers and peers instead of being passive by receiving information from teachers. In other words, constructing knowledge requires active engagement, and learning takes place when learners actively participate and interact with others. Students who are active learners are required to be practitioners, collaborators, and designers (Sun et al., 2016).

3.6. Social constructivism and mobile learning

Social constructivism provides an appropriate environment in which to integrate technology into the learning process (Brown & Campione, 1996). Social constructivism is one of the theories that helps when designing a technology-rich learning environment that emphasizes the role of learners in constructing knowledge in the social context. In fact, mobile devices include numerous applications that enable learners to communicate with other learners to obtain information, answer inquiries, and discuss tasks freely. All of these tasks contribute to social interaction as Vygotsky affirmed (Corbeil & Valder Corbeil, 2007). The use of technology enables teachers to apply social constructivism principles in various learning situations by connecting old and new information and bringing about social interaction. Technology also enables students to find new and meaningful situations that are closely related to what they have learned, which helps them to collaborate with friends and to solve the learning problems they face (Patten, Arnedillo, & Tangney, 2005). Likewise, the use of technology, such as the Internet and mobile devices, assists learners in accessing information that is related to their needs and provides learners with experiences that are difficult to acquire in other ways. Technology enables learners to discuss various perspectives on various topics, a process that supports the construction of knowledge (Alexander, 2004).

Social constructivism may be successfully applied in a mobile learning environment because mobile devices provide learners with social communication tools, add flexible tools for use in the learning process, and extend the learning process beyond schools to various places where other learners exist (Virvoue & Alepis, 2005). When applied effectively, mobile learning supports the social constructivist approach because mobile devices may expand discussions in the classroom and promote cooperation and communication among students from all over the world (Bryant, 2006). Students are able to converse with one another as they exchange opinions and experiences. Cooperation is not limited by time or a certain place (Switzer & Csapo, 2005). In this way, social constructivist learning objectives that are facilitated via the mobile learning environment provide learners with an opportunity to collaboratively build knowledge—through discussion and according to multiple viewpoints—and they also create an opportunity for teachers to support learners in constructing knowledge (Miller & Miller, 1999). One of the advantages of social constructivism is that it supports a student-centered learning approach. Some mobile applications foster this kind of learning by enabling learners to select convenient content. Thus, learners interact with content and classmates in classrooms effectively and efficiently (Leung & Chan, 2003). Social constructivists believe that true learning occurs when learners possess critical analysis skills, actively search for knowledge, and take part in social activities. As suggested, mobile learning provides an opportunity for learners to collaborate and exchange experiences with peers (Switzer & Csapo, 2005).

3.7. Conclusion

Learning in social constructivism considers three particular features of mobile learning: collaboration, personalization, and authenticity. Authentic tasks simulate real-world settings and place learners in actual practices. Personalization refers to the characteristics of educational applications—for example, customization, self-regulation, self-pacing, and choice. Finally, collaboration, an important component of learning, is essentially social interaction in the mobile learning environment. This kind of interaction can be increased by conversation, shared learning, representations with others, and integrating the responses that these representations spark (Santos et al., 2014). Based on Vygotsky's perspectives, young learners' engagement with educational and gamified apps' activities enable them to represent their internal visualization of topics by creating external structures.

CHAPTER FOUR

Research Design and Methodology

4.1. Introduction

This chapter provides a description of the methodological framework which I used to gather and analyse the data of the current research. The research methodology and design were guided by the research questions and objectives. I conducted a qualitative interpretative study, which enabled me to explore deeply the apps' and tablets' affordances regarding support of science learning and their influence on young learners' engagement. The aim of this study was to investigate and understand young learners' perceptions and experiences of utilizing apps and tablets as educational tools to support science learning. I sought to find answers to the following questions:

RQ1: What are children's responses to using educational science applications that support science learning in a Saudi Arabian Grade 1 class?

RQ2: How far do educational science applications support science learning in a Saudi Arabian Grade 1 class?

RQ3: What are the issues and challenges related to implementing mobile learning in a science class in a primary school?

This chapter aims to present an illustration of the selected and conducted research methodology, provide clarification of the philosophical paradigm underpinning the study, and afford justification and description of data collection methods and tools utilized to analyse data. Furthermore, I discuss in a comprehensive manner the procedure of the research, selection of the participants, tools used for data collection, and ethical considerations. After that, I address the nature of my position as a researcher and the rigour of the study by providing clarification of the measures taken to increase the trustworthiness of the research. Lastly, discussion of the data analysis and interpretation methods are presented at the end of this chapter.

4.2. Research Paradigm (Philosophical Framework)

Conducting research requires adherence to certain philosophical assumptions of reality and highly abstract principles (Guba & Lincoln, 2005). Where researchers can view the world through these assumptions and philosophical lenses they call them paradigms (Bateson, 1972, p. 320). Mackenzie & Knipe (2006) propose that, the concept of a paradigm is considered research's theoretical framework, including the group of logically related assumptions, positions and concepts that orient research and thinking. A paradigm enables one to frame the topic of the research and impact the comprehension of this topic (Hughes, 2001). Moreover, a paradigm provides for its holder representation of a worldview that defines the world nature, the place of the individual in it, the range of rapport to the parts of the world and the world itself (Guba & Lincoln, 1994, p. 107). There are three assumptions that the set of beliefs consist of, that are combined in practice: methodological, epistemological, and ontological. Regarding the methodological assumptions, they seek to address ways that assist in world knowledge discovery. The epistemological assumption is interested in identifying the rapport between the known and the knower. While the ontological assumption is concentrated upon the reality of nature (Guba & Lincoln, 2005, p. 22).

As this research aims to investigate the role of apps' and tablets' affordances in support of science learning as voiced and experienced by first grade children and explore the effect of these apps on children's engagement, it also examines the challenges encountered by those children while interacting with apps and conducting mobile learning. An interpretative paradigm has been selected to underpin this study and guide the gathering of data and analysis procedures. Regarding methodology, qualitative research was chosen because it allowed me to describe analysed data in a full and detailed manner. I selected the interpretative paradigm as the appropriate philosophical approach to underpin the current research design and methodology. This selection suited the research objectives and questions. The interpretative paradigm has a close relationship with constructivist theory, which I chose as the theoretical framework for the literature review. It also provides important assumptions about how we view the world as human beings. This philosophy emphasises the construction of meanings and an individual's ability to build meanings, which are derived through interactions between the researcher and the participants (Denzin & Lincoln, 2005). The aim of interpretative research is to reveal, describe in detail, and experience meanings (Given, 2008). Another aim is to understand the distinctive aspects of the phenomenon under study. How people build meanings in their social world is primarily the interpretative researcher's interest. Interpretive researchers believe in differences between people because no two people are the same in everything. Hence, these differences impact how people build meanings (Given, 2008). The researcher enters the world of the participants in the research and seeks to understand their world from their point of view. Knowing people's perceptions of the world helps the researcher to understand social phenomena (Mack, 2010).

Reality is interpreted through the perspective of individuals in a particular context. Researchers who use the interpretive approach take into consideration the internal reality of participants during the study of social phenomena (Rehnsfeldt & Arman, 2012). According to the ontological position of the interpretative paradigm, reality is subjective and therefore differs from one person to another. Individuals construct reality through interactions among language, consciousness, meanings, and instruments (Scotland, 2012). In fact, researchers must not expect participants to arrive at the same interpretations because individuals understand the same reality in different ways. They interpret events differently from their perspectives, which leads to multiple perspectives of the same incident (Robson, 2011).

This study aimed to explore the views of children about educational applications in supporting the learning of science and examine the difficulties they may encounter while using mobile devices in the science classroom. Ultimately, I have adopted the interpretive approach because it enabled me to investigate children's experiences with mobile devices through children's perspectives themselves; thus, this approach was suitable to fulfil the objectives of the present study. In the current study, I sought to recognise how mobile device applications support science learning. Thereby, I observed the young participants to understand the children's personal experiences with applications and how they engaged with these applications, as well as examined the challenges which children encountered when using portable devices in science classes.

4.3. Role of the Researcher in interpretive research

The researcher in interpretive research is considered an essential instrument to collect and analyse data. In addition, the researcher's desire to understand the social reality guides interpretive studies and propels them to discover participants (Given, 2008). In fact, the researcher understands that reality is based on epistemological and ontological beliefs. Interpretive research requires a focus on studying behaviour, intentions, and emotions. The researcher must be an active and effective recipient of new knowledge throughout the period of the study (Hudson & Ozanne, 1988). Researcher is normally not just a spectator, but also an observer and a participant in the activities, in certain contexts. As such, the researcher focuses on participants' experiences to gain deep understanding of social phenomena. Moreover, previous research experiences affect the interpretation of different phenomena (Anderson, 2010). The interpretative approach is an integral aspect of qualitative research. In this study, I employed two qualitative methods: participant observation (in order to understand the different types of behaviour of the participants) and two types of interviews (semi-structured face-to-face interviews and focus groups) in order to access the experiences and perspectives of the participants.

4.3.1. My role in the classroom

After I gained entry to the study site and obtained consent forms, I visited a first-grade science class and observed five children. I did my best to avoid being disruptive and intrusive. My goal was to examine how apps affected science learning, how children engaged with these apps, what challenges students faced when utilising mobile devices, how they interacted with peers and group members, and how tablets facilitated their science learning. Participant observation required me to integrate into the young learners' science class and establish rapport with them by engaging in conversations and helping them solve problems by themselves to become independent learners. I conversed with the children and listened to their remarks about the apps' contents, what they achieved, and their stories to gain a better understanding of the role of apps in supporting science learning. When I conversed with the children, I avoided judgmental language and used positive language. Furthermore, I took descriptive, objective notes about events in the classroom and what occurred between children during class. I documented the children's thoughts, reflections, conversations, body language, facial expressions, gestures, and interactions. I also noted what they were interested in and enjoyed, how they dealt with tablets by following directions and exploring functions, and any other seemingly useful information related to the children's use of tablets.

4.3.2. The science teacher's role in the classroom

At the beginning of class, the teacher introduced the new lesson for five minutes. She talked with the children about the new topic, then introduced the apps that were already installed on the tablets and reminded the children of the rules for using tablets in class. After that, the children began using the apps. The children divided into four groups, and every child had the freedom to choose which group to join. For the remaining forty minutes of class time, the teacher visited one group every five minutes to ask the students questions about their activities, share games, reassure them that they were on right track, give feedback, provide suggestions and clues, ask why and other probing questions, provide clarifications and more detailed information, brainstorm, and provide guidance and support to assist the children in finding answers independently.

4.3.3. The positionality of the researcher and its effect on the research

Rigour and lack of subjectivity are criticisms of social constructivist research and qualitative research in which researchers rely on subjective procedures and stances to carry out their research, and some argue that personal bias might distort the findings (Yin, 2009). In fact, all research that requires dealing with people is exposed to rigour and bias issues (Robson, 2011). As a result of that, I used an audit trail, thick description, and thick personal reflexivity to enhance this study's trustworthiness. Researchers' subjectivity presents in qualitative research when they explore and investigate human experiences (Cousin, 2010). The concept of subjectivity refers to the self-internal state that intentionality, beliefs, emotions, self-awareness of others, experiences, and thinking shape (Jupp, 2006).

Researchers' biographies might affect their ways of collecting, interpreting, and reporting data and impact their positionality. Researchers' disciplinary backgrounds, interests, and personal predictions can influence selected methods and methodology (Wellington, Bathmaker, Hunt, McCulloch & Sikes, 2005). Moreover, diverse dimensions of history, gender, social status, and race affect and shape researchers' production of knowledge and positionality. These dimensions are complexly intertwined (Scheurich, 1997). Furthermore, researchers should clarify their positionality with regard to agency, human nature, nature of knowledge, fundamental assumptions of social reality, and philosophical position (Sikes, 2004). Self-reflexivity—turning back on oneself, critically reflecting on the self as researcher, and a self-reference process—can define the position of a researcher (Aull Davies, 1999). Reflexivity is defined as actions that need direct subjective, active, and ongoing self-awareness (Finlay, 2003). Doan (2003) described this concept as consciousness mood. Both personal and interpersonal aspects of reflexivity might affect researchers' production of knowledge.

4.3.3.1. Personal reflexivity

The concept of personal reflexivity implies a researcher understands, examines, and recognises how he or she can interpose his or her assumptions and social background in the process of research (Hesse-Biber & Leavy, 2006). My perceptions and personal experiences inspired my resuming postgraduate studies in children's education, particularly science learning among Saudi first grade children. When I was a learner in schools, I found science and math were the most boring classes even though they were important for understanding many phenomena in life. Years passed, and my eight-year-old brother encountered the same problem in first and second grades. He did not like science class and found it hard to learn. In my opinion, these perceptions exist because of science teachers adopting a lecture-based method of teaching and because of students having a lack of hands-on experiences due to insufficient lab equipment and a lack of field trips due to weather and environmentally restricting conditions and the large number of students, which makes transportation difficult between the school and proposed setting to visit. I do not remember if I joined field trips in all of my education levels. The primary, intermediate, and secondary schools that I was enrolled in adopted the chalk-and-talk method for teaching science. Science teachers and textbooks were the only sources of information. They are not employing different effective pedagogies of science teaching and practical work due to huge number of students in classroom and lack of lab equipment. Teaching science in this way disengages young learners and increases their negative attitudes towards science learning. Thus, they will be unable to practice science as part of their daily life.

As a lecturer in the early childhood department, I am interested in technology and its role in supporting the learning process, especially during the childhood stage. This interest drove me to read deeply into previous studies that were aimed at clarifying the impact of technology's integration into educational institutions and the applications of mobile learning. I have found that most of the studies identified the effectiveness of utilising portable devices in the educational process at all stages. This does not mean I deny the existence of the negative effects with these devices, but I feel that with the spread of these devices in children's hands, educators could take advantage of their positive potential. Also, as a previous kindergarten teacher and a mother, I found some children learned using mobile devices and digital games. My daughters, in particular, gained advantages from using iPads, and they have learned many basic concepts, such as colours, seasons, and animals, from apps and YouTube. Saudi children access handheld devices and use apps heavily, and educators should take advantage of tablets' affordances to support the children's science learning. Tablets give teachers possibilities for creating enjoyable, interactive, engaged, and easier learning experiences. My past experience as a student assisted me in obtaining knowledge about the impact of adopting traditional methods for teaching science and the impact of that on students' developing negative attitudes toward it. Additionally, my ongoing experience as a mother and teacher has equipped me with knowledge about the potential of educational apps, digital games, and tablets to support children's learning.

4.3.3.2. Interpersonal reflexivity

This second type of reflexivity relates to the rapport between the researcher and participants and the way that can influence knowledge creation (Hesse-Biber & Leavy, 2006). Exemplary reflective questions might concentrate on identifying the participants' situation in the research and the rapport between research subjects and researcher (Cousin, 2010). I know about that very well, and my position in the study was an insider-outsider. My position was partially that of an insider because I shared some common ground with participants with regard to religion, language, cultural norms, society, and city and neighbourhood of residence. Furthermore, the participants will become more comfortable because of the sense of belonging (McNess, Arthur, & Crossley, 2015). However, I did not study or work at the school (context of research). Also, I did not have any previous relationship with teachers or students, which situated me as an outsider. Taking the researcher's positionality into consideration possibly shapes the data and therefore the study's quality. Researchers should be careful to avoid developing relationships with participants and in how they introduce themselves. Also, they should give attention to appearing in an appropriate way that is suitable to the research context (Hennink, Hutter & Bailey, 2011). I took these points into account, adapted my appearance to the school setting, and introduced myself to the children in a proper manner. As I explained in the observation section, I worked hard to develop good and comfortable relationships with the children by sharing some games and activities with them. The current research adopted social constructivism as a theoretical framework, so following its perspectives required me to perform the research with young participants where it is not appropriate separated myself from the study (Coffey, 1999). Continuously and explicitly providing a description of my subjective standpoint is a requirement of the self-reflexive approach. It was significant that children's experiences with handheld devices were recorded and interpreted thoroughly and clearly as they occurred, and my personal reflections were recorded separately, thus increasing the data's objectivity.

The potential bias was ameliorated by following**:** I followed the guidelines of the study's context and the institution. I reduced the likelihood of making mistakes by keeping detailed records. I described the study's limitations honestly. In interviews, I utilised open-ended questions which allowed information to flow freely. This revealed the young participants' attitudes and emotional responses to mobile learning. I also used open-ended questions to avoid restricting participants to a limited group of answers. In all parts of the study, I did my best to remain impartial because if researchers appear to feel a certain way, participants can sense this.

As a result, they may provide answers that conform to the researchers' expectations. Moreover, this enabled me to avoid implying that there was a correct answer. I avoided confirmation bias by analysing all of my data even if it seemed unimportant and by reviewing my findings with peers. I used three data collection methods (triangulation), which allowed me to understand the phenomena comprehensively as a researcher.

4.4. Research Methodology

Researchers' theoretical assumptions are guided and shaped the methodology and design of the research, selection of data-gathering tools, and analysis methods (Denzin & Lincoln, 2005). The philosophical paradigm underpinning the research influences the choice of research methodology, and also questions and objectives of the research do the same thing and impact the methodology. Creswell, (2009) suggest that the methodology of the research is defined as procedures, processes, and basic principles that lead and direct the methods utilized in design research. There is a difference between research methodology and research design. The design of the research explicates the tools used to answer research questions and procedures, whereas methodology clarifies the process of the research (Yin, 2009).

4.5. Qualitative Approach

Qualitative researchers seek, in an orderly way, to explore and understand the studied phenomenon in a natural context, without depending on numerical or statistical data. Qualitative research emphasizes the importance of the participants' interpretations of the social world because they contribute to understanding this world. It is inductive in nature, as theory is generated through research (Robinson & Kellet, 2004). Denzin and Lincoln (2000) offered the following definition in their book *Handbook of Qualitative Research*:

"Qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that makes the world visible. These practices turn the world into a series of representations including fieldnotes, interviews, conversations, photographs, recordings and memos to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them." (p. 3)

The purpose of this study was to explore how mobile device applications support science learning and the issues related to implementing mobile learning in science classes. Qualitative inquiry and analysis fit this purpose. The research design included the use of qualitative methods to address the research questions. Those who use the qualitative approach aim to understand culture, including the social reality of group and individual behaviour, experiences, values, feelings, and thoughts (Mack, Woodsong, McQueen, Guest, & Namey, 2011). The qualitative approach is characterized by several features. It provides an opportunity for the participants to chart their own perspectives through words or deeds, to discover trends and people's attitudes regarding the issue under study, to focus on the description of the phenomenon and acquire a deeper understanding of it, to understand a research problem, to explore a change or conflict, and to present a comprehensive overview of cultural information (Mack et al., 2011; Tracy, 2013). Furthermore, the qualitative approach is suitable for childhood studies because it contains various methods that enable children to interpret experiences (Robinson & Kellet, 2004).

Selecting the qualitative approach requires researchers to build a close relationship with their studies' participants in order to discover their opinions, viewpoints, experiences, emotions, and sensations. In other words, the qualitative approach is an interactive process between the researchers and the participants, through which researchers learn about the nature of the problem and about the participants' normal lives (Bryman, 2008). The researchers' personalities clearly affect qualitative research, as their opinions affect most of their studies' ideas and information, but this does not mean that researchers should limit the thoughts and words of their studies' participants, as doing so would limit the participants' true thoughts and feelings. I chose to utilise this approach because qualitative data enabled me to address the research questions more effectively than quantitative methods. One of the features of qualitative methods is their flexibility, which allows researchers and participants plenty of room for clarification, the possibility of follow-up and development, and a tremendous amount of information that may not be available when using quantitative methods. One defect of qualitative methods is that researchers need to spend a lot of time conducting interviews and collecting data. This may cause many issues; for instance, researchers may have to limit the number of participants because of the intensive nature of the data collection, which will make it difficult for them to make generalisations because of the small sample.

4.6. Research with Children

Children need to have the opportunity to present their views of the world they live in, even though carrying out research with young people may involve some ethical and methodological issues (Parsons, 2010; Wickenden, 2010). Including young learners' voices rather than utilizing them as research objects in this study was significant, because it contributes to recognizing that young learners are able to explain points of view and tell their own stories (Greene and Hill, 2005). Children playing social actors' roles in the research process allowed them to explain their views as reliable witnesses and ensure the data gathered from them are valid (Clark & Moss, 2001). Moreover, if children feel secure and valued, then they are more likely to participate in honest and open ways (Smith 2011). New sociology of childhood can be supported by providing children an opportunity to be active research participants and enabling them to take part in decision-making processes, comment on policy, and participate effectively (Harcourt & Conroy, 2011).

"Social actors, who have purpose, and who influence as well as being influenced; as people who construct relationships and childhoods, and who can report on and discuss their experience" (Mayall, 1999, p. 12).

Allowing children to discuss their experiences can help teachers, caregivers, and researchers understand the issues that are affecting them. Involving children in research requires a researcher to adopt methods that are accessible to their age and facilitate their participation (Christensen & James, 2008). There is no approach, method, or tool convenient for all children, all contexts, all environments, all phenomena, and all circumstances (Griffin et al., 2014). The activities that children use for data generation purposes should be closely connected and similar to activities they use and are familiar with in school and home contexts. With regards to the setting of the research, it should be naturalistic (Khimji & Maunder, 2012). Research with children requires researchers to take into consideration creating spaces_for young participants and children to be heard and listened to (O'Kane, 2008). The most important strategies that researchers should take into account to be able to build good relationships with children (Harcourt and Conroy 2011) are to pay attention to what the children say, listen carefully, maintain eye contact, interact with them, share interests and activities, and finally avoid behaviour correction and leave this task for the teacher; thus, the researcher appears as a different adult. These strategies enable the researcher to enter the children's world (Gansen, 2017). The essential in developing relationships with children is the quality of interactions and conversations, while time is not the central issue to developing this relationship (Mackey & Vaeliki 2011, p. 85). Einarsdottir, (2007) proposes that Children change their perspectives with the passage of time due to experiences and situations they go through. In order to understand children, researchers should study the cultural and social contexts of the child because the context and environment impacts the child's personality and views.

4.7. Selection of participants

The qualitative approach involves understanding and exploring a phenomenon in depth, concentrating in depth on single cases and small samples that are purposefully selected. Thus, a first-grade science classroom was the single case selected for the study. Homogeneity was utilized to select this subgroup as sampling procedure (Creswell, 2008). Typically, a small number of cases or participants participate in qualitative research because such research aims to make sense and comprehend complex phenomena in depth (Patton & Cochran, 2002). Where qualitative research required collecting and analysing a large volume of data (Creswell, 2008). In the current study, all participants were from first grade and attended school on a regular basis. They ranged in age from 6 to 7 years old. They were examined in a science classroom in depth to grasp and obtain information about the young learners' experience of using apps and tablets to learn science in a classroom context. The first-grade children were all girls due to the segregation policy in the Saudi educational system. They attended three science classes per a week. One of the classes was reserved to perform and complete the activity book tasks. Five students were randomly chosen to be observed and interviewed, and they also participated in focus groups. The whole class participated in the focus groups by the end of the study.

4.7.1. Pen portrait of five observed children

The participants were as follows:

Huda. Aged 6 years. She was at first grade in primary school. Lives in Riyadh. Her religion is Islam. She enjoyed colouring and drawing. Her favourite colour is pink and favourite class is art. She had an iPad at home.

Reema. Aged 6 years. She was at first grade in primary school. She lives in Riyadh. Her religion is Islam. She likes watching the Spacetoon channel and hopes to visit Disneyland. She had a tablet at home.

Farah. Aged 6 years. she was at first grade in primary school. She lives in Riyadh. Her religion is Islam. she wants to be veterinarian and enjoys taking care of her cat. She had an iPad at home.

Randa. Aged 6 years. She was at first grade in primary school. She lives in Riyadh. Her religion is Islam. Her favourite colours are pink and yellow. She loves watching Ryan and his family on YouTube. She had access to her sister's tablet.

Noor. Aged – 6 years. She was at first grade in primary school. She lives in Riyadh. Her religion is Islam. She likes science and math and does not like language class. She had access to her mum's iPhone.

4.8. Study setting

The setting of the study was a private school located in Riyadh, the capital city of Saudi Arabia. Riyadh is the largest Saudi city and is located in the centre of the kingdom. The location of the school is in a neighborhood located in east Riyadh. Most of the people in this community are middle class (Riyadh Municipality, 2015). Their cultural background is Islamic Arabic. The community is somewhat conservative and traditional in outlook. Saudi society's culture was formed according to the framework of the Arabic tradition and Islamic teachings. Islam is the main religion for all Saudis, due to the fact that the culture is based on the Quran and Sunnah (the practices and customs of the prophet Muhammad). Islamic traditions are the foundation for Saudi family life. There are many factors that impact the lifestyle of Saudi society, such as religious and political factors, and there is a strong adherence to customs and traditions (Long, 2005). I selected this school for two reasons. It is a convenient location for me because the school is next to my house and accessible by foot, so I did not need a car or bus, which facilitated frequent visits to the school and communication with the teacher for data collection purposes. The second reason was this school is private, and so there were fewer students than in public schools. The number of students did not exceed 20 in each class, which allowed me to conduct the study with the ideal number of students. Thus, the phases of the study went smoothly and allowed me to achieve accurate results.

4.9. Designing the study

As a researcher, planning and careful preparation are important and a requirement to undertaking research in a natural setting, which can be a challenging task. Effectively designing and preparing the research encompassed many procedures that are critical to reinforcing the quality of the study's outcomes. What I did before conducting the current study was as follows: I read more than 300 articles and reviewed the literature that concerns mobile learning and elucidated the basis of this new trend in learning and how to adopt it in classrooms. I focused on young learners using tablets for educational purposes. I gathered background information due to this extensive view, which enabled me to obtain knowledge about the best way to explore young learners' usage of tablets. Moreover, reading previous studies assisted me in obtaining information about the process of designing and preparing the application of mobile learning, particularly in primary schools. These processes embrace examining the objectives of the course, selecting and purchasing tablets, choosing educational apps, designing instructional activities, providing technical support, and creating practical methods of utilizing apps (Hutchison et al., 2012). Prior to designing the study, I took into consideration the theoretical approach underpinning the study, which is social constructivism. Adopting this approach guided the design of the study and the planned activities. Thereby, designing activities that allowed young learners to construct their scientific knowledge by utilizing tablets and apps was the first goal.

4.10. Planning the Study

4.10.1. Purchasing the tablets

I purchased 16 Huawei Media Pads with Wi-Fi and without SIM cards. I also bought small pink pouch bags to put the tablets in for protection purposes where pink favourite colour of most young girls. Each child had her own bag that included a tablet with name stickers on the back and a leaflet. The leaflet explained instructions and rules of tablets usage in the classroom and was illustrated to be easily understood and attractive.

Figure 4.1: Tablets that were purchased to use in the study by children.

4.10.2. Downloading and selecting educational apps

The next step after purchasing the tablets was operating and charging them. After that, I created an account in Google Play and linked all tablets with this account to facilitate downloading apps. I downloaded for each science lesson five or six types of apps. I placed them on the home screen with large icons to avoid confusion and enable children to reach the apps directly after unlocking the screen. A first-grade science syllabus generally involves these topics: plants, animals, the Earth resources. I started browsing apps that aimed to develop knowledge regarding these topics and tested them (see Table 4.1).

Table 4.1: Mapping apps to science curriculum

Weeks	Units	Chapters	Lessons	Students' performance objectives	Level of thinking	Apps/ Resources	Assessments
Four weeks	**Unit One** Plants around us	**Chapter one** Plants are living creatures	• Living creatures • Plants and their parts • Planting mangos • Revision	• Identify growth and development of living things • Compare observable features of living things such as movement, respiration, and support. • compare, classify, and sequence organisms, according to various characteristics.	Knowledge Comprehension Application	• Tools puzzle app • Magical seed app • Animal puzzle app • Kids sorting game app • Sorting games app. • My mango farm app • First grade science textbook	Teacher's assessments Observation Workbook reviews
		Chapter Two Plants grow and change	• Growing plants • Plants growing in many places • Different seeds • Revision	• Predict results of an investigation based on plants life cycles • Recognize plants' needs; water, air, soil, and sun • Identify development stages of plants	Evaluation knowledge	• Panda farm app. • Tree colouring book app. • Magical seed app • Line game for kids' app • Sort it out app • Fruit puzzle app • Fruit Memory game app	Teacher's assessments Observation Workbook reviews

						• Fruit colouring book app • First grade science textbook	
Four weeks	**Unit Two** Animals and their environments	**Chapter One** Animals around us	• Animals' types • Animals' needs • Animals' food • Revision	• Identify observable similarities and differences between/among different groups of animals such as; number of legs, body coverings, and size • Identify similarities and differences between animals and their parents.	Comprehension Knowledge	• Insects life cycle app • Kids Zoo Game app • Insects cards app • Birds games app • Animal world app • Connect the dots app • Find the differences app • Kingdom of birds app • Panda and insects app • Reptiles coloring book app • Animals sounds 3D app • Animal zoo game app • Panda adventure in the jungle app • Feed me app • Birds coloring book app • Spot it mania find differences app • Insects jigsaw puzzles app • Reptiles and frogs app • First grade science textbook	Teacher's assessments Observation Workbook reviews

		Chapter Two Animal living places	• Land habitats • Water habitats • Revision	• Compare habitats desert, forest, prairie, water in which animals live. • Describe natural homes and habitats of animals	Comprehension	• Wildlife & Farm Animals – Game app • Learn animals app • Friends of the forest app • Kids Sea Animals Jigsaw Puzzle app • Ocean adventure games app • Dolphin and fish colouring book app • Ocean animal puzzles Sea app • Fish games app • Ocean animals memory game app • Sea animals' games app • Animals match-up app • Animals memory games app • Animals connect the dots app • First grade science textbook	Teacher's assessments Observation Workbook reviews
Two weeks	**Unit Three** Our earth	**Chapter one** Earth resources	• Earth resources • Benefit from Earth resources • Maintain Earth resources • Recycling • Revision	• Recognizing basic Earth materials; rocks, soil, and water • . Compare the physical properties such as; colour and texture of basic Earth materials	Comprehension Knowledge Synthesis	• Rainy cloud app • Magical seed app • Pottery factory app • Milk factory app • Panda farm app	Teacher's assessments Observation Workbook reviews

				• Identify human common uses of natural resources in clean, cook, and eat • Identify common uses of basic earth materials in construction and decoration • Identify air, water, soil, trees as being natural resources: • Identify ways to conserve natural resources such as recycle and reuse		• Bake and decorate cupcakes app • Baking cake game app • Healthy little panda app • Builder game app • First grade science textbook	

There are thousands of apps in Google Play and selection was a challenging task. As a result of that, I took into account many standards before downloading any apps to be used by the children in science class.

● First, I read the users', educators', and parents' reviews and their points of view about the apps besides their rating in the store, which assisted me in obtaining a full idea of apps' disadvantages and advantages.

● Second, while searching for apps I focused on some criteria, which were as follows: the apps were easy to use and useful, supported creativity, promoted collaborative learning, and enriched communication and concentration. They also included interactive and visual elements to help learners to enjoy the interactive learning experience.

● Third, the structure was crafted to fulfil young learners' desires and needs; for example, the apps came with rewarding, immediate, and clear feedback in two forms: visual and oral (Herodotou, 2018).

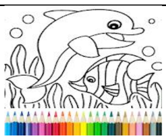
● Lastly, the landing page included large buttons and bright colours, which highly engaged children, and interface distractors were minimized (Mckenzie et al., 2018).

Figure 4.2: screenshot of landing page in animal lesson.

The apps' interfaces were functional, systematic, and intuitive (Marty et al., 2013). Furthermore, the absence of advertisements carried the most weight in the pedagogical app selection process (Santos et al., 2014). In addition, the apps featured minimal written content, as too many written words on a screen can easily overwhelm children (Giannakos et al., 2014). After I downloaded the apps, I tested their quality. I also tested the downloaded apps in all 16 tablets to make sure they all worked and did not freeze. I downloaded a copy of the students' science book on my computer from the Ministry of Education website. Reading the contents and lessons, I found each lesson in the book had objectives that needed to be accomplished. According to these objectives, I selected apps to fulfil them by performing various types of activities and providing interactive learning experiences to facilitate children's learning of these lessons. I gave the science teacher suggested apps to download on her own devices and test them. She gave me suggestions and advice from her perspective as a science teacher, and I took them into consideration (for a list of used apps see Table 4.2).

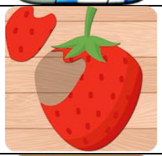
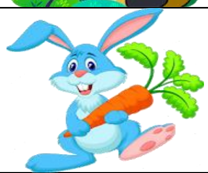
Table 4.2: List of used apps in this study

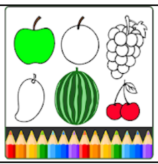
List of used apps in this study			
Apps' icons	Name of app	Developer	Scientific learning apps aimed to develop
	Insects life cycle	IM studio	• Recognising life cycles of some insects. • Discovering how the insects change as they develop.

	Dolphin and fish colouring book	Coloring games	• Recognising sea animals and creatures. • Comparing between them.
	Tools puzzle	abuzz	• Identifying living and non-living things. • Clarifying properties of non-living things. • Comparing between living and non-living things.
	Rainy cloud app	Baby bus games	• Recognising some environmental problems. • Discovering how rain form and fall. • Identifying the stages of water cycles.
	SORT IT OUT	App quiz	• Recognising some fruits and comparing between them.
	Kids Zoo Game	Androbaby	• Recognising farm animals, wild animals and pets.
	Wildlife & Farm Animals - Game	Knbmedia	• Recognising natural habitats of some animals. • Identifying wildlife and farm animals.
	Line game for kids	Biemore co., ltd	• Recognising flowers parts.
	Insects cards	App star studio	• Clarifying many kinds of Insects. • Comparing between them.
	Birds games	Batoki	• Discovering bird species.
	Animal world	Baby bus games	• Comparing between three different ecosystems (desert, ocean, and jungle). • Reinforcing the sense of environmental awareness. • Discovering animals characteristics. • Playing some roles such as veterinarians.
	Connect the dots	Kedronic UAB	• Exploring life underwater and observing its inhabitant. • Comparing between them.

	Learn animals	Gokids!	• Recognising different habitats animals live in and comparing between them. • Clarifying animals bodies - a head, a body, paws, a tail. • Recognising animals’ sounds. • Identifying little animals and adult animals.
	Ocean animal puzzles	Sedo games	• Recognising ocean animals and comparing between them.
	Milk factory	Crazyplex LCC	• Recognising the process of making milk from Farm to Factory and factory to shops. • Playing some roles such as; farmer and factory worker. • Identifying dairy products.
	Fish games	BKG studio	• Discovering sea creations.
	Ocean animals memory game	Memory game	• Recognising ocean animals and comparing between them.
	Pottery factory	Avenue gaming studios	• Recognising the different steps of making pottery. • Playing some roles such as; ceramic builder, designer, and sculpture. • Discovering the importance of soil which is an earth resource in making pottery and vases.
	Sea animals’ games	BATOKI - Best Apps for Toddlers and Kids	• Exploring sea life. • Discovering fish species and some sea creatures.
	Find the differences	Arclite Systems	• Identifying the differences between *animal species*.
	Sorting games	Fabulous fun	• Identifying living and non-living things.

	Kingdom of birds	Baby bus games	• Discovering six types of bird habitats. • Discovering six kinds of birds.
	Panda and insects	Baby bus games	• Recognising the life cycle of ant and bee. • Clarifying how bees make honey. • Clarifying how ants get food.
	Tree coloring book	Just creative club	• Recognising the differences between many types of trees. • Recognising the differences between tree leaves.
	Friends of the forest	Baby bus games	• Discovering forest animals' habitats. • Exploring animal traits and behaviors.
	Reptiles coloring book	Teacher paradise com.	• Recognising reptiles animals and comparing between them.
	Animals sounds 3D	Family kids studio	• Discovering carnivorous animals, mammals, pets, herbivorous. • Comparing between them. • Recognising their sounds.
	Animals memory games	abuzz	• Recognising the name of numerous pets, farm animals, jungle animals, insects and sea animals.
	Animals connect the dots	Escape publishing	• Comparing between wild animals, farm animals. • Identifying their sounds.
	Animal zoo game	Baby bus games	• Recognising the basic needs of animals to survive.
	Magical seed	Baby bus games	• Recognising the essential needs of plants to grow. • Identifying the pumpkin, grapes, sunflower, beans life cycles. • Comparing between the seeds of pumpkin, grape, sunflower, beans.

	Animal puzzle	abuzz	• Recognising animals and comparing between them.
	Kids Sea Animals Jigsaw Puzzle	Tiltan games	• Exploring life underwater and observing its inhabitant. • Comparing between them.
	Kids food puzzle	Big star games	• Recognising some fruit and vegetables. • Comparing between them. • Identifying inside fruit and seeds.
	Fruit puzzle	Skycap	• Recognising apple, mango, grapes, strawberry, pomegranate, apricot, bananas, peach, orange, papaya, watermelon, coconut.
	Kids sorting game	Abuzz	• Identifying living and non-living things.
	Panda farm	Baby bus games	• Recognising the process of Plant wheat. • Recognising the process of making food from the fruit and vegetables of the farm.
	Panda adventure in the jungle	Baby bus games	• Recognising the basic needs of jungle animals to survive.
	Feed me	Blue sun games	• Recognising the favourite food of some animals.
	Birds coloring book	AZ app creator	• Discovering bird species. • Comparing between them.
	Ocean adventure games	GFK studio	• Discovering whale, submarine, shark, lobster, crab, octopus, squid, son, electric eel, turtle, and goldfish.
	Bake and decorate cupcakes	Astibine	• Recognising the change in the mixture because of oven heat. • Identifying different kinds of food such as flour, sugar, chocolate, eggs, baking soda, and oil. • Playing a chief role.

	Animals match-up	Baby first	• Identifying animals body parts.
	Spot it mania find differences	Fabulous fun	• Identifying differences between animals.
	Supermarket game	Tap happy	• Identifying different kinds of food such as dessert, dairy, meat, and grains.
	Insects jigsaw puzzles	Apps for family	• Recognising ants, butterflies, bees, worms, and various other bugs. • Comparing between them.
	Fruit Memory game	Abuzz	• Recognising the differences between food objects.
	Baking cake game	Burbuja Games	• Recognising the change in the mixture because of oven heat. • Identifying different kinds of food such as flour, sugar, chocolate, eggs, baking soda, and oil. • Playing a chief role.
	Fruit colouring book	Tic tic games	• Recognising some fruits. • Comparing between them.

4.11. Undertaking the Study

The study took almost 11 weeks. An introductory week for first-grade children as first year students in primary school was the first week. I was around the children in this week and spent time with them by sharing some activities, which helped me develop a good rapport with them. Developing and maintaining relationships with young participants is quite important because this kind of rapport plays a crucial role in obtaining the desired information (Hatch, 2002, p. 51). Besides being around the children in the first week and playing games, I talked with them about the study, which took place in science class only. I clarified the objectives and procedure. Furthermore, I sent the consent forms to their parents and obtained them by the end of the week. In the following weeks, the study was started by implementing app-based science lessons with young learners. According to their timetable, they were supposed to take three science classes per week; one of them was to perform activity tasks so, the study was carried out during two lessons per week. During each lesson, I employed participant observation to collect data in addition to focus groups, which were held by the end of the study with the whole class. The semi-structured interviews with five students and the science teacher were held by the end of the study as well.

4.12. Data collection methods

The research strategy, objectives, and questions guided the choice of data collection methods. In addition to these aspects, the number of participants, funds, and availability of time also influenced the choice. Moreover, the kind of participants and desired information affected the selection of methods as well (Robson, 2011). The appropriate selection of methods is required to match the research questions, research objectives, and characteristics and needs of the target group under study and should relate to the determined time to conduct the study (Fargas-malet, Mcsherry, Larkin, & Robinson, 2010). The current study adopted a qualitative approach, which allowed utilizing multiple methods to gather data. Qualitative research utilizing multiple methods to collect data allows participants to participate actively (Creswell, 2003, p. 181), which affords a researcher deep understanding of participants and gives a voice to them. Furthermore, these methods extend and elaborate on the participants' perceptions, which facilitated and assisted the researcher attaining data saturation. Crystallising the data collection methods and answering the research questions were supported by utilizing a combination of data-gathering methods (Richardson & St. Pierre, 2005). To collect data, I used a blend of three methods: interviews, focus groups, and participant observation. The following sections provide discussion of them.

4.12.1. Participant observation

According to Tracy (2003), observation "*is a method through which researchers generate understanding and knowledge by watching, interacting, asking questions, collecting documents, making audio or video recordings, and reflecting after the fact*" (p. 65).

Observation enjoys an inveterate history in the social sciences and is of great importance in educational research. It involves viewing and closely monitoring the participants' behaviour regarding a particular phenomenon, in specific circumstances, or with regard to certain environmental factors; the goal is to obtain accurate information for diagnosing behaviour. The main objective of observation is to monitor social behaviour as it happens normally (Mack et al., 2011), so that it can be understood, analysed, and interpreted to provide a clear image of social life. Participant observation is a very useful method that enables researchers to describe what happened, the place and time, how a phenomenon occurred, and why it happened, with a focus on human interaction and meaning in daily life. This kind of observation grants special attention to human meaning from the participants' perspective (Jorgensen, 1989). It is convenient when the researcher has simple information about a phenomenon and wants to gain deep information to understand it perfectly (Jorgensen, 1989). Moreover, it is used to generate scientific facts about human life based on the reality in which the participants live, as the researcher is able, through participant observation, to observe meanings and participants' interaction (Jorgensen, 1989). In fact, collecting data needs to be in the natural setting of participants owing to the fact that meaning is heavily implicated by context. Observation enables a researcher to obtain data in a real-life setting (Cohen et al., 2010).

The researcher shares the daily life of the participants and watches what is happening and what is being said, which requires spending a long time with participants in fieldwork and playing different roles to understand the participants. The most prominent feature of this type of observation is that it allows the researcher to study participants in their environments, which assists the researcher in understanding phenomena (Griffin et al., 2014). The participant observer's roles at the research site requires participation in the activities; thereby, a researcher needs to incorporate participation and observation as her or his task and participate, observe, record, and analyse the topic of the research according to participants' perceptions and experiences. Being an insider observer means taking an emic stance (Creswell, 2008, p. 222). Through engagement in group activities and events, the participant observer's role provides proper means to assist in answering the questions of the research and serves the study's objectives (Robson, 2011).

The aim of the current study was to explore the role of apps and tablets affordances in support of science learning among Saudi first-grade children. The study also investigates their engagement with these apps and the influence of their engagement on their science learning. Employing participant observation in this research allowed me to observe young learners within their group deeply while they used tablets and apps in a science class. Moreover, the participation of the observer was very important to assisting the science teacher with implement mobile learning. Before each science lesson, I discussed with her how to introduce the lesson, brainstorming how to use tablets and testing app content to provide answers to technical questions and any kind of questions related to the apps' contents or science and seeing if there was any activity or task children needed to know how to perform properly. As explained earlier, meeting the science teacher was beneficial, but she still needed help and support to conduct activities in the correct manner.

Young participants overtly witnessed my role's requirements as participant observer, such as participation, observation, note taking, and presence in the classroom, which is in contrast with the role of complete observer, where the participants do not have any knowledge about her or his position (Robson, 2011). Assisting young participants in performing app activities and working closely with the science teacher were possible because of my known status. Being around children and observing them closely while utilizing tablets and also engaging with app contents (i.e., guiding and instructing them) enabled me to recognize and comprehend the young learners' experience in the real world, thus obtaining information about how they used tablets and apps to learn science and how they construct their knowledge. This study was incorporated with science lessons. In the first 10 minutes, the science teacher introduced the lesson and discussed with the children some aspects related to the lesson. The remaining 35 minutes, the children used the downloaded apps on the tablets within their groups. The class was divided into three or four groups. Children were free to discuss tablet affordances, app content, viewpoints, and technical advice and share information, but they were also required to respect the classroom rules: be kind, be a helper, no loud voices, no high volume sounds to avoid noise that might influence other children focus negatively, listen to the teacher, no running, and use tablets gently.

I conducted 20 participant observations during two lessons per week; each lesson lasted 45 minutes. I observed five children in particular. They were free to select which group they wanted to join and not obligated to select a specific group in each lesson. I wrote down some field notes about the young learners' experiences and actions while they interacted with the apps and tablets. I developed an observational protocol to help me answer the questions of the research and also guide and assist data collection. The observational protocol was filled out for each science lesson. It included background information (the name of the observed child, day, date, and total number of groups and students in the classroom). In addition, information about the lesson (topic, objectives, and list of used apps) was recorded. For each lesson, I took descriptive field notes consisting of children's recorded interactions with tablets and apps in detail and whether the type of interactions were verbal or nonverbal and the interactions with the teacher, peers, and group members regarding apps or science learning. In addition to what was mentioned previously, I utilized the descriptive field notes to record any concerns, problems, and emerging ideas. After finishing each lesson, I rewrote the field notes in full detail in a readable manner and elaborated on them.

4.12.1.1. Strength and weakness of participant observation

The most prominent characteristic of observation is that it helps researchers to understand complex situations because they can participate directly in normal contexts (Patton & Cochran, 2002). Observation can lead researchers to focus on important aspects of their studies (Oguz-Unver & Yurumezoglu, 2009). One of the most important advantages of observation is that it is a valid tool for evaluating the effectiveness of the educational process (in terms of achieving its goals and objectives) and of educational means and methods. Data collected through observation are, arguably, deeper than those collected using other tools, as observation provides comprehensive, detailed information, including additional information that researchers may not expect to uncover. I selected observation because it draws on witnessing events at first hand and the direct evidence of the eye (Denscombe, 2010, p. 196). Preferably, observations should be recorded immediately in order to rely as little as possible on the researcher's memory. Information can be forgotten, causing the results of the study to become incorrect or inaccurate. Observation may, in circumstances, be flawed, as researchers may encounter people who are deliberately difficult, such as those who exhibit fake reactions or impressions when under observation. Although observation is a flexible method that allows the researcher to gain deep information and can be conducted in different environments (Given, 2008), it is not convenient when used as a tool to answer questions about a large number of participants. Employing participant observation as a method of gathering data allowed active participation by researcher at the research site, which facilitated engagement with young participants as they saw the researcher work closely with the teacher and act akin to her (Robson, 2011). By utilizing participant observation, the researcher was able to observe and record participants' verbal and nonverbal interactions in a social context. In addition, the researcher's participation with the children in their environment allows him or her to attain information via children's behaviour and body language such as feelings, tendencies, and ideas, which may be difficult for children to express verbally (Given, 2008).

The known status of the researcher among participants may impact their behaviour, which obstructs the process of natural phenomena observation (Robson, 2011). Changes in actions and behaviours of participants might threaten the validity and reliability of recorded field notes. Being around the children in the introductory week and sharing in their games and activities allowed me to introduce myself. Moreover, as they had just started their first year at primary school, everything was new, whether science as a subject or the teacher. Thus, the teacher's assistant role appeared normal, which can minimise any threat. A participant observer's subjective standpoint when taking field notes might contribute to bias. However, being in the research site with young participants while they were using tablets and apps and recording observations enabled me during observation to distribute my attention evenly and widely, which reduced the bias drawback (Robson, 2011). Furthermore, to avoid bias, researchers should eliminate any expectations and prejudgments that may deform their interpretations. In other words, when starting observation the researcher should be open-minded (Robson, 2011). In addition, researchers should not ignore unfriendly participants and concentrate on welcoming and friendly ones

Concerning observational data, maintaining inclusiveness and accuracy can be attained by a researcher through writing down field notes narratively at the earliest possible time. I took these useful instructions into consideration while observing young learners' utilization of tablets and apps in a science classroom. I obtained knowledge about my feelings, perceptions, and position in the study by engagement with self-reflexive practices. In fact, the self-awareness technique facilitated recording the young participants' experiences thoroughly and clearly as they happened, and personal reflections were recorded separately, which enhanced the observational data's objectivity. Moreover, The current study employed focus groups and interviews as methods to gather data to support participant observation and obtain a crystallised and clear picture of the mobile learning experience of first-grade children in a science class and their perceptions of using tablets and apps as learning tools.

4.12.2. Interviewing

Interviewing is commonly used in social research as a method of gathering data (Mason, 2002). An interview is defined as a conversation between two persons: the researcher and interviewee. The objective of this method of information-related research is to obtain answers to research questions, knowledge about phenomena under investigation, and individuals' experiences. Unlike daily conversation, the dialogue is guided by objectives and questions (Brinkmann, 2012). Interviews are considered the main method of data collection in qualitative research. Through interviews, researchers can recognise the participants' thoughts, feelings, and perspectives, thus enabling the researchers to gain a deeper understanding of the participants (Hinds, 2000). Interviewing is a flexible method conducted in various forms; by telephone or e-mail, in a group, or face-to-face. Moreover, the categorization of interviews includes structured, unstructured, and semi-structured interviews (Bedoin & Scelles, 2015). Structured interviews are characterized by a high degree of inflexibility and objectivity. They are closer to surveys (Mason, 2002) consisting of closed and short questions. Unstructured interviews allow researchers to ask open and unplanned questions related to their studies. Such questions contribute to obtaining rich data due to an open and free style. This type of interviews is characterized by a high degree of informality and flexibility but requires complex analysis and is time consuming. The last type of interview is semi-structured interviews. The interviewer uses open-ended questions to engage the interviewee. These questions are determined previously and are related to the topic. The flexibility of this type of interview allows researchers to adjust the sequence of interview questions when needed during the interview (Robson, 2011). I employed in this study two types of interviews for data-gathering purposes, which were focus groups interviews and semi-structured interviews (for interview questions, see Appendix 5).

4.12.2.1. Semi-structured interviews

Semi-structured interviews are frequently used in qualitative research. They involve verbal exchanges in respect to particular issues and topics in an informal style (Borg, 2006). Asking the interviewees open-ended questions enabled them to express their thoughts, ideas, and views freely and flexibly (Mutch, 2005; Bedoin & Scelles, 2015). In particular, semi-structured interviews in this study took face-to-face form because of its suitability to fulfilling the objectives of the research and obtaining answers to the research questions. Furthermore, social constructivism guided the current study's epistemological perspective, which required obtaining data by employing dialectical discussions between the researcher and participants. Engaging in conversation with interviewees assists in exchanging experiences, co-constructing knowledge, and facilitating understanding via interactive dialogue between researcher and interviewee, where the interviewee provides interpretations of the researcher's questions (Kvale & Brinkmann, 2009). These interpretations contribute to understanding their experiences and perceptions about the application of mobile learning in a science class and usage of tablets and apps to support science learning, as well as how interviewees constructed their experiences. Utilizing semi-structured interviews in a face-to-face style enables researchers to interact with children as co-participants who are involved in the research process and have a significant role (Collins et al., 2004) and allows investigations of the topic of the research in detail. The style also enables children voices to be heard, which social-constructivism calls for. Young learners should be provided with opportunities to be social knowledge creators. During the interview, it is necessary to provide children with freedom in order to enable them to interpret their social world and express their perceptual and experiential realities (Silverman, 2000).

4.12.2.1.1. Strengths and weaknesses of semi-structured interviews

Interviewing is a useful tool for gathering data, particularly when a researcher is unable to observe the behaviour of participants (Creswell, 2008). It is adaptable and flexible in nature where the researcher in face-to-face interviews can adjust questions to maintain the conversation flow. Moreover, the interviewer in semi-structured interviews has room for flexibility, which enables them to ask main questions using the same method but they might modify their sequence in order to obtain further information (Miller and Brewer, 2007 p. 167). Additionally, due to the flexibility, this type of interview allows the researcher to ask questions beside what he or she planned, where they are asked in the natural course of things and emerge from immediate context (Denscombe, 2010, p. 175). Furthermore, using this type of interview enables researchers to obtain data not only from verbal responses, which represent answers and interpretations, but also from nonverbal responses (e.g., body language, emotions, and facial expressions). Such responses might help researchers understand the meaning of some interpretations (Robson, 2011). Face-to-face interviews allow a researcher to establish rapport with participants, which encourages cooperation and comfort that contribute to effective participation by participants. Moreover, this form of interview facilitates obtaining productive answers, which clarifications and explanations of questions encourage. Semi-structured interviews allow a researcher implicit open-ended questions in order to discover the causes of closed ended answers and expand interviewees' answers, which facilitates gathering useful information (Creswell, 2008). Discussion in a face-to-face manner offers a researcher in-depth knowledge about personal perceptions and experiences of participants (Patton, 1990). An interview is not just a normal conversation to satisfy the desire of two parties to talk; rather, it is an exchange of information which incorporates experiences, feelings, and attitudes and which is based on honesty and sincerity. The interview experience may also help the participants to learn something about themselves, such as their attitudes towards the world around them, thus helping them to create new, more desirable behavioural habits and ways of thinking while also gaining more useful information.

An interviewer's behaviour and skills influence the value of an interview, where conducting an interview in a professional and adept manner leads to obtaining useful, efficient, rich data. Interviewers should prepare themselves by predicting and planning an interview's content. By taking that into consideration, the interviewer should ask direct and clear questions, listen more than speak, and avoid leading, long, and biased questions. The greatest advantage of interviews, which encouraged me to choose this method, is that they allow researchers to explore the participants' motives and examine their experiences. During interviews, participants may talk about their secrets and events from the past (Tracy, 2013). This type of information and explanation may not be obtainable through observation alone (Hinds, 2000). Conducting a seamless interview requires a number of skills and a clear understanding of the research goals; interviewers must display empathy, provide smooth transitions between questions, and be attentive listeners (Tracy, 2003).

Several disadvantages are associated with face-to-face interviews in semi-structured form as a tool to collect data, which include consuming a researcher's time where he or she is required to first transcribe then analyse the extracted data. Compared with structured interviews, it is a more difficult and complex method. In addition, when a researcher's assumptions and perceptions are uncontrolled, it impacts data analysis and contributes to bias. Such tendencies are countered by conducting the current study with a reflexive procedure, where data analysis was not guided by feelings and perceptions and as reflective of the participants in areas of potential bias. The most prominent defects associated with using interviews include the fact that they require a long time to implement and great effort to gather the information. Interviews are influenced by the interviewees' desire to talk and by their ability to express accurately what they wish to disclose (Tracy, 2003). Some participants also reject the idea of recording interviews with the other participants in the study (Bryman, 2012). The data extracted from interviews might be deceptive where the participants may provide fake responses to please the researcher. To reduce this risk, I did my best to develop relationships and rapport with the young participants during the preparation week before interviews began by engagement and active participation in games and daily activities. I employed in this study summative post-study interviews with the science teacher and five observed children. I began the interviews by welcoming young participants, explaining to them the interview's purposes and thanking them for participating. I prepared a list of open-ended questions organized in flexible order. Adjusting questions was possible according to the children's responses. Moreover, I prepared alternative questions and a default wording list to be used when needed. During interviews with the children, the tablets were present with downloaded apps throughout the study to help them remember and promote their articulation of their perceptions and experiences with the tablets and apps in the science class. There are two factors that affect the success of the interview: participants must feel comfortable about the methods the researcher uses to interact with them (Griffin, Lahman, & Opitz, 2014) and about the place in which the interview is conducted; all surrounding conditions must be suitable, including the time of the interview. As a result, when the participant feels comfortable, it will increase his or her ability to interact and give accurate responses to the questions asked (Bedoin & Scelles, 2015).

The length of interviews in this study did not exceed 30 minutes, which helped in preventing young participants' boredom and fatigue. Audio recording the interviews is crucial because written notes are inadequate. Recording helps researchers to reconsider the statements made by the participants during the interviews. To guarantee interview data accuracy, I utilized a voice recorder app to record audio during interviews. Alongside I wrote down notes to make sure that data was not lost if an unfortunate situation occurred, such as sudden shut down, freezing, or any technical problem with app. Recording the interviews was with participants permission, which I asked for at the beginning of the interview. Using a voice recorder app assisted in enclosing the truthfulness of interview data by enabling coincident matching between spoken words and written words in transcripts (Hesse-Biber & Leavy, 2006). I interviewed participants in Arabic because it is their native language, which helped them in expressing and articulating their view points, interpretations, and thoughts. I immediately transcribed the recording of audio after completing the interviews to ensure data accuracy.

4.12.2.1.2. Conducting interviews with children

Interviews are commonly used in children's research. Conducting an interview with children differs from doing so with adults. The reason is due to the dissimilarity of experiences and also the different ways that children express thoughts, opinions, and feelings. Furthermore, children have vast imaginations, which may affect information accuracy. Thus, the researcher should be able to separate between information based on imagination and information based on real experiences (Einarsdotlir, 2007). Children have important perspectives, which may assist adults in understanding children's worlds (Robinson & Kellet, 2004). Interviews are one of the methods researchers can use with children to attain their points of view and opinions. Conducting interviews with children requires researchers follow techniques such as making eye contact with them and using phrases that make the children feel that the researcher is interested in hearing more them (Fargas-malet, Mcsherry, Larkin, & Robinson, 2010). When the researcher prepares the list of interview questions, he or she should take into consideration some important points: start with general questions, avoid closed questions (which can be answered with yes or no), and use open questions to allow children to express themselves and their ideas. In addition, using open questions enables researchers to ensure that children's answers are accurate and not just a guess (Fargas-malet et al., 2010). The researcher definitely wants participants to describe their experiences and wants to obtain descriptive answers through *what* and *how* questions (Brinkmann, 2012). When I interviewed children I avoided asking too many questions, abbreviations, selected noncomplex, simple words (see Appendix 5) (Fargas-malet et al., 2010). In fact, interviewing children requires researchers to be sensitive and adaptable to children's needs (Aubrey, 2000).

4.12.3. Focus group interviews

A focus group interview is a discussion between a number of informants that takes place in a relaxed atmosphere and provides researchers opportunity to gather shared experiences and perspectives (Krueger & Casey, 2009). This type of interview was chosen to be employed in this study to complement individual interviews, because it is an effective method by which to reinforce involvement from participants who do not know what to say and participants unwilling to be interviewed individually (Kitzinger, 1995, p. 299). Focus groups' hallmark as a method to collect data lies in the utilization of the interaction between group members to produce insights and data. In addition, a researcher can obtain thorough and pertinent data where each participant can impact the discussion by her or his answers. Moreover, focus groups are a practical way to examine the reasons why participants hold the opinions they do as they concentrate on participants' reasoning. Such factors cannot be explored by conducting observation alone (Denscombe, 2010). Focus groups can act as a means to elaborate, clarify, and confirm observation. Furthermore, employing this method in qualitative research is extremely useful because it enables a researcher to obtain rich data by deep exploration of experiences, perceptions, and views of a group of people simultaneously (Patton, 2000). Within focus groups, association between discussing certain topics and dynamic interactions lead to making this method a valuable way to gather data. In addition, this tool not only provides researchers with data on what participants think but also clarifies the reasons for provided answers that can be encouraged by sharing and comparing ideas (Morgan, 2006).

A researcher's role in this type of interview encourages interaction of participants via prompting them to take and exchange opinions and ideas, as well as suggesting discussion topics. It also triggers the conversation between group members with subjects and remarks (Sandelowski, 2010). One should avoid taking turns in discussion by encouraging dynamic observation, stimulating responses to comments of other participants in order to educe other perspectives and views, creating an environment that is nonevaluative and nonthreatening to allow participants to express themselves freely and openly (Stuart et al. 2007). The debating that takes place between participants during focus group meetings is very beneficial in offering data related to what a particular group of participants considers, or in which way they perform, or how they undergo (Henwood, 2014). Researchers need to prepare questions that require interviewees' reflection (see Appendix 5). They should act as a discussion guide between group members and as facilitators of interactive discussion. Being within a group reveals to participants' different and similar perceptions and experiences related to the topic of discussion and throws light on beliefs and important issues for the researcher (Krueger & Casey, 2009). In other words, interaction between participants provides a researcher with an opportunity to recognize how they agree and disagree relative to their views, opinions, and personal experiences (Flavin, 2017).

There are some inherent disadvantages associated with conducting focus groups, such as some participants declining to give answers and talk; in other situations, some participants might unduly influence others (Dulemba, Glazer, & Gregg, 2016). If the group involves participants with strong and active personalities, it might be hard to retain the group on the topic. Moreover, bullying or a disruptive personality leads to developing a negative dynamic if the researcher is not vigilant (Ritchie, Lewis, Nicholls, & Ormston, 2013). In fact, a disruptive member in the group leads to derailing the purpose and the aim of the discussion.

In this study, I conducted three focus groups to explore participants' perceptions, views, and experiences of utilising tablets and apps in science class for learning purposes. Each group consisted of five children and each focus group discussion lasted for 45 minutes. The children were homogenous in a number of points; they shared common characteristics (gender, culture, language, context, and age) and studied in the same classroom. This homogeneity between group members increased interaction as they were able to express sensitivity and issues of conflict and also feel more secure (Robson, 2011). Individual face-to-face interviews and focus group interviews were conducted in a private and quiet place. The discussions were audio recorded using a voice recorder app. Guiding discussion by the researcher required me to be sensitive to resulting cues from interactions and flexible to produce high quality data by facilitating effective discussions. Employing focus groups with children is very useful and allowed their active participation in issues connected and related them. One of the reasons for selecting focus groups to be conducted with children was to support a social constructivist belief, which is that children are active knowledge creators and social agents. Thereby, designing research and selecting tools to collect data should consider children's needs to have time and space to discuss and reflect issues with peers and adult. As a result of that, focus group interviews in the current study were employed to promote young participants to reflect on their mobile learning experience in a science classroom.

Research question	**How the methods used addressed the question**
RQ1. *What are children's responses to using educational science applications that support science learning in a Saudi Arabian Grade 1 class?*	- - Observations of children using such apps enabled me explored how they respond to them, through an analysis of gesture/body language/language, and so on. - - Individual and focus group interviews with children identified what they thought about using the apps.
RQ2. *How far do educational science applications support science learning in a Saudi Arabian Grade 1 class?*	- - Observations of five particular children enabled analysis of how far the apps support science learning. - - Individual interviews with children enabled exploration of how far children feel specific apps supported their learning, and why/why not. - - Focus group interviews identified how far children feel the apps in general supported their learning, and why/why not.

RQ3. *What are the issues and challenges related to implementing mobile learning in a science class in a primary school?*	- - General observations I made of the implementation of the use of tablets in the classroom enabled this question to be addressed. - - The interview with the teacher allowed an exploration of her perceptions of this issue.

Table 4.3: outline of research questions and methods.

4.13. Ethical consideration

"If social research is to remain of benefit to society and the groups and individuals within it, then social researchers must conduct their work responsibly and in light of the moral and legal order of the society in which they practice. They have a responsibility to maintain high scientific standards in the methods employed in the collection and analysis of data and the impartial assessment and dissemination of findings." (Mertens and Ginsberg, 2009, p.13)

Mertens and Ginsberg (2009) indicated that ethical issues need to be given prime importance. Certain ethical concerns are raised and associated with conducting research in real-world contexts with participants regarding the possibility of anxiety, harm, and distress that might occur to participants who take part in the study (Robson, 2011). Involving high-risk participants such as young learners and children in research strongly requires implication of ethical consideration owing to their vulnerable status. The participants in this research were children. They played a social actor role by active participation in their knowledge constructions but, at same time, they need care, so young learners are seen in this situation as competent yet vulnerable (Lahman, 2008), and their rights are protected by ensuring their privacy and anonymity (Denzin, 1989). Furthermore, Denzin believed that a qualitative researcher is a guest entering the lives of participants and exploring perceptions, feelings, and personal experiences. Thus, a researcher's code of ethics should be strict and their manners should be good. As researchers enter the private space of participants, they should take into account the highest ethical standards when designing research and maintain the wellbeing, safety, anonymity, and privacy of participants in their research study (Patton & Cochran, 2002). Moreover, researchers should respect the participants' dignity and not use them as means to achieve the research goals (Mack et al., 2011). I worked hard to create a pleasant atmosphere for the children participating in this study.

The current qualitative study was conducted in a primary school in Riyadh (institutional site) with children (first grade), which was associated with some ethical issues. They were completely addressed and considered. Before conducting the study, I obtained ethical approval form from University of Sheffield, particularly the ethical research committee (see Appendix 3). The ethics committee's recommended principles were complied with by developing information sheets in three versions for parents, first-grade children, and the science teacher and consisted of research proposal. Besides that, I also developed consent forms to be given to them (see Appendix 4). These forms were crucial because they clarified the procedure clearly and provided children and parents with important information about the meaning of taking part in the research, thus ensuring participants' and researcher's safety. The ethical concerns included decreasing anxiety and distress that may occur because of participation, respecting the choice not to participate, confidentiality, and anonymity. Information sheet versions offered important details about the study; the young participants', the teacher's, and the researcher's roles; the selected methods for gathering data, and how to deal with the assertion of freedom of participants' choice to take part in the study. In addition, I informed them about their rights to obtain a copy of the findings and access the study's results. Likewise, I gained access to the school by obtaining the local educational authority's permission in Riyadh.

One week before the start of the children's first semester of school, the head teacher and teachers returned to school after the summer holiday to prepare everything. In this week I met the head teacher of the school. She had already given me her verbal approval to conduct the study. Throughout the meeting, I gave her a consent form to sign and a copy of the information sheet, which was translated into Arabic to be understood. Moreover, I explained to her the process and the aim of the study and also discussed all of the study's details. After that, the introductory week started and I handed out information sheets and read consent forms to the children, described the project, clarified their rights as participants and their roles, and answered any questions raised to make sure that the children obtained complete information about the research. I asked the children to take these documents and their parents' version of the documents home before deciding on participation in the study after discussing this issue with their parents (see Appendix 4). Furthermore, I met children's mothers when they accompanied them during introductory week as they started first grade in primary school. I explained to them verbally the study's details and informed them their information sheets and consent forms were in their children's bags, so they could read them with their daughters carefully, discuss, and decide.

I frequently reminded the young participants about their rights to withdrawal and stop participating at any time. They only needed to tell me about withdrawal or tell the science teacher. Thus, I found different ways to complete lessons such as using the activity book. I put a lot of effort into maintaining the young participants' confidentiality, privacy, and anonymity prior, throughout, and following gathering and analysing data. A greater level of confidentiality took place while handling the young participants' and teacher's audio recordings and provided information. I used pseudonyms and anonymised data in order to protect their identities. In addition, I did not utilize any quotes from collected data that may uncover participants' identities to maintain the anonymity. Gathered information was stored on a password-protected laptop computer, which was a safe place that nobody had access to (excluding me and my supervisor). Moreover, I made great effort to maintain the children's protection, wellbeing, and safety. I worked as hard as I could to ensure that the children were comfortable by avoiding discomfort or embarrassment during focus groups and interviews. I also avoided distressing them by asking sensitive questions. Interviews were carried out in the resource room, which was private space. During focus groups and interviews, I was very aware of and sensitive to verbal or nonverbal reactions that indicated discomfort, which requires a researcher to offer alternatives, give a break, or stop the conversation. I ensured the young participants' online safety when utilizing apps and tablets. Every app was used in the science class. Exposure to content was tested by me and the science teacher. Furthermore, the children did not have access to the Internet because all of the apps used in this study work without need of an Internet connection. The downloaded apps to be used to support science learning were designed for use by children specifically and encourage collaboration in a secure and safe environment.

4.14. Research Trustworthiness

Qualitative research is associated with a number of concerns that need to be recognized and addressed for the purpose of research trustworthiness. Numerous qualitative researchers have utilized the term "trustworthiness" as a substitute for the positivist criteria of reliability and validity (Cousin, 2010). To evaluate and ensure the quality of this study and its trustworthiness, I utilized multiple measures: peer debriefing, data thick descriptions and an audit trail, personal and impersonal reflectivity, and triangulation, which is a research method's crystallisation (Lincoln & Guba, 1985). Additionally, I provided discussion of a lack of objectivity and issues of generalisability and describe the measures of quality criteria that I utilized to enhance the study's trustworthiness.

4.14.1. Issues of generalisability

The current study has a number of limitations which were clarified and discussed in the findings chapter. One of these limitations was that I cannot generalise the findings, but generalising the results of this research for the wider population was not the aim. For researchers, concentrating on this issue might distract them from fulfilling the research study's key objectives and answering the research questions in a rigorous manner (Stake, 2005). The study's context was distinct and specified a first grade science class at a private primary school in Saudi Arabia's capital city, Riyadh. All participants were middle class. Therefore, generalising the results to other schools in the same city was not possible. However, applying the findings to students and schools that resemble the current study's participants and school, respectively, might be possible. As consequence of that, in the beginning of this chapter, I explained the reasons for selecting both the participants and study site. Furthermore, I discussed the findings, how tablets and apps support children's science learning, and how the affordances of apps and tablets influence children's engagement. Describing the findings in a thick and rich manner provided deep understanding of the applications of mobile learning and the role of apps and tablets' affordances in supporting science learning and enhancing engagement. Comparing other researchers' findings with the current study's findings requires participants and schools with similar characteristics to make my study's results applicable. The purpose of this study was to explore the role of educational apps and tablets in support of science learning and their influence on children's engagement. The theoretical framework developed for this study regarding the use of young learners' apps and tablets in a science classroom for learning purposes might provide insights into other situations or cases. The current research concentrated on a new field in the research world and a new trend in education: mobile learning. Its results might contribute to theoretical generalisation with significant implications among policy makers, teachers, and other researchers. Thus, it provides an introduction to expanded research that can afford statically generalisable results.

4.14.2. Thick description and audit trail

I utilized an audit trail to ensure my findings' trustworthiness. An audit trail requires researchers to save full records of the procedures used and data extracted from their studies, including the raw data; data snapshots, observational field notes, transcripts of focus groups and interviews, audio recordings, memos, artefacts, pictures, videos, used materials, and snapshots (Robson, 2011). I kept the field notes, audio recordings, transcripts, data analysis, and interpretation details. Applying an audit trail enhances the study's trustworthiness by explicitly accounting for all analytic, methodological, and theoretical processes and decisions, which allows others to audit the researchers' actions, influences, and choices. Thereby, their findings can be confirmed (Koch, 2006). Researchers can establish trustworthiness by carrying out the research in an accurate, comprehensive, and honest manner that readers can clearly see (Robson, 2011). In relation to the current study, I strived to enhance my study's trustworthiness by providing my research process's full, detailed records. Offering transparent and thick descriptions of the study's track from starting through reporting the findings increases the researcher's accuracy and engages the audience in the reported experiences by offering them adequate and clear interpretations of the study (Stake, 2005). I explained clearly the research process's stages, including the design of the research, methods of gathering data, organization of the data steps, analysis of the data, and lastly, process for reporting the data. Moreover, I described the rationales for decisions I made throughout the study. Also, I kept the records of my reflective notes and descriptive field notes to protect data collection and improve analysis accuracy.

4.14.3. Crystallisation

To further enhance trustworthiness, I used crystallisation. This term refers to the combination and application of a variety of research methods (focus groups interviews, semi-structured interviews, and participant observation) utilized to gather and analyse data to examine and explore one topic (mobile learning). Validity can be deconstructed through this process. Crystallisation can partially increase and thoroughly deepen the understanding of a complex research topic by requiring researchers to gather data from diverse resources that provide the same information (Richardson, 1997). Crystallisation is unlike triangulation; in triangulation, the researcher needs to examine discourse from various viewpoints to reach a single truth, whereas the crystallisation process uses multiple methods of inquiry to produce many truths (Ellingson, 2009). That means crystallisation is more than triangulation. Using crystallisation in this study assisted me to provide a well-developed, thorough, and robust account of the studied phenomenon, produce thick descriptions, and achieve data saturation, thereby deepening and enriching the findings' comprehension.

4.14.4. Peer debriefing and support

Researchers suggest a helpful means of enhancing the trustworthiness of qualitative research is peer debriefing (Creswell & Miller, 2000; Robson, 2011). This process requires researchers to expose themselves to peers' impartial views about the researchers' studies. The purpose of the analytic session is to explore aspects of inquiry that may exist in an implicit manner only in the inquirer's mind (Lincoln & Guba, 1985). Employing this technique in qualitative research helps to ensure the validity of the data gathered, whereas peers can help researchers detect problems in their research, such as assumptions and bias, vague descriptions, and general errors in data (Merriam, 1998). Selecting and using this technique required me to engage with peers in discussions in a systematic and routine manner. Those peers were not in contract with me but were just involved to review and evaluate my data collection processes and methods. I shared my data collection procedures and methods, descriptive records, raw data, data analysis, inference decisions, and coding with my supervisor and peers who have background knowledge in conducting qualitative research. They assisted me in revealing any bias and recognizing any inconsistencies that I may have had as the researcher. They offered me useful information and valuable advice. I recorded their suggestions and comments, took them into consideration, and applied them where necessary to recheck areas they advised me to recheck as well as those areas with which they agreed. Furthermore, I compared several pieces of my thematic analysis with another qualified researcher's data analysis (Silverman 2001), which stimulated me to verbalise and articulate tacit information and implicit thoughts. The peer debriefing procedure assisted me in taking into account the singularity between participants' views and my own deductions as the researcher, in such a way that contributed to preventing any bias from taking place in the current study. After this section's discussion of the study's trustworthiness, the next section provides a discussion of the procedures I used for analysing data.

4.15. Data Analysis

In the beginning of this chapter, I discussed the methods I used to collect data. These methods enabled me to gather a wide variety of data, as I outlined in the following table 4.2:

Data sources	Description
1- Participant observation	I conducted 20 observations on five children, two per week for 45 minutes.

2- Face-to-face-semi-structured interviews	I conducted six individual interviews, five of them with the same five children I observed and one interview with a science teacher. Each interview lasted for 30 to 40 minutes.
3- Post-study focus groups	I conducted three focus groups, each group had five children. Each focus group discussion lasted for 45 minutes.

Table 4.4: Outline of data sources.

In this study, analysing data began at the same time as gathering data. Qualitative data analysis is an ongoing procedure, so starting early is best (McQueen & Knussen, 1999, p. 239). Qualitative researchers are concomitantly involved in collecting data, analysing data, and interpreting the findings of the research (Hesse-Biber & Leavy, 2006). Data analysis includes segmenting the data into smaller units to detect distinctive elements. Qualitative research produces a large amount of data in the form of words (Wellington, 2000) and, in this case, moving images. According to Miles and Huberman (1994), data analysis contains three phases: reducing the data, displaying the data, and performing the data collection in a workable format for the researcher to be able to answer his or her research questions:

"Valid analysis is immensely aided by data displays that are focused enough to permit viewing of a full data set in one location and are systematically arranged to answer the research question at hand". (Huberman & Miles, 1994, p. 432).

The analysing process in qualitative research requires researchers to immerse themselves in the data by working with it so that the data is organized, broken into manageable units, and synthesised. These data preparation stages enable researchers to place data into patterns and discover significant aspects that need to be considered and studied, so they can successively reach a decision about what to tell others (Bogdan & Biklen, 1982, p. 145). I analysed this study's data in an inductive manner by using NVivo 12 software, identifying issues that emerged in relation to the research questions. I applied thematic analysis, which requires a researcher to deal with data by utilizing a process of identification, analysis, and interpretation of theme patterns (Braun & Clarke, 2006). Thematic analysis affords a systematic and accessible procedure for dealing with qualitative data by generating codes and themes. Codes are small analysis units that include the data's interesting features related to the questions of the research. Themes are larger than codes and offer researchers a framework that enables them to organize and report their analytic observations (Clarke & Braun, 2017). Summarizing the data content is not the only aim of thematic analysis, but identifying and interpreting the data's features are as well.

I selected this method to analyse the data for many reasons, with the first being its flexibility in regard to the approaches used for generating meaning, gathering data , selecting sample size and constitution, and preparing research questions. Thematic analysis enables researchers within and across data to identify patterns that relate to participants' practices, behaviours, perspectives, views, and experiences in such a way that assists them in comprehending what participants do, think, and feel. This type of analysis can be utilized in analysing small or large amounts of data and with heterogeneous and homogeneous samples. Furthermore, the hallmark of thematic analysis is its ability to analyse any type of data from qualitative techniques that extensively are employed, such as focus groups and interviews using emerging methods like story completion and qualitative surveys. Likewise, this process of analysis can be utilized for both deductive and inductive reasoning in addition to the previous merits of thematic analysis, highlighting differences and similarities across a data set, providing a data set's thick descriptions, and enabling the data's social interpretations (Clarke & Braun, 2017). As Braun and Clarke (2006) indicated,

"If we imagine our data three-dimensionally as an uneven blob of jelly, the semantic approach would seek to describe the surface of the jelly, its form and meaning, while the latent thematic approach would seek to identify the features that gave it that particular form and meaning" (p. 13).

I followed the framework of Braun and Clarke (2006) in which they suggested six phases that need to be used in thematic analysis to ensure effective data analysis.

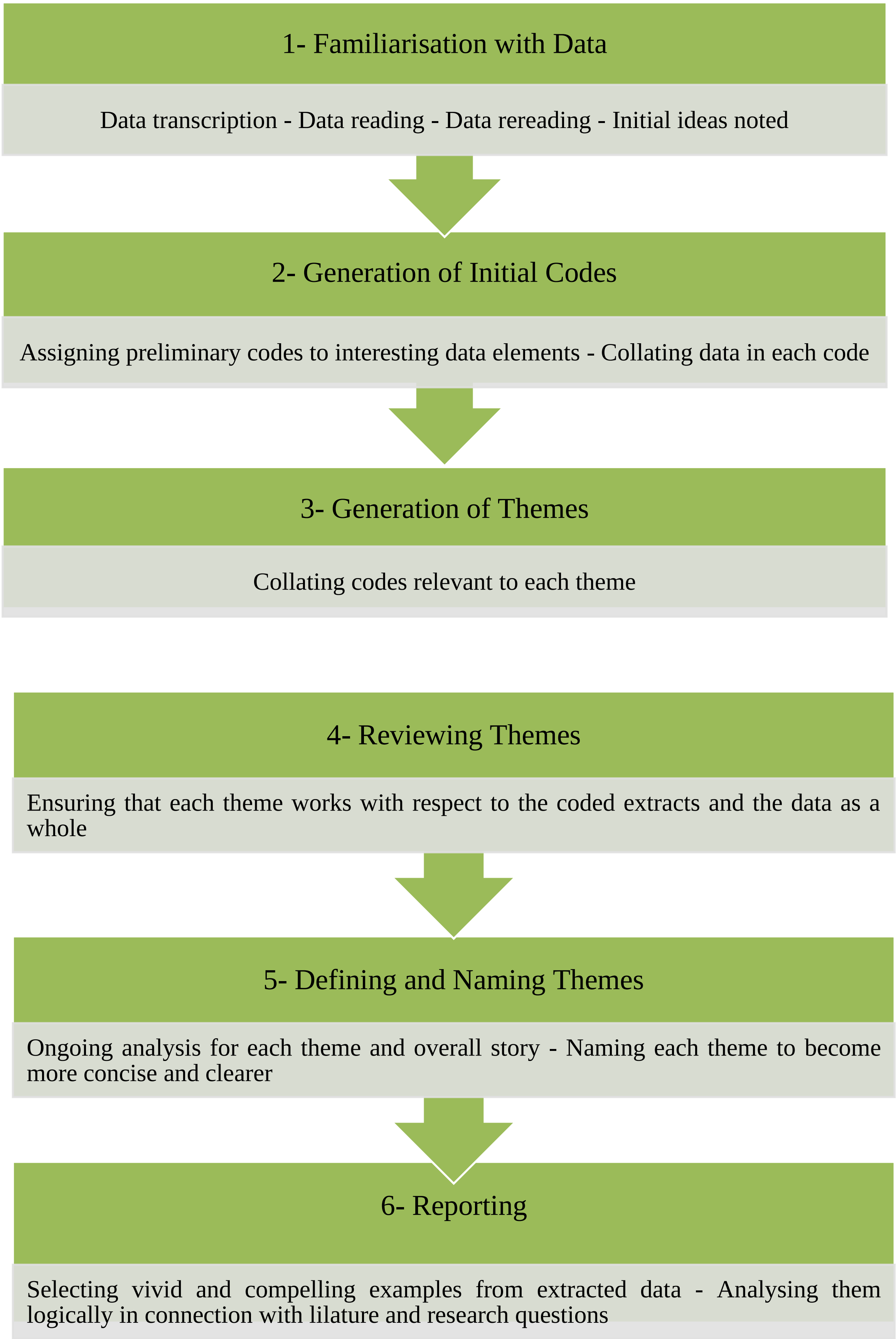


Figure 4.3: process of data analysis and interpretation

4.15.1. Familiarising myself with data:

In this first stage, I immersed myself in the data by listening to all of the audio recordings, transcribing them into Microsoft Word documents, and translating them into Arabic, which was the mother language of participants. I also transcribed data in both verbal and nonverbal forms. The transcription task assisted me in familiarizing myself with the data and informed me about the early stage of analysis by affording me a comprehensive understanding of the data (Braun & Clarke, 2006). After I transcribed the audio recordings, I repeated listening to them to make comparisons between them and the transcribed texts to ensure the transcription's accuracy. Then I engaged in reading and rereading these transcripts and observational field notes in a careful manner more than once and while making notes. Deep engagement while reading these documents encouraged brainstorming and pattern identification that related to my research objectives and questions.

4.15.2. Generating initial codes

For researchers, dealing with a large volume of data in qualitative research is a challenging task in which data has to be managed and analysed in an appropriate manner, requiring hard work that consumes their time. This is considered one limitation of this research. In this current study, using NVivo software assisted me in managing and organizing the data. I attended a workshop and watched videos on YouTube to know how to use this software properly and take advantage of it. It was very useful for organizing data. I uploaded the data as a whole—both field notes and transcripts—into NVivo, which contributed to creating the initial codes (see Appendix 2). According to Strauss and Corbin (1998), coding is the process of breaking down, examining, comparing, conceptualizing, and categorizing data. Codes can provide and identify labels for interesting data related to the research questions. Interesting data elements were coded by collating them into meaningful groups. As mentioned earlier, I used inductive thematic analysis with the data. This is also known as bottom up or data-driven analysis, and coding in this kind of analysis relies only on data with no link between coding and specific pre-existing coding frames. The inductive approach allowed me to carry out data analysis in a detailed manner and provide a rich and full account of the data. I conducted the coding recursively, carefully, and systemically using an inductive approach in the raw data coding process. After that, I organized them within each code.

4.15.3. Searching for themes

Throughout this stage, codes were grouped beneath themes and subthemes, which required me to review the coded data in order for organizing areas of overlap and similarity between codes and thinking about the rapport between them. Additionally, I defined any issues or broad topics around cluster codes. The fundamental procedure of generating themes and subthemes involves clustering and collapsing codes that appear to participate in several features together. Thus, they describe and reflect on a meaningful and coherent pattern in the data. Furthermore, during this phase, I started exploring the connection between themes in order to obtain knowledge about how they work jointly to tell the data's comprehensive story. The process of searching for themes was facilitated by using NVivo. This software enabled me to look at the entire data set, which allowed me to make comparisons between interviews of both types of individual with focus and observation groups and crystallise acquired data that fell under different themes (see Appendix 2). In fact, the crystallisation process provided me an opportunity by considering the data from different angles in which various data aspects were emphasized in diverse analysis phases.

4.15.4. Reviewing themes

This phase needed to be done in two analysis levels. The first level was checking themes with regard to the coded extracts. This level can be carried out by reading and rereading the extract of coded data under each theme then ensuring that these extracts are placed into the right theme and fit it very well. Refining the coded data extracts contributes to constituting a coherent pattern of them. The second level requires applying a similar process to the data set as a whole to examine each theme's validity with respect to the entire data set as well as coding any missed data. Furthermore, generating a thematic map ensures a rigorous representation of meanings in the data set as a whole. The themes of the current study passed through these two stages where they were reviewed and refined. I started by reviewing the extracts of coded data. I examined the perspectives of young participants about the same issues in term of similarities and differences. I compared and contrasted young learners' opinions about using apps and tablets to learn science in order to generate subthemes. Moreover, the comparison assisted me in generating analytical dimensions of identified elements or topics. I checked each theme's components and how the data extracts fit these themes. Each theme was reviewed and refined in relation to the data set as whole. I ensured that emerging themes and subthemes from my inductive analysis provided precise representation of the meaning of the data set.

4.15.5. Defining and naming themes

Themes in this phase need to be defined and refined to be utilized in the analysis, making sure that each emergent theme and entire theme set is defined and named clearly. I carefully read the data extracts under each theme to define and identify its contents. I repeated the reading more than once to make an examination of the entire data set, ensuring that the patterns and emerging themes were meaningful and could be precisely substantiated and articulated. I organized the themes and subthemes in internally consistent and coherent patterns, ensuring that each theme fit into the overall story. Furthermore, the names I gave the themes and subthemes when I started my analysis were modified to make them punchier, more concise, and clearer (see Table 4.5).

4.15.6. Producing the report

Writing up the analysis is the final phase of thematic analysis. The piece of writing should be detailed to provide an interesting, non-repetitive, logical, coherent, concise, and compelling story of the data. When I wrote up my data analysis, I utilized compelling and vivid data extracts as examples that relate to the literature, themes, and research questions and support the topic I was discussing and reporting.

Themes	Subthemes	Codes
1- Engagement	Cognitive engagement	● *Persistent effort to solve problems* ● *New knowledge* ● *Links between new knowledge and experiences* ● *Awareness of apps' content and of how to use them*
	Emotional engagement	● *Tablet affordances* ● *Informal classroom atmosphere*
	Factors related to science apps	● *Feedback* ● *Various roles* ● *Entertainment and games*
	Factors related to tablets	● *Multisensory experience* ● *Multimedia*

2- Factors that Promote engagement	Factors related to mobile learning systems	• *Freedom to choose* • *Social learning*
3- Apps support science learning	Gamified apps	• *Adventure and role-playing games* • *Simulation games* • *Problem-solving games*
4- Scaffolding Of Science Learning	Teachers	• *Cognitive scaffolding* • *Technical scaffolding* • *Effective scaffolding*
	Peers	• *Cognitive scaffolding* • *Technical scaffolding*
	Apps as scaffolds	• *Cognitive scaffolding* • *Technical scaffolding* • *Effective scaffolding*
5- Challenges and barriers	Issues related to tablets	• *No home button* • *Slow responses and freezes*
	Issues related to teachers	• *Lack of experience with mobile learning* • *Lack of experience with mobile learning and training needs* • *Workload-related conduct in mobile learning* • *Control and class management*
	Issues related to school administration	• *Inadequate funding* • *Lack of Internet access* • *Lack of devices*

Table 4.5: Outline of themes and sub-themes

As all focus groups and interviews were conducted in Arabic, during the data analysis I translated the data extracts into English to maintain the findings' authenticity, and the conducted study was to be released in English. The translation task was carried out by me for three reasons: I shared young participants' same language (Arabic); I believed that as a social constructivist researcher, the translator's standpoint was affected by the social world and its influence on his/her translation and interpretation of data (Temple & Young, 2004). The last reason for conducting translation myself was to enhance the reliability of the data analysis by maximising the consistency of translation.

4.16. Chapter summary

This chapter provides justifications and explanations for my decisions to utilize the social constructivism approach as the methodological and epistemological underpinning of my research. The research questions and objectives I selected allowed me to conduct the qualitative interpretative study on understanding and exploring the role of educational apps and tablets in support of science learning among Saudi first grade children and on enhancing their engagement. Employing the qualitative approach allowed me to carry out intensive exploration and obtain deep understanding about young participants' attitudes and perceptions regarding using apps and tablets in science class. I provided a detailed discussion about how the nature of qualitative interpretative research enabled me to compile my own interpretations as a researcher along with a multi-faceted account of the young participants' viewpoints. I conducted participant observation, focus groups, and face-to-face, semi-structured interviews to gather data to examine and understand the collected data. I carried out the inductive thematic analysis of my observational field notes and transcripts by utilizing NVivo software. In addition, I employed a number of measures to ensure the trustworthiness of the research and meet quality criteria, such as self-reflexivity, thick description, an audit trail, peer debriefing, and crystallisation. Also in this chapter, I reported and discussed the ethical considerations of the study. In the next chapter, I will describe, analyse, and discuss the study's findings.

CHAPTER FIVE

FINDINGS

Using apps to support science learning among first-grade students in Saudi Arabia

5.1. Introduction

In this study, I attempt to examine the role that educational apps play in support of science learning, as well as the extent of children's engagement and interaction with these apps during science class. In this chapter, I examine the themes that I found in the data and provide a verbal quotation to illustrate each; the purpose of these quotations is to elucidate the children's views about the mobile learning experience. The names of the participants are not mentioned because the data are anonymised in accordance with the study's ethical considerations of study. I thus use pseudonyms to refer to the participants

The findings chapter starts by considering the children's cognitive and emotional engagement. Then, I examine the factors that promoted that engagement, including the children's interactions with the apps. Next, I discuss the apps that support science learning. After that, I focus on scaffolding in the mobile learning milieu, including teachers' and peers' scaffolding. Lastly, I describe the challenges and barriers that the first-grade students faced when using the mobile learning application in science class. Table 1 lists the themes, subthemes, and codes that emerged from the data analysis.

Themes	Subthemes	Codes
Engagement	Cognitive engagement	● *Persistent effort to solve problems* ● *New knowledge* ● *Links between new knowledge and experiences* ● *Awareness of apps' content and of how to use them*
	Emotional engagement	● *Tablet affordances* ● *Informal classroom atmosphere*
Factors	Factors related to science apps	● *Feedback* ● *Various roles*

that promote engagement		• *Entertainment and games*
	Factors related to tablets	• *Multisensory experience* • *Multimedia*
	Factors related to mobile learning systems	• *Freedom to choose* • *Social learning*
Apps Support science learning	Gamified apps	• *Adventure and role-playing games* • *Simulation games* • *Problem-solving games*
Scaffolding of science learning	Teachers	• *Cognitive scaffolding* • *Technical scaffolding* • *Effective scaffolding*
	Peers	• *Cognitive scaffolding* • *Technical scaffolding*
	Apps as scaffolds	• *Cognitive scaffolding* • *Technical scaffolding* • *Effective scaffolding*
Challenges And barriers	Issues related to tablets	• *No home button* • *Slow responses and freezes*
	Issues related to teachers	• *Lack of experience with mobile learning* • *Lack of experience with mobile learning and training needs* • *Workload-related conduct in mobile learning* • *Control and class management*
	Issues related to school administration	• *Inadequate funding* • *Lack of Internet access* • *Lack of devices*

Table 5.1: Outline of themes, subthemes, and codes.

5.2. Engagement

- How do young children engage with science-related mobile applications?

I observed first-grade students as they utilised tablets during science classes; I also conducted interviews and focus groups, during which I obtained the full particulars of the children's impressions and opinions of the mobile learning experience. As I will demonstrate, I found that the children were highly engaged, both cognitively and emotionally, with the tablets and the educational applications, despite experiencing some obstacles and challenges. Two sub themes fall under the main theme of the children's engagement with the tablets: cognitive engagement and emotional engagement. To address these subthemes, I explain and clarify how the children engaged with the tablets from own viewpoints, which I obtained via the interviews and focus groups. In addition, I conducted observations to get a clearer picture of the children's cognitive and emotional engagement.

5.2.1. Cognitive engagement

There is a strong relationship between cognitive engagement and learning (Axelson & Flick, 2011). If children are positively engaged in learning, they improve their learning outcomes (Taljaard, 2016). Cognitive engagement in the science class is related to the students' experiences of competence, as well as to their ability to successfully overcome scientific problems and to effectively participate in activities (Wang, Willett, & Eccles, 2011). In fact, this kind of engagement is clearly manifested in the science class when students make an effort in understand the topic or the tasks, when they persist in completing activities, and when they use various strategies to solve scientific problems (Schmidt, Rotgans, & Yew, 2011). Cognitive engagement is fundamental to scientific achievement. When learners are cognitively engaged in science class, they tend to use diverse learning strategies; these strategies are fundamental agents in learners' achievement and in meaningful learning (Bircan & Sungur, 2016).

In the mobile learning context, technological tools such as tablets can be used to enhance constructive learning, enabling students to solve problems and engage in meaningful and authentic learning, thus developing their knowledge and understanding (Jonassen & Reeves, Thomas, 1996). Furthermore, tablets and other handheld devices have proven to be effective at engaging learners and at helping them recognise ways to present their learning (Dunleavy et al., 2009). Furthermore, these devices help students to control their learning, which can expand their flexibility and interactivity (Oludare Jethro et al., 2012). The data from this study revealed four aspects that reflect cognitive engagement in science class: persistent effort to solve problems, new knowledge, links between new knowledge and life experiences, and awareness of apps' content and of how to use them.

5.2.1.1. Persistent effort to solve problems

Problem-solving skills are extremely important in science learning, as they are fundamental in the construction of knowledge. Mayer and Wittrock (1996) described problem-solving skills as cognitive processes in which students find solutions for problems to achieve goals.

My observations of the children in the science class revealed that their interactions with the educational apps helped them to cognitively engage and to learn science. The apps particularly helped the children when they made a special effort to accomplish specific goals to complete tasks such as solving puzzles and playing memory games. This supports the findings of Guzey and Roehrig (2009), as the students were able to effectively use apps to acquire scientific knowledge in a classroom and as, through the apps, the children engaged in knowledge construction and developed their thinking. The apps also promoted problem-solving skills, and some children used their own strategies to solve problems, as reflected in the following observation:

Noor chose insects app puzzle. She needs to place the insects' pictures in correct spots. She placed all the pictures on the top of the screen then dragged each insect in correct given spot. She organized the pictures on the top because she did not want to get confused by sparse pieces of puzzle. She wanted to focus on one piece get done with it in right manner then move to another piece. (field notes, lesson 14)

Involving the students in the problem solving required four stages: 1) recognize the problem, 2) design a strategy to solve the problem, 3) practice that strategy, and 4) examine the solutions. Some of the stages required children's persistence and patience because some apps (such as puzzle and matching apps) required the use of cognitive abilities to reach the solutions. The majority of children use several strategies to solve problems in digital activities such as solving puzzles and matching; these include the use of previous knowledge and the trial-and-error method. This indicates that they persisted until they had reached their goals and had completed the task in the correct manner. This is consistent with the findings of Sánchez and Salinas (2008), who indicated that playing mobile games helped eighth-grade students to develop their problem-solving skills and enabled them to complete their overall tasks with high levels of enthusiasm, persistence, and interaction. When the children in my study made efforts to complete the activities properly, they improved their skills and knowledge, thus enhancing their self-esteem, as reflected in the following observation:

Reema selected connect dots app, she needs to connect the dots with one another to shape up the rabbit. She connected the dots randomly; she did not follow the number ordering. The picture was not formed. She kept trying until she realized that she needs to follow sequential ordering of the numbers. As she dragged from first dot (number 1) to second dot (number 2) and complete connected the dots the rabbit was *formed*. *She clapped for herself when the rabbit picture displayed on the screen. (field notes, lesson 2)*

Huda selected a matching game. She is being asked to match baby animals to their moms. She was able to finish the task in the right manner, and she told Wafa, 'I matched all of them correctly the first time; I did not make any mistakes'.
Wafa – 'Was it easy?'
Huda – 'Yes.'
(Huda explains to her mate how she could play the game) 'You have to help the baby animals to find moms. If you look at the baby animal and see that it looks like his mom, put him on the box with mom. The mom was happy when I got her baby back and she smiled.'
Wafa – 'Easy.'
Huda – 'Because I have taught you how to play it.' (field notes – lesson 13)

Figure 5.1: Example of animal in-app.

The previous example indicated that Huda was able to match the baby animals with their moms, solve the problem, and complete the game, which led to a boost in her self-confidence as a result of mastering the activity. Huda's sense of achievement and pride give her an ability to help her peers confidently. Undoubtedly, self-esteem and self-efficacy increase children's self-confidence.

5.2.1.2. New knowledge

Children's use of tablets in a classroom context encourages their learning through several pathways, such as educational apps, games, and multimedia (Montrieux et al., 2015). Apps are considered useful in science class due to their enhancement of children's learning and achievement, as well as their encouragement of engagement, as these apps provide children with joyful learning experiences (Chu & Hung, 2015). According to cognitive theory (Mayer, 2005), presentation of information in both visual and auditory forms; enables students to use their capabilities more effectively, which creates deeper learning (Hochberg, Kuhn, & Müller, 2016). Tablets' functions help children to learn science, as tools such as multimedia and animation offer them the chance to move beyond the borders of the school to use their imagination to visit zoos, libraries, museums, other countries, and even spaces that would be impossible to view in reality (Zawilinski, 2016). This feature of technological tools allows children use their imaginations to acquire new knowledge about new concepts, including abstract ones related to science that they would not deal with in reality.

My observations demonstrate that children's interactions with apps give them opportunities to interact with multimedia components (including audio, images, and animations) that provide unique learning experiences, thus allowing them to acquire new scientific knowledge. This finding is supported by Mangen (2010), who described tablets as educational tools that (through their apps) offer children multisensory experiences and encourage interactions that facilitate new, engaging, and enjoyable learning experiences. as indicated in the following transcript:

Sarah – what did you have learnt from apps in science class? Like new information or new skill?
Randa – something new
Sarah – yes, please
Randa – I have learnt about how rain falling

Sarah – can you show me the app that help you learn about rain falling?
Randa – that one
Sarah – rainy cloud app helps you to learn about how rain falling? How the app helps you learn?
Randa – in rainy cloudy app, I saw the story of clouds. The clouds in the sky got together they clashed then turned into dark or gray color. After that the rain fell. I love when it is raining because I like to play in the patio under the rain with my brother.

Observational skills are also important to children's science learning, as observation enables children to gather information and aids in their problem-solving. Children use their senses to observe, to sort and classify objects, to follow sequences of events, and to take note of details that can be used to make comparisons. My observations of the children suggest that tablets provide children with great science learning experiences that help them to develop their observational skills by interacting with tablets' apps and engaging with the apps' content via their senses (hearing, sight, and touch). The children employ these three senses at the same time as they interact with tablets, which leads to deep observation and ensures that learning takes place. It appears that, as children compare and contrast pictures and audio, they can recognize differences and similarities in some important aspects. This means that children use their senses to make observations and explore, thus acquiring new knowledge, as in the following examples:

Randa -selected insects' app she looked at the insects' picture then she told the teacher the fly and the bee could fly like birds
teacher – but they are different can you tell me how come they different?
Randa – yes, the bees and butterflies are smalls and birds bigger than them and the birds have feathers, but bees and flies do not have feathers. (field notes, lesson 15)

Figure 5.2: Example of insects in-app.

Huda selected animal apps when she looked at turtle picture. She told Samar, "The turtles and snails have something on their back they are always hold them. I think this stone on the turtles back made them walk slowly". Then she told Samar that turtles are bigger than snails and also, they have four feet. (field notes, lesson 13)

Reema told teacher the snakes and caterpillars their look like each other.
Teacher – Maybe the look but they are different? Who can tell me the difference between snakes and caterpillars?
Reema – snakes longer than caterpillars
Samar – snakes bigger than caterpillars
Huda – caterpillars have small feet but snakes they do not. They are slithering to go anywhere (field notes, lesson 15).

The insects app and animal apps involved animated videos and pictures that enabled children to identify different kind of insects and animals and compare between them. While the school book contains a few static pictures comparing with these apps.

5.2.1.3. Links between new knowledge and life experiences

Cognitive engagement differs from other types of engagement because it is associated with internal processes; this type of engagement requires researchers to make accurate observations when judging children's engagement with the apps. The indicators of cognitive engagement include critical thinking, self-regulation, and the ability to connect new knowledge to both prior knowledge and life experiences (Khan & Ahmad, 2017). These links are indications of high cognitive engagement (Bircan & Sungur, 2016). Certainly, critical thinking encompasses several essential skills for learning in general and learning science in particular. Children showed some of these skills while they interacted with tablets and apps. For example; firstly, they solved problems represented by puzzles, matching, and memory games. Secondly, they learnt through playing and discovering. Thirdly, they expressed their feelings appropriately. Fourthly, they identified similarities and differences, and lastly, they made predictions of upcoming events. The following are some examples that exhibited children's critical thinking skills;

Farah selected the flower puzzle app and selected the pink rose picture. She was able to solve it in three minutes. She recognized the shapes and developed strategies to achieve her goals.
Hints, positive feedback, instructions that apps provided children increased their speed of completion tasks. Additionally, When children overcame challenges while using apps, they increased their self-esteem and self-confidence due to their pride in themselves and sense of achievement.

Farah selected the cooking app. She chose to make a cake, and when she put the cake inside the oven, she told Anfal, 'I made a cake and put it in the oven; the heat will rise the cake and become spongy. Looks delicious. I love cakes.' (field notes, lesson 5)

Figure 5.3. example of cooking in-app.

Farah's example proved that she identified the cause-and-effect relationship; she understood the effect of the fire on the cake rising. Children distinguishing between cause and effect is considered sign of critical thinking and an important skill in learning science.

Randa – Selected the insects app and looked at the insects' pictures; then she told the teacher that the fly and the bee could fly like birds.
Teacher – 'But they are different. Can you tell me how they are different?'
Randa – 'Yes, the bees and butterflies are small, and birds are bigger than them, and the birds have feathers, but bees and flies do not have feathers.' (field notes, lesson 15).

Huda selected the animal app and looked at a turtle picture. She told Samar, 'The turtles and snails have something on their back, they are always holding them. I think this stone on the turtles' back made them walk slowly'. Then she told Samar that turtles are bigger than snails, and they have four feet. (field notes, lesson 13).

Reema told teacher that snakes and caterpillars look like each other.
Teacher – 'Maybe they look [similar], but they are different. Who can tell me the difference between snakes and caterpillars?'
Reema – 'Snakes are longer than caterpillars.'
Samar – 'Snakes are bigger than caterpillars.'
Huda – 'Caterpillars have small feet, but snakes do not. They slither to go anywhere.' (field notes, lesson 15).

The previous examples exhibited that children were able to analyse apps' pictures by comparing them and identifying similarities and differences, which reflects their understanding and thinking process. This skill assists children in organizing new and known knowledge.
The data from this study suggest that some of the educational apps used for science teaching in this study enabled children to connect their prior knowledge with new knowledge and with their life experiences. This finding is supported by (Chang et al., 2016), who found that drawing with tablets enabled students to connect their life experiences to scientific knowledge and that students used tablets as means to summarize scientific facts. Consider the following examples:

Noor looked at the bee picture where this picture clarifies the parts of bee's body then she told lama, "If you see the bees fly in the garden or on the flower do not touch them because they will sting you, the bee stung my brother on his feet and he cried all day long." She put her finger on the bee bottom precisely on the bee stringer and told Samar the bee strung my brother by this needle. (Field notes, lesson 14).

Certainly, the science book has numerous pictures that could deliver the information, but when I compared these pictures with what the apps offered, I found that they explained general concepts and neglected details. The book background has a lot of colors and details that disperse children's attention and reduce their focus on the pictures' details. Apps' pictures are clearer than those in books. Furthermore, animated images display more details, which enabled children to compare and analyse. By using apps, children could manipulate pictures by touch; they could zoom in and zoom out of pictures, giving them a sense of control and allowing them to see the smallest details. Apps present varied types of pictures, such as animations, illustrations, and photographs, sounds which are features missing in books.

Randa told her group when she saw the butterfly in the insects app that the butterfly was a caterpillar when she was a baby.
Wafa – 'How do you know that?'
Randa – 'I saw her story in the Bream (Arabic children's TV channel); she was a tiny green caterpillar, then she ate a lot of leaves, then she turned into beautiful butterfly.'
Wafa – 'I love butterflies.'
Randa – 'Me too; their colors are very beautiful, and they do not sting like bees.' (field notes, lesson 15).

In this example, Randa selected the insects app. While she browsed it, she saw more than four pictures of types of butterflies, which helped her recall prior information about butterflies' life cycle and connect it with new information. She also shared this information with her group members. The book has one small picture for one kind of butterfly, and this picture is not clear because there are many written text around it.

5.2.1.4. Awareness of apps' content

Learning takes place when children interact with educational applications; this includes when they become aware of apps' content, how the apps work, the apps' purpose or objective, follow directions, recognize the apps' features, and implement the apps' tasks (Noorhidawati et al., 2015). My observations of children revealed that the majority were aware of how to operate the tablets, including the buttons' functionality, and could understand the apps' details. This indicates cognitive engagement, as in the following examples:

Reema selected animal app, she touched all available pictures cow, sheep, after while she noticed an audio icon and she tapped on it. She knew that this app combines pictures of animals with audio and audio activated upon tapping on the icon. (field notes, lesson12).

Farah selected coloring and drawing apps she drew a house on the blank sheet, she was aware of many things, draw on blank sheet using her index finger, change color by tab on color wheel, and tap on eraser icon to erase the mistakes. (field notes, lesson 8).

Huda selected fruit app and choose memory activity from the menu. when she started the games, she flipped over all fruit cards randomly. When she finished flipping over the cards she *found the repeated fruit. Thus, she understands how to play memory game and how to complete it. (field notes, lesson 9).*

Noor discovered how to change the background of the drawing app. She told her group about her discovery and she was excited while she explained the other children how to change the background. (field notes, lesson6).

I also noticed that, when children discovered new aspects related to the functions of the apps or the tablet's function, or when they discovered new information related to science, they were willing to share that information with their group or other classmates. This action led to enhanced self-esteem and self-confidence, and it encouraged cooperative learning among the children. My observations revealed that some children's behaviors during their interactions with the tablets required little mental attention: touching, shaking, swiping, punching, listening to music, and using the camera (Hirsh-Pasek et al., 2015). In addition, some children became disengaged with some apps because they were not interested in those types of apps, as in the following example:

Reema selected animal book which consisting of images (pictures of animals) and text (name of animals) and audios (sound of animal). She looked at the screen and tapped on the pictures nothing happens when she kept tapping the picture become larger. She tapped on the audio icon then tapped on arrow icon to move to next page then skip all pages quickly without listen to the audios. She exited from the app she looked bored. (field notes, lesson13).

Throughout the project, the majority of the children were able to browse the available apps and to select the apps that matched their interests. Each student had five apps to choose from. In fact, the children differed from each other in terms of personality, preferences, and interests, even when they were of the same age or in the same class. I took into account the principle of individual differences by providing the children with a range of app options to choose from.

Children exhibited cognitive engagement with app contents when they put a lot of effort into solving problems by using different strategies to achieve their goals. These attempts to achieve assist children in learning new knowledge and mastering scientific concepts. Cognitive engagement clarifies children's thinking about ideas and concepts.

5.2.2. Emotional engagement

This theme relates to the children's emotions and attitudes while interacting with apps during science class. During their interactions with the apps, they displayed various emotions—some positive, some slightly negative, as in the study by Noorhidawati et al. (2015). Emotional engagement also concerns children's reactions to peers and teacher. In fact, this type of engagement plays a pivotal role in the learning process because, when young learners are engaged, they actively participate, especially if their activities interest them and provide them with enjoyment; ensuring that learners are engaged within their zone of proximal development (Vygotsky, 1978) and thus are actively engaged in the learning process is the main ambition of the social constructivist approach. The majority of children exhibit interest and positive emotions such as enthusiasm, motivation, and enjoyment (Niemi, Harju, Vivitsou, Viitanen, & Multisilta, 2014). Motivation, which researchers can recognize through behaviors and attitudes, and which is associated with personal interest, can thus affect children's achievement (Waege, 2009). In the current study, children expressed their emotions (whether positive or negative) in three ways: verbally, through facial expressions, and with body language. I deduced these emotions by observing their behaviors as they interacted with the apps; they mostly seemed to be happy, as shown with laughter, smiles, amusement, and active behavior. This finding is supported by (Hong, Hwang, Tai, & Tsai, 2017), who found that technological tools such as handheld devices motivate students to learn science by making learning interesting; this encourages students to use those devices in their studies and to use apps to learn the practice of scientific inquiry. Moreover, (Khan & Ahmad, 2017) indicated that the use of the GBL app in science class influenced students by increasing their emotional engagement.

I also noticed that, in the science classes in this study, two factors encouraged children's positive emotional engagement. The first factor was related to the tablets' affordances or the apps' features; the affordances that seemed to motivate the children included ease of use, the ability to play various roles, instant feedback, entertainment, games, encouragement of imagination, and the ability to use interactive touchscreens. When I asked the children about why they preferred tablets to books, the majority stated that their preferences were due to the tablets' multimedia options and games, which helped them to have fun while learning science, as Farah explained in her description of her experience using a tablet in science class:

I have a lot of fun in science class. Because I play games with my best friend lama and the pictures in the apps are so beautiful. I like the animals' pictures in the tablet more than book because they are colorful and they have sounds.

When learning science, the majority of children preferred a tablet to books. In response to my question about the experience using the tablet to learn science, Reema explained the following:

I love to use tablet to learn science more than book. Science book is boring we just look at pictures and writing down, but the tablet has many games.

In addition, I noticed that the tablets' large touchscreens, sounds, and choice encouraged the children to play games and to interact with apps' content, thereby engaging them and helping them to play games smoothly, as indicated in the following transcript:

Sarah – why do you prefer the tablet more than book?
Reema – tablet has big touch screen. I can color any picture by touch the colors.

Tablets' audio and visual features are perceived as favourable tools for science learning. These functions allow children to, for example, listen to assorted sounds, look at various pictures, and solve puzzles with several levels of difficulty. In this study, those features appeared to increase children's enjoyment of science learning. They were also useful in that they enabled science learners to observe, compare, and analyse information. The tablets' multimedia options also likely enhanced the children's emotional engagement, as represented in their motivation and cognitive engagement with the learning content. As mentioned earlier, children can use tablets to listen to assorted audio, but I noticed that the instant feedback in the apps seemed to particularly motivate them. They displayed varied reactions to this feedback and showed emotions through facial expressions, for example:

Randa dragged all puzzle pieces in the right spots afterwards, the app generated the following audio (fabulous) she seemed excited with app response smiling appeared on her face. (field notes, lesson 10).

Farah played match fruit game and completed it in right manner afterwards, the app generated the following audio (excellent). When she listened to app response she smiled and clapped for herself (field notes, lesson 8).

The children expressed that the tablets' functions increased their satisfaction with their use of the tablets for educational purposes. These functions also allowed the children combine learning and entertainment. Huda, for example, indicated the following in her interview:

Sarah – does the tablet help you learn science?
Huda – yes
Sarah – how the tablet helps you? Can you give me an example?
Huda – yes, I learn what animals like food. I will tell you about the game in the tablet I played it. I should put for the animal the food they love. If they do not love the food they did not eat it, and she became sad because they are hungry. I gave the monkey banana and she ate it and I gave lion steak and he ate it.

Randa also indicated as similar idea:

I prefer science class the most because I have a lot of fun I could play games and learn new things in science.

The majority of the children indicated that they enjoyed using tablets in science learning because of the wide variety of available apps, which was convenient and aligned with their curriculum. The children also agreed that tablets made their learning process more enjoyable, as indicated in the following transcript:

Noor – I love to use tablet in classroom because tablet make me happy.
Sarah – how the tablet makes you happy?
Noor – because it has a lot of apps we can do a lot of things with them. We can color, play games, plant flowers and shopping.

Another example clarifies how playing roles engaged Huda emotionally, thus helping her to understand the characters' feelings:

Huda selected animal bath app then selected to took care of the panda. she imagined the panda is her pet, and she considered herself responsible of him play the role. where she bathed, washed, fed, dressed him. Until she finished all tasks she told Amal look at the panda smiled and happy
Huda – do you know why?
Amal – no
Huda – because he is clean and feel comfortable. (field notes, lesson 20).

The children appeared to enjoy using play in science learning. They were also emotionally engaged with the apps. Moreover, the children were more likely to engage with tasks if they perceived those tasks as useful, important, and interesting (Bircan & Sungur, 2016). More precisely, engagement seemed to result from positive emotions such as enjoyment, as indicated in the following:

Farah – when is the bell rings? (ask the teacher) (each class 45-minute-long by the end of the class the bell rings)
teacher – after ten minutes
Farah – I still have time.
Teacher – have time for what?
Farah – play another game. I just played two games (she means, use two apps). I need more than ten minutes to play all six games.
Teacher – but you have another classes
Farah – yes, I know that. We have fun playing games. (field notes, lesson 3).

Similarly, Noor indicated the following:

I hope we have more than two science classes because I enjoy learning science via tablet. Science class not like other boring classes.

In addition to the tablets' functions, another factor encouraged the children's emotional engagement when working as a group, which was learning with their peers in the mobile learning context, and using tablets to play with each other. These kinds of learning gave them the freedom to talk and gave them the sense that they had a choice as to whether to play with an app or join a group. The children also seemed to enjoy the freedom offered by the mobile learning environment, as this increased the autonomy of their learning. On the other hand, the children were not allowed to talk with each other in their other classes. As a result, they appreciated the flexibility and informality of mobile learning and thus became highly emotionally engaged in that process, as Noor indicated in the following transcript:

In science class teacher Dana let me play with Amal and talk with her. She is my best friend. We ride the same bus when we go home after school. Her house is next to my house.

Amal added the following:

Yes, in science class we could play games, use book or tablet to learn, and talk. Teacher Salma does not allow us talk in reading class she told us listen, listen, listen. (FG, 1).

The previous examples suggest that the children interacted with the tablets and apps positively and that they engaged with the content because of the tablets' affordances, which enhanced their interest in learning. In fact, children could talk, discuss, have fun in practical science lessons but they do not have lab at school to conduct such these lessons in safe manner. This is supported by Henderson & Yeow (2012), who indicated that children's motivation to learn could be enhanced through the use of interactive touchscreens. This is also broadly in agreement with the findings of Byun & Loh (2015), which indicated that tablet screens' designs, colors, and visual elements, as well as the apps' audio, can influence students' emotions and moods. In addition, tablets keep students emotionally and behaviourally engaged during the learning process. As explained above, children demonstrate positive emotions and thus become emotionally engaged with apps. However, they also experience negative emotions, which they exhibit as they interact with apps; these emotions include boredom and confusion. These emotions are usually caused by mistakes, lack of interest in the apps' contents or in their types (as every child had unique preferences in this regard), inability to complete tasks, inappropriate levels of difficulty, or lack of reading or writing skills. Here are some examples:

Reema looked confused because she selected to play with 56 pieces puzzle when she controlled setting puzzles. She started with most difficult level. (field notes, lesson 2).

Huda selected the app (reptiles coloring book) she just tapping on the screen. Then she told the teacher – today I will not color. Teacher ask her about the reasons. She told her I do not like to color reptiles they are not beautiful like other animals. They are ugly. (field notes, lesson 13).

Given the above explanations and the examples of children's engagement with apps in science class, I conclude this part with a science teacher's response to a question regarding her observation-based opinions of her students' engagement:

Last year I taught first grade students they did not like science classes at all. even If I brought some tools and samples to make simple experiences or changed my teaching styles. They always told me science and math were very hard to learn. First grade this year surprised me. They told me and other teachers that science was their favorite class. I notice their motivation, enthusiasm and efficiency. It was significant difference between two classes I lived through as teacher. I think tablets create a desire inside them to learn and love science.

5.3. Factors promoting children's engagement with apps in science class

In the previous section, I explained engagement in relation to cognition and emotion, but actually, several reasons promote engagement. I present them in the following section to clarify what fosters children's engagement and why they engage with apps in science class.

5.3.1. Feedback

Feedback is essential in the learning process. In a mobile learning context, feedback can be delivered in two ways: auditory or visual feedback (Dirksen, 2009; Snell & Snell-siddle, 2010). Apps display different responses to children's answers. These responses may involve written labels, motivational messages, points, badges, and access to advanced levels (Hirsh-Pasek et al., 2015). Positive feedback, which is offered in some apps, should immediately follow optimal challenging tasks where children must make an effort to accomplish them. In my observation of children, while using apps, they checked their answers and problem solutions to see whether they were correct, so they could measure their understanding of the science task through feedback. If the feedback was positive, they realized that the answers were right. If it was the contrary, they realized the answers were wrong. Feedback enables children to correct their mistakes, make judgments regarding their work, and adjust their thinking quickly. This concurs with Li and Hegelheimer (2013), who indicated that educational apps' feedback assists children with measuring their progress in the learning process. This is demonstrated in the following example:

Abrar asked for Huda's help with playing the bird game. Huda told her that the first thing is to match the birds with their shades. If they give you stars, that means you have done a good job (field notes, lesson 13).

Immediate feedback allows children to continue their tasks without waiting for their science teachers' feedback. Huda realized that receiving positive feedback (stars) means she was in right track which can reduce distractions, keep children positively engaged with the apps' activities, and help them stay on task, thus maintaining their focus. In addition, feedback provides children with opportunities to identify their weaknesses become more independent and construct their knowledge without relying on the teacher, enhancing their autonomy in learning (Van Nuland et al., 2015). This is in line with Sha, Looi, Chen, and Zhang (2012), who indicated that numerous educational apps employ provision feedback, which assists children's autonomous learning. The data obtained in this study revealed that providing children with optimal challenges and tasks, followed by instant positive feedback, encouraged their sense of accomplishment and competence and enhanced their motivation to learn science. Children enjoyed and greatly appreciated positive feedback. This finding is supported by Masrom, Nadzari, and Zakaria (2016), who indicated that immediate feedback helps children improve their performances in activities. This encourages their sense of accomplishment, which positively affects learning achievements and motivation. This effect is reflected in the following observation:

Farah matched the polar bears to the environment they should live in. The app generated audio ('great job'). When she heard the audio, she smiled and told the teacher 'I'm smart. I put the bears in their favorite place. I know which place they prefer to live in. No one told me. They love snow and ice' (field notes, lesson 17).

Noor told Amani, 'I got done with the fish puzzle. Right then, something happened, like a party. Do you know what happened?'
Amani – 'No.'
Noor – 'A lot of balloons fell. They are so beautiful' (field notes, lesson 14).

For some children, positive feedback enhanced self-efficacy. Children were motivated to learn science, seek more challenging activities, and spend more effort on accomplishing a task. Undoubtedly, positive feedback helps children finish the activity in the correct manner and lifts their confidence when they are doing next activity. This finding is also in agreement with Achterkamp, Hermens, and Vollenbroek-Hutten (2015), who indicated that utilising technology supported feedback strategies, which can increase self-efficacy among students when they are experiencing success.

Reema – 'I collected six stars in the memory game.'
Wafa – 'Amazing.'
Reema – 'I will play another game to collect ten stars.'
Wafa – 'I think it will be harder.'
Reema – 'No, I do not think so. I just need to find the similar fruit pictures' (field notes, lesson 19).

Figure 5.4: example of fruit and vegetables memory game.

Children expressed greater satisfaction with positive feedback in the form of rewards, as indicated in the following transcript:

Sarah – What is your favorite app?
Noor – I like game apps.
Sarah – Why do you prefer this type of app?
Noor – Because if I win the game, I have stickers, smiley faces, and stars.

Throughout the project, I noticed that children differed in their preferences of feedback types. As reflected in the following observation, some preferred visual feedback, whereas others preferred auditory:

When Huda did the matching game right, the app generated audio ('well done'). After that, Huda told Wafa, 'I want balloons like what you have to pop them' (field notes, lesson 9).

Sometimes, however, the apps' feedback was not sufficient for children. Some of them showed their teacher what they did with the tasks. They needed more positive feedback and showed off their skills and knowledge to their groups, peers, and teacher. After the teacher responded to their work, they displayed their pride and felt honored. This response shows how the teacher's response can positively affect their self-esteem. In sum, I carefully selected apps in this study by eliminating those that contained negative feedback, which may adversely affect children's willingness to learn science. Feedback in learning science is crucial because providing children with guidance is necessary to construct interpretations of phenomena. Furthermore, feedback is considered a substantial factor in guiding the learning process (Sha et al., 2012).

5.3.2. Playing different roles

Role-play games are defined as digital games where children assume the role of a character or copy people they have seen in real life. This kind of game is beneficial for children in fostering more imagination in their play. In addition, imaginary play, which occurs when children play fictitious roles, is considered key for cognitive, emotional, and social development (Sukstrienwong, 2018; Verenikina I.a Herrington, 2010). Vygotsky believed that playing roles forms the basis for children's awareness of the world and enhances their cognition of reality. Children are attracted to games where they can control everything or games that enable children to act as adults, and pretend play provides children with a natural experience to develop their cognitive skills. In addition, imaginative play significantly contributes to the development of children's ability to think (Vygotsky, 1967). From a cultural-historical lens, playing role-play games enable children to manage their emotions and learn about adults' rules and roles (Verenikina & Kervin, 2011).

Children's engagement in role-play games provides opportunities for experimentation, exploration, and manipulation, which are considered essential for constructing knowledge (Verenikina et al., 2016) and learning science. In the current study, children experienced a variety of roles, such as chief, farmer, worker in milk factory, worker in bread factory, animal caregiver, and worker in pottery factory, through the game apps. These games provided children with a safe environment to make mistakes, as well as encounter and explore new things, experiences that are related to the science curriculum. Because the participants in this study were all girls, it is worth mentioning that the girls preferred role-playing games, such as bearing, feeding, nurturing, and mimicking, more than boys. Gender differences can impact app preferences among children (Admiraal, 2015) due to socialized gender roles (Jansz, Avis, & Vosmeer, 2010).

In my observation of the children, some children tended to play the role-playing games in pairs; they split the tasks of the activity, thus generating social interactions. When children played role-playing games with their peers, they collaborated, took turns, and shared. This finding is in line with Vinogradova and Ivanova (2016), who indicated that role-playing games encourage socialization and cooperative skills. Using these games in the learning process are an efficient means for teaching and development. Vygotsky believed that social interactions between children and the social, cultural, and historical contexts of their societies were of utmost importance in developing a human being. Particularly, children's social interactions with one another had a significant impact on their cognitive development (Lawrence, 2018), which may positively affect their ability to learn about science.

Throughout my observations, I noticed that when children played role-play games, they showed verbal behavior such as helping, negotiating, suggesting, resolving conflicts, and rejecting, as reflected in the following transcript:

Reema selected the grocery shopping app (the goal of this app is to teach children about fruit and vegetables). She browsed it then used it while telling Wafa, 'I have a great idea'.
Wafa – 'What is your idea?'
Reema – 'Play as family. You are the dad, and I'm the mom. Then we go shopping for food for our home.'
Wafa – 'Mmm, okay, but we will play the game in my tablet not yours.'
Reema – 'But I already started it.'
Wafa – 'Okay, you can play by yourself.'
Reema – 'Okay – okay, we will use yours, but we have to take turns. Me then you.'
Wafa – 'Okay.'

Reema – 'Mom starts telling dad that she could not cook because no vegetables, okay?' (creating scenario).

Wafa – 'Okay.'

Reema – 'My name is Aziza and you?'

Wafa – 'My name is Saad.'

Reema – '1, 2, 3, start!'

Reema – Changed her voice then told Wafa, 'Saad, I did not cook lunch today.'

Wafa – 'Why, Aziza?'

Reema – 'Because no vegetables.'

Wafa – 'Let's go to the supermarket.'

Reema – Told Wafa with her real voice to open the app quickly.

After that, they followed the game steps, which required them to shop for vegetables and fruit according to the list provided by the app when they started the game (field notes, lesson 6).

This example demonstrates that children create scenarios based on their personal experiences in real life. Furthermore, their engagement in role-playing games on tablets required them to use different forms of negotiation and interaction between the app and the pair (Fleer, 2016). The occurrence of social interactions in a mobile learning context motivated students to learn (Jansz et al., 2010), potentially influencing children to develop positive attitudes towards science. Moreover, Some children redesigned the use of their apps, which were originally designed for individual use, to involve pairs of children at the same time. When children played with others, they appeared more empowered and likely to take advantage of the affordances of the apps (Verenikina et al., 2016). In Falloon and Khoo's (2014) research on children's social interactions with peers while using open-design apps, they found some instances of interaction and collaboration in the forms of suggesting new ideas, taking turns, being flexible, being agreeable, helping, and correcting (Falloon & Khoo, 2014).

Throughout the project, the majority of children preferred the role-play games the most because they enabled them to engage their imagination and extend their play beyond the tablet to include peers or small groups in a science class context. This is indicated in the following transcript:

Sarah – 'What is your favorite type of apps that you have used in science class?'

Huda – 'I liked the app where I pretend to be a farmer.'

Sarah – 'Can you tell me why you prefer that app?'
Huda – 'Yes, because I planted the pumpkin seeds and took care of them.'
Raghad added, 'Yes, we took care of the plants by protecting them from monkeys.'
Raneem added, 'I liked the games because I can be chief, I can be farmer, I can be anything I want' (FG, 2).

This example indicates that children engaged with games because they allowed them to engage in an assortments of acts that might be difficult or impossible to act in their real lives (Jansz et al., 2010). The data suggest that the type of app can play a vital role in peer interactions in science class. For instance, open-design apps, such as role-playing games, encourage social interaction and collaboration among first-grade children. Moore (2014), who conducted her study on preschool children using apps in their free time, found that this type of app greatly impacted children's engagement and interaction with others. In summary, role-play games and apps can help children gain an understanding about the world around them, enabling them to experience events or characters through apps that make science more relevant to children through play.

5.3.3. Fun to use

Enjoyment and having fun while playing educational apps and games can assist children in mastering the game and learning. The lack of entertainment or boredom can lead to disengagement and failure in learning (Touati & Baek, 2017). According to the United Nations, knowledge, entertainment, and pleasure are considered to be important needs for children's well-being, so children's need and desires for entertainment must be satisfied like their learning and other needs (Shaw & Tan, 2015). Educational apps produced for both learning and entertainment attract children's attention through their designs, which are considered basically as playful (Israel et al., 2016; Noorhidawati et al., 2015). In a mobile learning context, entertainment takes place when children are entertained when they play games via apps, where their play is seen as a main contributor to their development, whether cognitively or socioemotionally. Children enjoy using game apps because they are fun. In an educational context, fun can be translated into motivation and engagement with learning contents (Atwood-blaine & Huffman, 2017). The reason behind children's engagement with entertaining activities is to experience enjoyment (Shafer, 2013). Children feel motivation and persistence when they enjoy the activity and what they are doing in general (Lumby, 2011). The entertainment value of game apps motivates children and influences their persistence to master the game (Riconscente, 2013).

The majority of children indicated that they liked the educational apps because they provided a sense of fun. The children appeared more enthusiastic about learning and agreed that using apps in a classroom can make learning about science fun. This concurs with Lohr (2011), who found that using tablets in a scientific context increased children's motivation to learn science. In her study, children engaged in activities through fun. This engagement was a major contribution in assisting children to learn and retain what they had learned about science (Lohr, 2011). Conversely, this finding was not support by Iten and Petko (2016), who indicated that fun, entertaining apps increased children's cognitive load, consequently distracting children from engaging in the learning process. In addition, having fun and enjoying game apps did not influence children's success (Iten & Petko, 2016). Children having fun in a school context has positive consequences, nevertheless, because this can influence their attitudes towards school. However, fun is not always an indicator of a learning occurrence. It is important to mention that the facilities of the classroom in which I conducted my study included chairs, tables, a white board, a projector, and a cabinet of resources. These simple facilities did not provide the children any entertainment; they were in kindergarten the grade before and spent most of their time playing and having fun in corners and outdoors. Their previous circumstances promoted children's engagement with tablets as an educational tool that made learning about science a fun activity. Children showed amusement and excitement when engaged and expressed great satisfaction with using apps in science class, which offered fun and entertainment. In response to my question regarding the reasons for preferring a tablet more than a science book, the children answered as follows:

Reema – 'I play interesting games and have fun. If I win, I have prizes, stars, or balloons.'
Farah – 'I love the tablet. It has a lot of funny games and funny pictures.'
Randa – 'We can play a lot of games and learn, not just sitting on the chair.'
Noor – 'I have fun, play and draw and talk with my friend.'
Huda – 'I liked playing with the tablet. It was fun. In the tablet, a lot of apps, they were interesting.'

The children appeared to have fun and enjoy using the apps; they were laughing and smiling when they saw animations and animals and when they heard animal sounds. As evidence of this fun and excitement, children engaged with the apps in the following examples:

Reema laughed when she heard the name of a peacock bird in Arabic, and she told Abrar that it was so funny (field note, lesson 12).

Huda laughed at how a kangaroo walked, then she stood up and jumped, copying the kangaroo's way in walking. All the children laughed, and Wafa told her, 'You are so funny' (field note, lesson 13).

Moreover, in the following examples, children had fun and experienced pleasure while they interacted with the apps' contents:

Noor, when she saw a cactus image, she told Ayah and Amal, 'Tom, when he running, he hit this tree and he cried and said, "ouch, ouch, ouch."' Her group laughed at her (field note, lesson 6).

Farah selected the fruit app, and she saw a kiwi picture while she browsed the app. She then told Saja, 'Do you like kiwi?'
Saja – 'Yes' (smiled).
Saja – 'What about you?'
Randa – 'No, it is sour. When I tasted it, my face became like that' (she scrunched up her face like sour lemon face). After that, Saja laughed and told Randa, 'Your face is funny' (field note, lesson 8).

All these examples demonstrate that children in a science class enjoy using apps for learning and even do not want the class to finish. They thanked me for bringing tablets and downloading new apps for each class. For example, Randa told me*, 'Thank you, Mrs. Sarah. You put new and wonderful apps in the tablets to help us learn science',* indicating that they engaged with the apps and preferred them as a fun way to learn science. Regarding the teacher's opinion, she stated:

We all know that the children's main activity is playing through play. They can discover and settle in a new scholastic environment, but with these class's possibilities, they could not play or have fun. Using a tablet as an educational tool helped them combine fun by playing educational games and learn science. Also, using tablets made science class the most important class among children and made children interested in and enjoy learning science.

Overall, children had fun and enjoyed the apps' games, animations, sounds, activities, and multimedia, leading to higher engagement with these apps than books with limited activity.

5.3.4. Multimedia

Tablets provide children access to a rich assortment of multimedia learning resources. Multimedia in its presentation offers different stimuli through a number of elements, such as text, graphics, sounds, spoken words, animations, videos, audio, and music. This combination of stimuli invokes the participation of children's senses and engage them in the problem-solving process (Kapri, 2017). Learners' moods and emotions in a learning context are affected by auditory and visual elements; therefore, multimedia elements affect engagement through sensory stimuli (Byun & Loh, 2015). Using Apps' interactive multimedia when learning about science creates interesting learning environments, driving away boredom (Raditya et al., 2017). Ciampa (2013) and Pellerin (2014) argued that apps using multimedia in all forms (e.g., videos, images, and audio) triggered children's interests and sensory curiosity. In addition, multimedia has a positive impact on children's stimulus to learn, thereby promoting them to use tablets for learning purposes. Combining educational apps' visual and auditory features makes learning about science believable and natural. It also make science interesting to learn (van der Meij, van der Meij, & Harmsen, 2015).

The data obtained in this study revealed that apps' use of multimedia has a significant influence on engagement, motivation, and learning outcomes. The majority of children enjoyed using apps because of their multimedia elements. The apps' use of multimedia increased the children's sense of curiosity, which led to encouraging engagement, as indicated in the following transcript:

In response to my question about reasons for their preference to learn science from apps more than books, Meenah answered, 'Apps have games that make us happy not board'

Shatha added, 'Yes, we had a lot of fun using apps in science class. I will tell you why we all like apps more than books.'
Sarah – 'Why?'
Shatha – 'Because in apps, we can watch animals and listen to their sounds, and when you give them food, they are eating and talking.'
Ghala added – 'In book, no sounds, just looking at pictures and reading.'
Meenah added – 'And we cannot color pictures by touching' (FG, 3).

In another example of how multimedia rewards capture children's attention and satisfaction, Huda told Reema*, 'I get dancing stickers when I win. I love them so much' (field notes, lesson 11).*

Some educational apps selected in the current study combined images, sounds, audio clips, a musical background, and animations to help the children stay engaged with the contents in the apps, such as Milk factory, My mango farm, Magical seed, and Pottery-making factory. Children greatly appreciated the apps' multimedia elements because of the resulting excitement and fun they had from an app-based science-learning context. All children were excited about using pictures, videos, and animations to learn about science; the multimedia elements captivated them. This finding is in agreement with Korakakis, Pavlatou, Palyvos, and Spyrellis (2009), who indicated that multimedia apps that display 3D interactive animations boost students' interest and make science more attractive to them. Moreover, Koseoglu and Efendioglu (2015) found that using multimedia apps to learn about the nervous system increased students' enjoyment in learning about science. Furthermore, Hautala et al. (2018) found that multimedia tools were useful for increasing children's engagement and interests in life science.

Some educational apps included multimodal features, such as auditory instructions, which helped children control the activity and achieve their goals to gain a sense of accomplishment, competence, and pride. The multimodal features thereby improved their self-efficacy, impacting children's later achievements in science, as indicated in the following transcripts:

Farah selected the magical seed app. She followed the panda farmer's instructions to plant grape seeds, protect the grape tree from monkeys, and take care of it. When she saw the bunch

of grapes, she was very excited, and she told Lamar, 'The grapes appeared because I looked after them. I will plant grapes in our patio. I know how to plant' (field notes, lesson 8).
Randa told the teacher, 'I love this app,' (pointing on the screen) 'rainy cloudy app.' The teacher asked her why. She said, 'Because the little cloud talked and taught me about raining. I love the pink bow that she wore.'

These examples suggest that auditory instructions and animations helped children achieve their goals. They also assisted them in learning about raining and plant's needs, as well as what happens to seeds after they are watered and covered with soil via some animations of stage of grapes' growth, which is impossible to see in real life. Multimedia elements do what textbooks cannot for children. This is in line with Yen, Tsai, and Wu (2013), who indicated that a 3D animations app helps students learn about concepts in natural science. Multiple representations of multimedia can assist children experience scientific phenomena that might be unfeasible to see and experience in real life. These apps help children understand scientific concepts, whereas textbooks may not help them understand unobservable phenomena (Nielsen et al., 2016).

Science classrooms in Saudi Arabia, which is a developing country, are based on teachers' oral explanations; this is considered an unsuitable learning environment to learn science (Koseoglu & Efendioglu, 2015). Using apps to learn science enables children to conduct simple experiments, which are needed to gain an understanding of scientific phenomena, in a virtual environment via multimedia. In fact, these apps help engaged children explore important scientific concepts; however, the school may not be capable of offering materials for these experiments because of their costs (Kapri, 2017). Children engage with multimedia because of its flexibility; children have the opportunity to choose from a wide range of media options that accommodate individual differences in preferences of learning styles, allowing children to learn at their own pace. However, textbooks do not offer children these choices to help them stay interested and enjoy learning (Oludare Jethro et al., 2012). For instance, in an interview with the teacher, she said:

The variety of activities offered by apps such as matching, solving puzzles, drawing, coloring, and watching animations assisted children in selecting a preferred learning style, whether it is visual or auditory (teacher interview).

In this study, children had the freedom to select the apps whose designs, styles, content, type, and methods of presenting concepts and information they most preferred. As a result, children took responsibility for their science learning. In cases where children required assistance, they asked the teacher or me. The teacher asked children some questions while they played with the apps to help them reach the information independently and through scaffolding. Children learned independently in the group setting via handheld devices. Using pictures, videos, and animations makes learning science lessons more enjoyable. Apps' multimodal features led to an increase in children's motivation by providing an assorted selection for expression and enabled them to make decisions (Fatina & Quniebi, 2016). In sum, an important factor in improving the learning process is active engagement. Multimedia provided children with great opportunities for active engagement by stimulating their visual, auditory, and tactile senses and raising their interests in learning about science.

5.3.5. Multisensory experience

The capabilities of interactive tablets' multimedia elements can stimulate sensory systems, including the auditory, visual, and tactile pathways (Oliemat, Ihmeideh, & Alkhawaldeh, 2018; Wood et al., 2016). Tablets, which provide children easy access to multimedia resources and stimulate children's senses, improve children's engagement and learning outcomes. Multisensory activities are effective for learning because they are close to the natural setting, make learning fun, and enable children to connect to real-life situations (Taljaard, 2016). Chu Ng and Seeshing Yeung (2011) suggested that utilizing multisensory tools to learn about STEM subjects make them more interesting and meaningful. Tablets provide multisensory functionality for children engaged in many learning styles. Vygotsky and Piaget believed that employing various methods in education are important because children's levels of mental readiness are not at the same level, even if they are in similar age groups (Taljaard, 2016). In fact, tablets' multimedia approach presents learning concepts in a variety of ways, which enable children to use a preferred style to learn and meet their needs (Walling, 2014).

The data showed that children showed a higher level of engagement with apps' activities because of their higher level of sensory stimulation. For example, Farah said,*" In the tablet, we can learn about animals and listen to their sounds and play a lot of games".*

In the previous example, Farah engaged with the app because of its multimodality, which combined pictures and sounds, unlike books, which are created for visual learners only. My observation of children suggests that they are interested in all the tablet's functions, but they preferred the touch function the most. It stimulated their tactile sense and increased their engagement with the educational apps' content. Moreover, the capability to touch characters and objects of interest which displayed on the tablets' screens delights children (Giannakos et al., 2014). This is reflected in the following interaction between Reema and Wafa:

Reema told Wafa – 'I will tell you something funny.'
Wafa – 'What?'
Reema – 'Yesterday, I touch the TV screen. I thought it was big tablet' (laughed). 'I love the tablet because of its touch screen. I hope the TV comes with a touch screen too' (field notes, lesson 4).

The previous example is evidence that touch screen interactivity, one of tablets' special features and unlike printed books, allows children to touch digital objects and receive an immediate response. Children interacted with apps through the tactile sense by using fingers directly on the screen without requiring traditional input devices such as a keyboard or mouse. In addition, because young children have not fully developed their fine motor skills, they are not capable of dealing with conventional computers, which require them to use a keyboard and mouse. In consideration of this, tablets are considered to be the best alternative for children, who can operate the device directly with their fingers (Papadakis, Kalogiannakis, & Zaranis, 2018). This is also explained by Noor:

'The tablet is too easy. I can do everything with my finger. Play and color with my finger, everything with my finger.'

Tablets' touch-based features allow children to use them easily and independently (Oliemat et al., 2018), and engage in learning activities such as solving puzzles, matching and coloring—activities that may faster their learning. This is shown in the following interaction between Farah and Ayah:

Farah told Ayah, 'My finger is like a pencil and crayons. I can write and color by it' (field notes, lesson 8).

Tablets' surfaces allow children to use their fingers to directly touch the graphical icons. This direct manipulation attracts children and enthuses them (Oliemat et al., 2018; T. Wang et al., 2016). It also allowed them to interact with the digital world by tapping, dragging, swiping, pinching, and stretching (Lu, Ottenbreit-Leftwich, Ding, & Glazewski, 2017). This interaction is indicated in the following transcript:

Huda told Ghaida, 'Look, look' (she meant at her screen). 'If you touch the monkey, he is jumping and dancing.' She laughed at the monkey and said, 'Naughty, funny monkey' (field notes, lesson 16).

Children's interactions with tablets through touch may develop cognitive and motor skills, which can impact their thinking and coordinate finger movements (Kammer, Dang, Steinhauf, & Groh, 2014). Throughout the project, the majority of children could use different touch gestures such as tapping, swiping, and dragging, which they need to interact with tablets to perform tasks. According to Papadakis et al. (2018), children aged four and above can use seven types of gestures during their interactions with tablets' touch screens. Children engage with touch screens because of the immediate response that follows each touch and selection; this give them a sense of control and helps them maintain their focus and interactions. This finding is supported by Hirsh-Pasek et al. (2015). Furthermore, Tabuenca, Kalz, Ternier, & Specht, (2016) indicated that children's direct manipulation of tablets promotes a higher level of engagement because they can control the digital objects that appear on the screen. This direct engagement increases their motivation and self-confidence, in addition to providing opportunities to practice their autonomy and learning independently. This is reflected in the following observation:

Randa told Mena, 'You cannot pop the balloons in this way. If you just touch them, they will not pop. You have to do it like this' (explained by practically tapping on screen). Then she looked again at Mena's screen and told her, 'Fast, fast, fast,' to pop all of them (field notes, lesson 15).

This example shows children engaging in an immediate response—popping balloons when tapped on. In brief, tablets' multimedia presentation allows children to have a fully sensory experience that engages them in deeper learning (Wang, Xie, Wang, Hao, & An, 2016). Likewise, tactile technology enhances children's attention and delivers interactive experiences

(Ciampa, 2014). Using children's senses of touch to perform tasks not only satisfied their desires to touch but also may develop some skills, as indicated by Noorhidawati, Ghalebandi, and Siti Hajar (2015), who found that perception and manipulation of digital objects encouraged children's recognition skills and cognitive growth.

5.3.6. Freedom and autonomy:

Offering children the opportunity to make choices encourages independence, which can increase feelings of autonomy (Ciampa, 2014). Autonomy may motivate children into becoming active learners. In these roles, they have the freedom to link their activities to their goals. As a result, children develop a sense of control over their learning (Sha et al., 2012). In fact, a high level of engagement is associated with a high level of choice and children control, which they consider as crucial aspects of motivation (Jones et al., 2013). To enhance autonomy, learning tasks should match children's interests, be attractive, and provide them with diverse choices. The value of a task is linked to children's task choices (Bircan & Sungur, 2016).

A sense of regulation and sense of autonomy are considered as essential points in constructivism. Using tablets in a classroom context transfers certain responsibilities to children, such as selecting a preferred activity or app, making decisions related to the activity, or solving problems that they face (Nino & Evans, 2014). Children's need for autonomy when learning manifests through their desire to make choices without pressure. Satisfying this need plays an essential role in supporting their feelings of competence.

In a mobile learning context, autonomous learning is encouraged due to the ease of navigating tablets and apps (Lynch & Redpath, 2014) and the feedback that apps provide as a response to a child's performance. Feedback helps children measure their understanding, assess themselves, and obtain information about their performance (Van Nuland et al., 2015), and a multimodal representation of information allows children to select their preferred learning style (Walling, 2014). Tablets in a science classroom are another medium children can use to answer their enquiries about science; this reduces the teacher's workload so she can dedicate more time to each of the children (Williams, Nguyen, & Mangan, 2017). This is demonstrated in the teacher's transcript:

Last year, I was the only source of information. Children completely relied on me even when they used the book because they were unable to read. I read for them and discussed the pictures all together. Using the tablet decreased their dependence on me due to their interactions with *the apps and their multimodal features, which assisted them in learning and facilitating understanding.*

Using tablets as an educational tool to learn about science increases children's sense of autonomy and independence, in addition to enhancing motivation and engagement (Moore & Adair, 2015) and promoting student-cantered learning (Kukulska-Hulme, 2013).
Throughout this project, children had the greater freedom to select apps, groups, and peers; spend time on the apps; make decisions; play strategies; repeat and make mistakes; and ask questions. The majority of children highly enjoyed apps that offered various choices, such as Magical Seed, Learn Animals, cooking in the Kitchen, and Bird Game, as indicated in the following extracts from field notes:

Farah pointed out on Samar's screen (on the animal zoo app) and told her, 'This app has a lot of games. You can feed baby giraffe or turn the baby animals back to their homes or puzzles. You can do a lot of things' (field notes, lesson 17).

Huda told Lama, 'You can choose any seed you want to plant. You can plant a tree or flower' (field notes, lesson 9).

Figure 5.5: example of magical seed in-app.

Randa told Wafa, 'First thing, look at the pictures, then select what you like'. She meant the plant-puzzle pictures (field notes, lesson 11).

This finding is in line with Atwood-Blaine & Huffman (2017), who indicated that students highly valued playing Great Stem Caper, which is a free choice game. Students enjoyed playing in a free-choice environment, in which they felt engaged and motivated to learn about science.

Tablets enable children to take responsibility and ownership of their science learning by manipulating the device, selecting the app, and interacting with content through their preferred method. The sense of autonomy stimulated by offering children learning experiences allow them to experience freedom and extend their choices.

5.3.7. Collaborative learning

Social interactions occur when two or more children engage in play and exhibit two kinds of behavior: verbal or non-verbal (Arnott, 2013). Social interactions are considered an important aspect of collaborative learning (DeWitt et al., 2013). Vygotsky (1967) considered social interactions between children as a crucial factor that impacted development. Furthermore, Vygotsky believed that social interactions among children had a significant effect on their cognitive development (Lawrence, 2018). In addition, he thought that children should not learn scientific knowledge directly, instead they should construct them in the course of discussion. Children's interactions and tutoring are considered convenient platforms to enhance their understanding of scientific principles (DeWitt et al., 2013). Children's social interactions when playing apps and games are useful in increasing their sense of achievement (Sung & Hwang, 2013; S. Wang, 2014). Involving children in small groups or a collaborative learning environment is an efficacious strategy to boost children's engagement and learning (He, Shewmaker, & Nguyen, 2017). Communication among children is crucial to learning about science because it allows them to share ideas, plan, solve problems, and connect new knowledge with their existing knowledge. Moreover, collaboration among children within a group motivates them to learn, improves their memory, and builds deeper understanding (DeWitt et al., 2013) In-group learning provides children an opportunity to construct meaning and process information (Reychav & Wu, 2015).

In this study, most children's social interactions were represented in peer collaborations in a group context. This does not mean they do not interact as a group; rather, it means the peer interactions were higher. As I mentioned earlier, children have the freedom to choose their group and peers, which can lead to active interactions and engagement because they feel comfortable with peers who share the same interests. According to a social-cultural system, learning takes place when children interact with each other to create collective knowledge. In this system, peers, teachers, and technology provide scaffolds to help the students learn.

Throughout this project, peer interactions manifested in many styles, such as engaging in conversation, sharing ideas, providing technical assistance, participating in a game, listening, smiling, or laughing. In fact, children's interactions relied on, a child's development, playing context, and relationship between playmates (Lawrence, 2018). Furthermore, the type of app shapes children's interaction with each other (Agostini & Di Biase, 2012). According to Vygotsky, peer interactions, which are characterized by exchanging ideas, lead to greater knowledge construction (Wang et al., 2016). Social interactions between peers and feedback have significant influence on students' learning processes (Gielen & De Wever, 2015). Obviously, active learning is related continual communication between peers (D, Mchaney, Ph, & Burke, 2017).

In a mobile learning context, collaborative learning skills exhibit actions such as asking peers for help, offering help, explaining, giving feedback, communicating, solving problems, finding solutions for conflicts, and sharing information (Boticki, Baksa, Seow, & Looi, 2015). I found that children collaborated with peers and that their collaborations took multiple styles—sharing ideas, sharing discoveries, talking about prior knowledge and experiences, arguing, negotiating, or providing opinions or technical assistance (scaffolding) (Kucirkova, Messer, Sheehy, & Fernández, 2014). This is illustrated in the following examples:

Huda selected the matching game. She was asked to match baby animals to their moms. She finished the task accurately and told Wafa, 'I matched all of them correctly from the first time. I did not made any mistakes.'
Wafa – 'Was it easy?'
Huda – 'Yes.'
(Huda explains to her playmate how to play the game.) 'You have to help the babies' animals find their moms. If you look at the baby animal and see it look like his mom, put him on the box with the mom. The mom was happy when I put her baby back, and she smiled.'
Wafa – 'Easy.'
Huda – 'Because I taught you how to play it' (field notes, lesson 13).

Randa told her group when she saw the butterfly in the insects app that the butterfly was a caterpillar when she was a baby.
Wafa – 'How do you know that?'
Randa – 'I saw her story in the Bream [Arabic children TV channel]. She was a tiny green caterpillar, then she ate a lot of leaves, then she turned into a beautiful butterfly.'
Wafa – 'I love butterflies.'

Randa – 'Me, too. Their colors are very beautiful, and she does not sting like bees' (field notes, lesson 15).

Noor discovered how to change the background of the drawing app. She told her group about her discovery, and she was excited while she explained to the other children how to change the background (field notes, lesson 6).

These previous examples represent forms of children's interactions while using apps. For example, children assisted their peers in learning how to play the games and offered technical support. Additionally, looking at pictures helped them to remember and recall some information and prior knowledge, which they shared with peers or group members. These actions involved talking, explaining, or helping develop children's social and cooperative skills. The majority of children seemed to enjoy working with apps in a group. They engaged in discussions and interacted in their small groups with an emphasize on the personal responsibility of members. This finding is supported by Reychav & McHaney (2017), who indicated that students who participated in their study found collaborative work within mobile learning environment highly enjoyable, motivating them to use handheld devices for learning purposes. As Noor indicated in the following transcript:

'In science class, Teacher Dana let me play with Amal and talk with her. She is my best friend. We ride the same bus when we go home after school. Her house is next to my house.'

Amal added the following:

'Yes, in science class, we can play games, and talk. Teacher Salma does not allow us to talk in reading class. She told us to listen, listen, listen' (FG, 1).

Similarly, Farah indicated:

'I have a lot of fun in science class because I play games with my best friend, Lama, and the pictures in the apps are so beautiful. I like the animals' pictures in the tablet more than the book because they are colorful and they have sounds.'

The previous examples demonstrate the satisfaction children get from working and talking with their friends or classmates. They appreciated informality in group moods because it gave them the freedom to discuss and share app discoveries with group members. They enjoyed conversations about apps' contents and characters, which engaged them emotionally and cognitively. An employed mobile learning approach in science promotes social interactions between peers and the sharing of information. In addition, it improves students' learning interests and attitudes (Hwang et al., 2011). Children's communications within a collaborative group highly benefits their understanding of science (Warwick & Mercer, 2011).

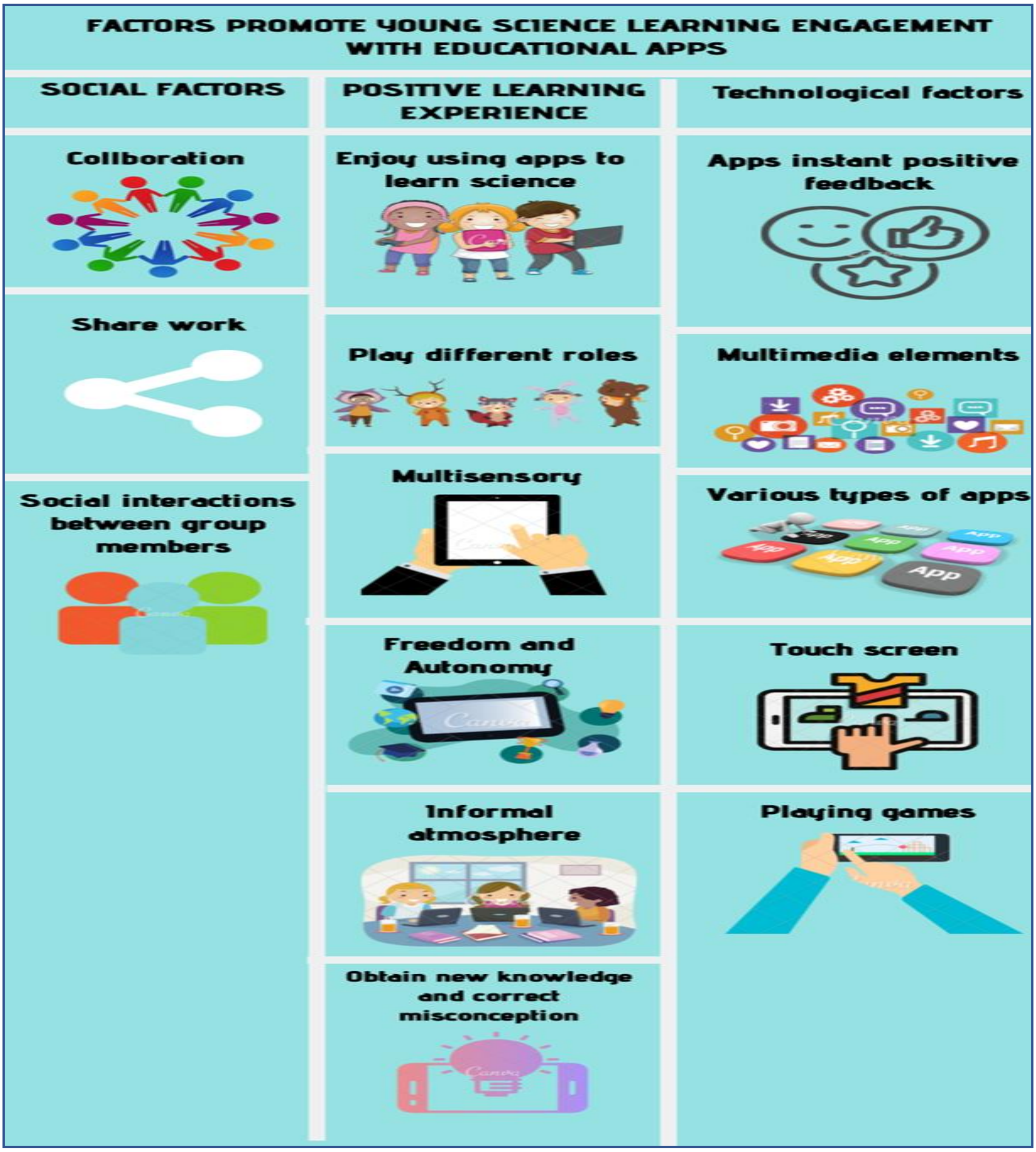


Figure 5.6: infographic of the factors that promoted engagement children with educational apps.

5.4. Apps support science learning

One theme that emerged from the analysed data is the role of apps in supporting science learning amongst first grade children. As mentioned in the previous section children engaged with educational apps in their science class cognitively and emotionally, as tablets' functionality and apps' interactive contents attracted them. Factors of attraction have a great impact on their motivation to learn science and engagement (Khan & Ahmad, 2017). The children expressed greater satisfaction when using tablets as an educational tool to learn science; for that reason, science learning become more enjoyable. The joyful learning experiences offered to children through apps and digital games could enhance their learning achievement.

5.4.1. Gamified apps

In the current study each student in the classroom had her own tablet. The tablets were ready to use, and five or six apps related to each science lesson were aligned with the curriculum. The downloaded apps were categorized into three types of games: adventure and role-playing games, problem-solving games, and simulation games. Besides the three gamified apps, I sometimes downloaded some creativity-based apps such as colouring apps to enhance their enjoyment, as enjoyment positively influences their motivation and learning outcomes (Fokides, 2017). Regarding flashcard apps and e-books, I downloaded some of them four or five times but noticed that the majority of children selected and preferred gamified apps more than these apps. I focused on these types of games because all the participants were girls, and these kinds of games attract them more than action and fighting games. Furthermore, role-playing and adventure games allow children to construct their identities through customized avatars in a virtual world. In fact, avatars are considered to be vehicles that enable children to interact directly with an authentic learning environment. In addition, these avatars allow children to participate in inquiry activities to explore game tasks (Chen & Chen, 2015). Finally, the previous three types of games were very suitable in supporting first grade science curriculum topics. Children's interactions with diverse types of apps lead to improvements in their learning satisfaction and allow them to structure their knowledge, which help them perform learning tasks (Hwang et al., 2016). Diversity in the types of apps leads to dissimilarity in apps' content presentation, which assists children in learning by appealing to their interests and curiosity (Mills et al., 2017).

In fact, the contents of apps are considered to be important sources of information in science classes, as the variation in types and content can promote scientific skills such as prediction, observation, manipulation, and exploration (Vinogradova & Ivanova, 2016). Children who just started school have not fully developed their metacognitive skills. To engage them in mobile science learning, the apps and software should provide learning activities characterized by clear structure and guidance. Also, they do not require a lot of reading and writing (Hautala et al., 2018). Using children of well-designed mobile games, including a variety of authentic activities and realistic experiences, could influence science learning. Learning occurs when students are exposed to authentic tasks, as practicing them contributes to generalizing to some situations in real life (Beier et al., 2012)**.** Several educators and scientists have noted the potential of digital games in promoting children's scientific expertise Clark, Sengupta, Brady, Martinez-Garza, & Killingsworth (2015); for example, Bressler and Bodzin (2013) used in their study the case of the stolen score sheet, which is a mobile mystery game. This inquiry-based game is designed to develop forensic science knowledge. The findings of the study demonstrate that the SSI game engages students in collaborative problem-solving and increases their interest in learning science. Likewise, S'cape is an adventure game that requires students to solve problems using their observation of chemical and physical changes. Campbell et al. (2013) integrated this game into a science class and found that the game assisted students' learning about change in substances nature which is a core concept. Additionally, it assisted in developing their skills in analysing and interpreting data. Wang Towey, and Jong (2016) also integrated into a science class the popular game Minecraft, which is run on a platform for mobile devices. They indicated that using this game improved students' learning. Also, students who used Minecraft learning activities showed enthusiasm and engagement, which led to positive effects in students' learning outcomes. All of these studies are proof that incorporating mobile games into science learning can be a powerful technique for improving children's scientific understanding. Interactive play could encourage science learning and a higher order of thinking.

The data extracted from observations, interviews, and focus groups have revealed that apps and digital games support children's learning of science. Digital games and multimedia apps could provide unique learning experiences for children regarding abstract scientific concepts where they are unable to see their details through simple observation (Israel et al., 2016). Furthermore, the introduction of mobile games in the science classroom may be advantageous to facilitate children's understanding of how principles underlying scientific concepts function and encourage creativity (Wang et al., 2016). Under the theme of apps supporting science learning, apps' game categories emerged as sub-themes. I will explain each type of these games and provide examples of their role in facilitating science learning and helped children construct their scientific knowledge.

5.4.1.1. Adventure and role-playing games

Integrating role-playing game apps into science learning develop children's intrinsic interest in science, as these games expose children to roles they are unable to encounter in the school context (Miller et al., 2011); to accomplish the goal of these types of games, the child assumes the character role (Chen & Chen, 2015). Role-playing apps provide children the opportunity to engage in a variety of adult roles that help them identify the related scientific knowledge of these roles (Vinogradova & Ivanova, 2016). Some digital games enable learners to play roles for training purposes, which allows them to think about real problems taking place in the world around them (Beier et al., 2012). Mobile games afford children role-playing opportunities that can affect their competence, sense of agency, and interest in science learning, where interest should be increased among children because of its role in the evolution of scientific self-concepts (Beier et al., 2012). Instead of utilizing abstract thinking in children's learning of science, they should learn from various experiences characterized by the following: 1) be direct, which involves being inverted from their reality and life; 2) be contrived, which involves employing interactive multimedia such as apps; and 4), finally, learn from dramatic participation (e.g., role playing), as some apps offer children opportunities to live these important experiences by mimicking adult roles for enhanced learning purposes (Giannakos et al., 2014), as indicated in the following transcript:

Sarah – 'What is your favourite type of app that you have used in science class?'
Huda – 'I liked the app where I pretend to be a farmer.'
Sarah – 'Can you tell me why you prefer that app?'
Huda – 'Yes, because I planted the pumpkin seeds and took care of them.'
Raghad added, 'Yes, we took care of the plants by protecting them from monkey.'
Raneem added, 'I liked the games because I can be chief, I can be a farmer, I can be anything I want' (FG, 2).

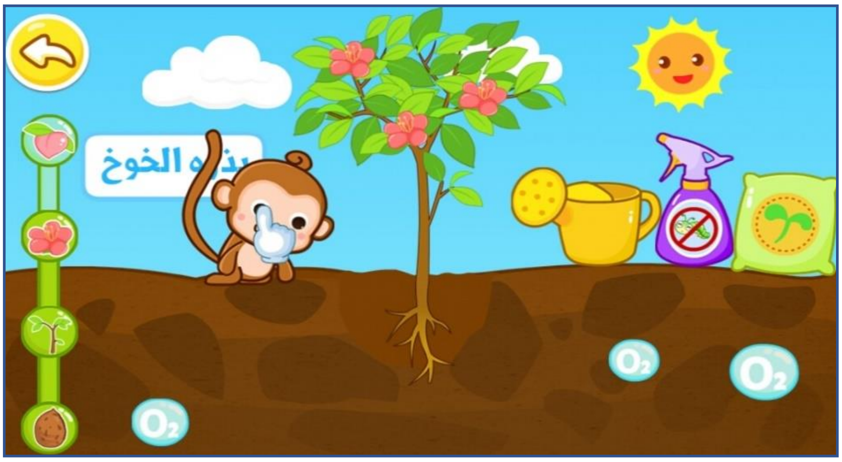


Figure 5.7: example of magical seed app.

The children greatly enjoyed role-playing games where they had the chance to deal with new experiences related to the world they lived in. Playing the role of farmer assisted Huda in learning how to plant pumpkin seeds. The virtual farming experience also enabled her to obtain knowledge about the pumpkin's life-cycle and its need as a plant. This knowledge is a part of the science Saudi curriculum, as outlined in Table 1.1. This finding is in agreement with Lee and Tu (2016), who indicated that employing apps in learning about four seasons, five senses, and plants improved children's science knowledge and enhanced their learning (Lee & Tu, 2016). In the same vein, Huang et al. (2010) developed a mobile learning system to assist student in learning about plants. Moreover, recent findings have demonstrated that digital resources have a remarkable improvement in students' learning. Employing tablets' multimedia effectively in science class engaged children in exploring concepts that are pertinent to daily life experiences (Barak, Ashkar, & Dori, 2011). This finding is supported by Chen and Chen (2015). Gamified apps allow children to immerse themselves in a virtual context where they can experience new things and repeat them. These contexts are related to adults or cannot be obtained in children's daily lives. Such games can increase the likelihood of providing children with authentic learning, as reflected in the following observation:

Reema selected the grocery shopping app (the goal of this app is to teach children about fruit and vegetables). She browsed it and then used it while telling Wafa, 'I have a great idea.'
Wafa – 'What is your idea?'

Reema – 'Play as a family. You are the dad, and I'm the mom. Then we go shopping for food for our home.'
Wafa – 'Hmm, okay, but we will play the game on my tablet, not yours.'
Reema – 'But I already started it.'
Wafa – 'Okay, you can play by yourself.'
Reema – 'Okay – okay, we will use yours, but we have to take turns. Me and then you.'
Wafa – 'Okay.'
Reema – 'Mom starts telling dad that she cannot cook because there are no vegetables, okay?' (creating scenario).
Wafa – 'Okay.'
Reema – 'My name is Aziza, and you?'
Wafa – 'My name is Saad.'
Reema – '1, 2, 3, start!'
Reema – She changed her voice and then told Wafa, 'Saad, I did not cook lunch today.'
Wafa – 'Why, Aziza?'
Reema – 'Because there are no vegetables.'
Wafa – 'Let's go to the supermarket.'
Reema – She told Wafa in her real voice to open the app quickly.
After that they followed the game steps, which required them to shop for vegetables and fruit according to the list provided by the app when they started the game (field notes, lesson 6).

Wafa and Reema interacted as peers in their discussion, they created scenarios, and negotiated all these actions to complete the activity, thus supporting each other's learning. The scaffolding provided by the app was also important for learning about various types of fruit and vegetables, which is an element of the Saudi science curriculum for this age group. The knowledge was represented in an animation style. Animation can add value to science lessons because of its capability to represent real-life situations (Kittidharma-opas & Tirakoat, 2012). What I mentioned earlier is broadly in agreement with Ercan, who proposed multimedia software to help children learn about food and healthy nutrition. After conducting the application, he found that integrating multimedia into science education developed children's achievement, where multimedia assisted children in creating a mental model or image of complex scientific concepts to help them learn easily (Ercan, 2015). Such grocery shopping apps offer children the opportunity to interact with peers, and multimedia apps promote children's logical reasoning and generate cognitive dissonance (Nthiga, 2017). Learning science requires children to communicate socially and interact with each other, as social interactions allow them to link new knowledge with prior or existing knowledge. Furthermore, social interactions in science class are very important for children to exchange ideas, plan, solve problems, and think critically, thus developing their understanding and supporting their learning (DeWitt et al., 2013). Integrating role-playing games into the learning process aids children in making sense of their world (Anderson & Barnett, 2013).

Providing children audio-visual aids through educational apps helps them communicate ideas and concepts, leading to improvements in their science performance (Thomas & Israel, 2014). This finding is in broad agreement with Hwang et al. (2016) who proposed a mobile learning system where students use selected mobile apps to complete learning tasks. The objective of these tasks is to support students' inquiry-based learning about aquatic animals and plants, which is a beneficial method to acquire scientific knowledge. The result of the study showed that the adoption of mobile apps is beneficial in assisting students acquire scientific knowledge, thus helping them perform learning tasks, as indicated in the following transcript:

Sarah – 'Did the tablet help you learn science?'
Huda – 'Yes.'
Sarah – 'How did the tablet help you? Can you give me an example?'
Huda – 'Yes, I learned what food animal like. I will tell you about the game on the tablet I played it on. I should give the animals the food they love. If they do not love the food, they do not eat it, and she became sad because they are hungry. I gave the monkey a banana, and she ate it. And I gave the lion a steak, and he ate it.'

In the previous example Huda explained her role in taking care of animals, where she fed them their favourite food. Through this experience she learned about some animals' necessary needs, various food preferences, behaviours and sounds. In this way, the app supported learning about animals needs, which is a part of the Saudi science curriculum. Mobile-based games offer children interactive learning experiences where they combine fun and educational objectives (Sung & Hwang, 2013). This offers children the opportunity to learn science in interesting ways to increase their understanding of the concepts (Hendajani et al., 2018).

Gamified apps offer children an authentic context where they can elucidate what they have learned (Morris et al., 2013). Active science learning occurs when children construct what they learn based on prior knowledge instead of being passive learners (Hendajani et al., 2018), as reflected in the following observation:

Huda selected the animal-feeding app. She saw a baby giraffe and baby sheep drink milk and then asked the teacher if baby animals drink milk.

Teacher – 'Yes, some of them.'

Huda – 'I think baby birds do not drink milk.'

Teacher – 'What do you think they love to eat?'

Huda – 'Hmm, worms. I saw on YouTube that baby birds in the nest cannot fly. Their mom brought them worms, and she put the worms in their mouths because they did not have hands' (field notes, lesson 16).

Figure 5.8: example of feed animal app.

The animations of animals that Huda saw on the app evoked questions in her mind about baby animals' needs concerning milk. She asked the teacher and received the answer, which is considered new knowledge. The answer reminded her about the baby birds' situation, which is considered prior knowledge. Her connection between the newly obtained knowledge and prior knowledge enabled her to understand that not all baby animals need milk, as they might need other kinds of food. This supported her learning about animals' needs, which is a part of the Saudi science curriculum. As a school subject, children are not easily attracted to science (Bidarra & Rusman, 2017). In fact, a loss of interest in science leads to children's difficulty in connecting their everyday life with science (Aristeidou & Spyropoulou, 2015). Digital games could provide a virtual environment that allows children to engage and absorb themselves in learning science, where they perform activities with considerable enjoyment. The multimedia offered through apps increases children's learning interest, as multimedia is considered a great

solution for the boredom commonly seen in the traditional learning method for science classes, which is less communicative and depends on teacher lectures and reading books (Raditya et al., 2017).
Digital games are considered to be a cultural tool, which Vygotsky indicated can be used to create a positive learning experience, as these games enhance motivation, which leads to positive influences in science learning (Morris et al., 2013).

5.4.1.2. Simulation games

Simulation games provide children learning experiences that allow them to practice scientific methods. As they interact with game materials, they perform their investigations and acquire knowledge about modelled concepts (Srisawasdi & Kroothkeaw, 2014). This type of game is designed to mimic some real-life activities or phenomena for learning and training purposes (Chen & Chen, 2015). Digital mobile games can provide active learning experiences through simulations in some science topics that students might have otherwise found boring (Ormsby et al., 2011). Moreover, simulations and animations improve children's conceptual understanding of the real world, as the development of such an understanding is the most important objective of science learning (Barak & Dori, 2011). This type of game impacts children's identity and furthermore assists them in using their thinking to solve problems independently (Beier et al., 2012). The digitized science classroom allows students to deal with experiences that are unattainable in the conventional classroom, as handheld devices such as tablets and iPads allow students to use their hand gestures to manipulate virtual objects, as this simulated experience leads to stronger learning, as explained by Farah in the following transcript:

Sarah – 'What have you learned from the apps in science class?'
Farah – 'Hmm, how do you make delicious toast?'
Sarah – 'Can you tell me the recipe? I mean, how do you cook it?'
Farah – 'Yes, it is too easy. Add some flour, oil, water, and salt. Then mix them. Mix, mix, mix. Then put the mix in the pot, bake it, and eat it' (laugh).

In the previous example Farah mentioned that the bread factory app taught her to make toast. This app gave children the opportunity to simulate the role of a factory worker and showed them what they needed to run the bread factory. Playing this simulation game enabled children to learn how to make bread virtually step by step, beginning with collecting wheat spikes, extracting grain, grinding them, kneading the flour to make dough, and baking. The farming simulator and the experience of making bread assisted children in gaining information about growing wheat and taking care of it, supporting their learning about plants' needs, which is an element of the Saudi science curriculum.

Similarly, Reema indicated that in the following transcript:

Sarah – 'What have you learned from the apps in science class?'
Reema – 'The app taught me how to make a beautiful vase using clay like playdough.'
Sarah – 'What is clay?'
Reema – 'It is soil and water. Mix them, make a vase, and decorate it.'

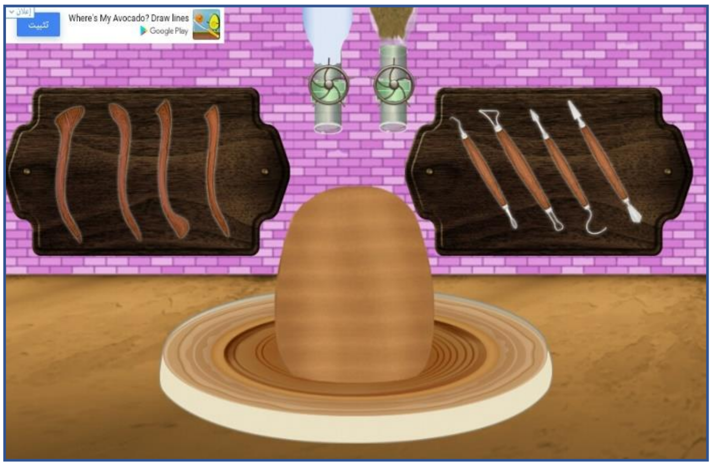


Figure 5.9: example of vase making app.

In her interview, Reema indicated that the pottery factory app taught her how to make a pottery vase. The app allowed children to create pottery step by step in the pottery-making factory. This included collecting clay, straining it, making dough, carving, baking, and lastly decorating the pottery piece. Children have many choices to select from such as shapes and colours. The simulation of working in a pottery factory and creating pottery vases virtually assisted children in obtaining knowledge about the resources that earth provides us, which is a part of the Saudi science curriculum. We can use them and gain benefits from them, as they are available for all humans to use.

As she used the same app, Noor followed the steps to make a vase, and when she arrived at the baking stage, she asked the teacher the following:
Noor – 'Why did you burn it? (meaning the vase).

Teacher – 'You mean bake it. What do you think?'

Noor – 'To make it dry.'

Teacher – 'We could put it under the sun in an outdoor place, and it will get dry.'

Noor – 'Hmm, I think because you can change its colour to black when burned.'

Teacher – 'I do not think so. We could paint it with black colour.'

Teacher – 'I will tell you why.'

Noor – 'Why?'

Teacher – 'We need to bake them to protect the vase from easy breakage and to make it stronger' (field notes, lesson 18).

In this example, both the app and the exchange with the teacher enabled Noor to develop her understanding of relevant scientific knowledge, such as the importance of heating pottery to harden it and increase its strength. The app enabled Noor to follow the sequence of this process, but she needed the teacher's input in order to understand fully the meaning of this step. According to Vygotsky, meaningful learning takes place when children interact with a more knowledgeable other such as a teacher. This interaction assists children in solving problems within their zone of proximal development as they become active learners. Thus, in building their learning and acquiring and exploring new knowledge, they benefit from more knowledgeable others. In the current study, the science teacher and the researcher were more knowledgeable others who helped children facing difficulties, supported them, and discussed any questions (Lee & Tu, 2016). Likewise, children's interactions with the interactive multimedia offered by apps activities require them to view, listen, compare, and observe, which significantly increases their knowledge. Dynamic pictures and video are forms of multimedia that support learning science, as they bring the outside world into the class, assist teachers in delivering instructions, and correct learners' misconceptions (Ekanayake & Wishart, 2014), as reflected in the following observation:

Reema and Wafa used the same bread factory app. Reema told Wafa to kill the bugs, as they will eat the flour. Then she told the teacher, 'I think bugs like to eat flour. I should protect my flour from them.'

Teacher – 'They ruin the flour. We should keep flour in a dry, clean place' (field notes, lesson 19).

In this example, both the app and the teacher assisted Reema in gaining the correct knowledge about how to keep food safe. The teacher extended the learning so that Reema could understand how to store flour. Harnessing the potential of interactive media in science learning leads to enhancing students' understanding of scientific principles and makes learning them more interesting (Taufiq et al., 2016). Handheld devices aid children in taking responsibility to find answers without the teacher or parent's help (Burden et al., 2016); for example,

Reema started the milk factory app and then selected the camel to get the milk from. She told Aya that the camel has milk like cows and sheep, she was surprised and found it so funny' (she laughed) (field notes, lesson 19).

Figure 5.10: example of milk factory app.

Reema appeared not to know that a camel produces milk like cows and sheep. By using the milk factory app, she encountered that new information. Reema pretended to be worker in a milk factory while playing this game, wherein she visited a farm and watched cows to learn about their favourite food. Also, she was asked to get fresh milk to process through a machine at a factory in order to produce dairy products like butter, cheese, and yoghurt. Using this app helped children to obtain knowledge about the animals that produce milk such as goats and camels, they learned how to extract milk from them, and about dairy products, knowledge which is a part of the Saudi science curriculum. Moreover, they learned about dairy products and how the milk should be processed and filtered to remove bacteria and kill germs. Children must understand the process of making dairy products, packing, and how they are prepared to eat. An interactive learning environment can be designed by harnessing handheld devices' multiple functions, as these devices provide a platform that supports animation and stimulation to elucidate abstract concepts. This leads to inspiring highly active students to easily construct difficult scientific concepts (Tüysüz, 2010), as indicated in the following transcript:

Sarah – 'What have you learned from the apps in science class, such as new information or new skills?'
Randa – 'Something new?'
Sarah – 'Yes, please.'
Randa – 'I have learned how rain falls.'
Sarah – 'Can you show me the app that helped you learn about rain falling?'
Randa – 'That one.'
Sarah – 'The rainy cloud app helps you learn how rain falls? How does the app help you learn?'
Randa – 'In the rainy cloudy app, I saw the story of clouds. The clouds in the sky got together, they clashed, and then they turned into a dark or grey colour. After that the rain fell. I love when it is raining because I like to play on the patio under the rain with my brother.'

Randa explained that the app taught her about the rain, which is an abstract concept. Using simulation apps in the science class can allow children to visualize abstract concepts and unfamiliar objects to supports their understanding of these abstract concepts (Bull & Bell, 2005). Similarly;

Randa told the teacher, 'I love this app (pointing to the screen), the rainy cloudy app.' The teacher asked her why. She said, 'Because the little cloud talked and taught me about rain. I love the pink bow that she wore.'

The adventurous cloud app assisted Randa in learning how rain occurs by taking her on a virtual adventure around the world to see different places and learn how the animals and plants need water and fight disaster. Also, the app offered valuable information about air pollution and dry ponds, which are considered big environmental problems affecting humans, animals. These are important elements in the Saudi science curriculum. The same app supported Wafa's learning about pollution and recycling, as indicated in the following example:

Sarah – 'Do you think apps help you learn science?'
Reema – 'Yes.'

Wafa – 'Yes.'

Sarah – 'How do the apps help you learn?'

Wafa – 'They help me to have information.'

Sarah – 'Can you give me an example of the information you have received from apps?'

Wafa – 'Yes, do not throw rubbish in the street or in the sea because pollution can happen' (FG, 3).

All previous examples proved that the potential of handheld devices and their applications such as visualisation and multiple representations make scientific concepts and principles more accessible. That was supported in many studies; for instance, Islam, Ahmed, Islam, and Shamsuddin (2014) developed multimedia applications to help children learn about the solar system. The application contains animation videos where visual learning materials are combined with verbal instructions. They found that employing this blended approach fostered children's acquisition of scientific knowledge (Islam et al., 2014). In the same vein, Space Hunter is a game designed to support children learning about the solar system and celestial objects. After implementing this board game, the researcher found that Space Hunter helps children in structuring a higher conceptual abstraction, further improving their learning performance (Taufiq et al., 2016). Moreover, Tarng, Ou, Lu, Shih, and Liou (2018) developed a mobile learning system to facilitate students' understanding of sun path changes by using an augmented reality app on mobile devices. The result shows that using this type of app to learn about astronomy science is more effective than the traditional method. Additionally, the app aids students in their learning and enhances their learning achievement. Korakakis, Boudouvis, Palyvos, and Pavlatou (2012) developed Atomic Orbitals, which is multimedia application. After incorporating this app into the science class, the researcher found that the Atomic Orbitals app provides students an interactive 3D virtual environment that leads to a highly effective learning process.

Likewise, Islam et al. (2014) found that taking advantage of multimedia functions such as animation attracts students' attention, which leads to a deep understanding of the lessons, as the media delivers information successfully and entertains students at the same time. Aksoy (2012) found that conducting an animation technique helped seventh grade students learn about humans and the environment and enhanced their academic achievement. Additionally, the researcher found that adopting animation in science learning showed changes in a realistic way (Aksoy, 2012). Moreover, Yen, Tsai, and Wu (2013) conducted a study exploring the influence of augmented reality and 3D simulation approaches on learning about moon phases. They found that employing approaches such as these in science learning is useful in improving students' learning. Lastly, Aristeidou & Spyropoulou (2015) developed the Eclipse Android-based app whose purpose is to facilitate students' learning about lunar and solar eclipses. The result indicated that the pictures and videos on the app support students' learning. Additionally, the app's materials are presented in an easily understood and interactive way that attracts students' attention. Modern technology brings about enormous opportunities for science learning because of its functionalities in displaying scientific phenomena. In fact, some of these phenomena are too small to be seen, and they are too abstract, complex, and dangerous to be explored in real life. Therefore, technology capabilities present these phenomena through simulation and models that facilitate comprehension of them (Lei et al., 2016). Some science experiments and activities need plenty of time. They can be conducted in short durations of time using simulation games due to their capabilities that contribute to better conceptual understanding of scientific concepts (Srisawasdi & Kroothkeaw, 2014), as indicated in the following transcript:

Farah selected the magical seed app. She followed the panda farmer's instructions to plant grape seeds, protect the grape tree from monkeys, and take care of it. When she saw the bunch of grapes, she was very excited, and she told Lamar, 'The grapes appeared because I looked after them. I will plant grapes in our patio. I know how to plant' (field notes, lesson 8).

The app enabled Farah to learn about the life-cycle of grapes and the needs of plants, which are part of the Saudi science curriculum. This is supported by Song and Wen (2018), who adopted the BYOD approach and found that the selection of apps supports students' learning about flowers and seeds and helps them achieve their learning goals. Likewise, the rock cycle app helped students construct their knowledge and promoted learning concepts, as students benefitted from animation techniques offered by the app (Lin & Atkinson, 2011). Moreover, Choi, Land, and Zimmerman, (2018) found that equipping students with tablets supported deeper science learning about trees' life-cycles and guided them in making decisions during the problem-solving process.

Likewise, the Ecomobile app was incorporated into the science class to help children learn about the pond environment. This supported students' learning about water quality measurement and engaged them in scientific activities (Kamarainen et al., 2013). Multimedia capabilities that offer visual and aural aids improve the science learning process, as these capabilities help children imagine scientific concepts in order to understand them comprehensively (Raditya et al., 2017).

Farah planted virtually using the magical seed app. She arrived at the step where she was to add fertilizer. She asked the teacher, 'Is this plant food?' She pointed to the fertilizer bag.
Teacher – 'Yes, it is called fertilizer.'
Farah – 'I think adding it will make the tree grow faster.'
Teacher –'Yes, but the tree also needs something else. Do you know what?'
Farah – 'Yes, sun, water, and soil' (field notes, lesson 9).

Numerous scientific fields deal with phenomena characterized by abstraction and multidimensionality, which lead to difficultly comprehending and applying knowledge, particularly among children, as children need to construct a flexible mental model to be able to deal with abstract concepts such as planting and what happens to seeds after covering them with soil. In fact, advancements in technology offer a variety of handheld devices that provide access to multimedia resources and support children in building a mental model through visualized complex concepts (Anderson & Barnett, 2013). Also, incorporating visual elements into science learning makes it more permanent (Bulu, 2010). This is supported by Huang, Lin, and Cheng, (2010) who developed the MPLS mobile learning system to facilitate students' learning about plants. They found that utilizing MPLS benefitted students academically and supported their learning.

I explained earlier the role of some apps such as the milk factory, bread factory, pottery-making factory, and magical seeds in supporting children's science learning. It is worth mentioning that all of these apps' contents are represented in an animation style, which is an effective tool that can be used to deliver learning experiences, especially among children. The adoption of an animation style helps children acquire efficient knowledge where they feel a sense of reality over learning materials. Animation offers two unique features, motion and trajectory, which picture books cannot provide (Karacop & Doymus, 2016). Learning science through animation can increase curiosity and scientific knowledge (Barak et al., 2011)**.** Harnessing the potential of technology such as 3D animations and pictures offers children simulations that assist them in constructing their understanding of the surrounding world and enhance their scientific knowledge. Yet simulation capabilities could be superseded by some real situations that are difficult to create in real life (Aristeidou & Spyropoulou, 2015). Scientific literacy could be supported by digital games, especially in three aspects: acquiring skills, content knowledge, and grasping the nature of science (Morris et al., 2013), as explained by the science teacher:

At the end of each unit I apply monthly school assessments to assess children's scientific skills related that unit, monitor their progress, and check if they meet the curriculum objectives. I found that most of the students achieved the unit goals. I was surprised that some students have additional valuable information that does not exist in the book related to the curriculum topics, and they told me they got them from the apps. From my point of view, the apps facilitate learning difficult and abstract concepts by playing the games; as a result, indirect learning occurs.

Some Saudi schools, including the school that participated in the study, suffered a lack of laboratories and equipment to conduct even simple experiments, preventing students from important learning experiences. In fact, developed technology and mobile apps can be the best solution, as simulation apps can provide students an opportunity to conduct science experiments using virtual labs. That will help students gain knowledge about some scientific experiments that require labs for proper explanations. Virtual labs are considered to be the best alternative compared to lectures. For instance, in her study Tüysüz implemented 16 virtual experiments by using flash applications. She found that adopting these apps had a positive impact on ninth grade students' achievement (Tüysüz, 2010). In particular, handheld devices in the science class allowed students to create a mobile laboratory where numerous apps could be utilized to explain, document, measure, share, photograph findings, record, and collect data (Furman et al., 2018).

Mobilized science learning improves students' conceptual understanding (Looi et al., 2015). Mobile games have the capability to blend serious science topics with enjoyment, which makes these games powerful tools that can be used to enhance science learning. Simulation techniques assist students in constructing their scientific knowledge. Mobile applications have enabled students to utilize and take advantage of multimedia so they can access various and rich learning resources (Huang et al., 2010). Educational apps' multiple representations of information offer children various examples that assist them in grasping new knowledge representing real-world problems through multiple modalities, scaffolding, feedback, and rich information sources.

5.4.1.3. Problem-solving games

Puzzles and matching activities fall under this type of game. To succeed in these games, children are required to solve well-structured problems (Chen & Chen, 2015). In fact, these games help children learn strategic thinking and have positive effects on their knowledge retention (Sung & Hwang, 2013). Playing brain games leads to content learning among children, where they are making decisions and solving problems through continual feedback. Moreover, adopting this approach assists children in understanding complex and interrelated concepts (Marino, Becht, et al., 2014).

Farah matched the polar bears to the environment they should live in. The app generated audio ('great job'). When she heard the audio, she smiled and told the teacher, 'I'm smart. I put the bears in their favourite place. I know which place they prefer to live in. No one told me. They love snow and ice' (field notes, lesson 17).

Pervious example clarified that, Engaged Farah in matching activity supported her learning about animals' suitable environments and habitats.

Figure 5.11: example of learn animals app.

Achieving deep science learning requires students to engage in problem-solving. To manage the complexity of problems, teachers should provide them tools, scaffolds, and social support (Choi et al., 2018). Incorporating games into science education boosts children's learning. These games enable visualisation and experimentation. In particular, visualisation is considered a substantial factor helping children with discovery and problem-solving (Sánchez & Salinas, 2008). Digital games allow children to exercise their mind by playing well-designed games, which in itself is considered a process of learning. When children try to find ways to solve the problem, they immediately engage in a cognitive process, which involves finding solutions (Doleck, Bazelais, Lemay, Saxena, & Basnet, 2017), for instance,

Noor chose the insect puzzle app. She needed to place the insects' pictures in the correct spots. She placed all the pictures on the top of the screen and then dragged each insect to the correct spot provided. She organized the pictures on the top because she did not want to get confused by the sparse amount of puzzle pieces. She wanted to focus on one piece so as to be done with it in the right manner before moving on to another piece (field notes, lesson 14).

This is supported by Sung and Hwang (2013), who found that students' mindtool apps, which are educational and collaborative games to learn science, improve their learning achievement. In addition, they enhance their motivation and learning attitudes. Utilizing these games promotes problem-solving and collaborative skills. Gamified applications expose children to positive learning experiences as they interact with game materials, for instance, the mastery of problems by finding the best solutions, using failure to assist them in learning to eventually win, competing until reaching the targeted goals, and playing roles (Fraser, Shane-Simpson, & Asbell-Clarke, 2014), as indicated in the following observation:

Huda selected the matching game. She was asked to match baby animals to their moms. She finished the task accurately and told Wafa, 'I matched all of them correctly the first time. I did not make any mistakes.'
Wafa – 'Was it easy?'
Huda – 'Yes.'
Huda explained to her playmate how to play the game: 'You have to help the baby animals find their moms. If you look at the baby animal and see that it looks like his mom, put him on the box with the mom. The mom was happy when I put her baby back, and she smiled.'
Wafa – 'Easy.'
Huda – 'Because I taught you how to play it' (field notes, lesson 13).

Equipping the science classroom with technology tools such as mobile devices and using them in an appropriate way engage students in a constructive knowledge process and improve their problem-solving skills, as they are allowed to develop their critical thinking (Guzey & Roehrig, 2009), which is considered to be a substantial science learning objective where learners can grasp and judge inputs in order to make the appropriate decision (Lai, 2015). In addition, thinking critically requires learners to recognize the problem and find solutions, observations, predictions, analyses, explanations for making a decision, and comparisons (Sung & Hwang, 2013), as indicated in the following observations:

Huda selected animal apps when she looked at the turtle picture. She told Samar, 'The turtles and snails have something on their back; they are always holding them. I think this stone on the turtle's back made them walk slowly.' Then she told Samar that turtles are bigger than snails and that they have four feet (field notes, lesson 13).

Reema told the teacher the snakes and caterpillars look like each other.
Teacher – 'Maybe they look alike but are different? Who can tell me the difference between snakes and caterpillars?'
Reema – 'Snakes are longer than caterpillars.'
Samar – 'Snakes are bigger than caterpillars.'
Huda – 'Caterpillars have small feet, but snakes do not. They slither to go anywhere' (field notes, lesson 15).

The app fostered children's critical thinking skills as they solved the puzzle and analysed the pictures, which enabled them to compare insects. Children learned about insects' characteristics and behaviours, which are a part of the Saudi science curriculum. In fact, children must think critically in science because, in that way, thinking will lead to the development of their analytical skills and of their capacity to make convenient choices that positively impact their everyday life by avoiding bad decisions (Syabandari, Firman, & Rusyati, 2017). New knowledge can be generated as a result of critical thinking where children engage in complex thinking that allows them to reach creative solutions for problems (Doleck et al., 2017). Puzzle activities help children acquire some basic abilities (e.g., think independently, explore actively, research, and express clearly) (Huang, Liao, Huang, & Chen, 2014).

Noor selected the fish puzzle. She completed some pictures of different kinds of fish. Then she asked the teacher, 'Do fish have teeth or only sharks?'
Teacher – 'What do you see in the picture? (pointed out into screen)

Noor – 'I think they have tiny teeth and the sharks have big teeth. They could eat other fish' (field notes, lesson 14).

The fish puzzle app was selected to support children learning about fish characteristics, which is a part of the Saudi science curriculum When Noor solved the fish puzzles, she recognised that shark had teeth, which aroused questions in her mind about other fish. Noor asked the teacher and she focused Noor's attention on the fish's mouth. The clear and detailed pictures of fish enabled Noor to recognise the difference between the fish's teeth and compare them. In this way, the teacher's support assisted Noor to find the answer for her question. The combination of the app's design and the teacher's support led to Noor's science learning in this example.

Figure 5.12: example of fish puzzle.

Farah browsed the animal app, which included different types of animal environments and habitats. She matched the penguin with the igloo, and she asked the teacher why we do not have snow in Riyadh for penguins to live in: 'I love them; I wish we have snow.'
Teacher – 'There is no snow in Riyadh because our weather is called a desert, which is hot, and penguins will not like it' (field notes, lesson 17).

Using handheld devices' apps in science learning provides students with situations that allow them to construct their knowledge. When children face certain problems, they tend to solve them or ask adults or more experienced people for help. This effort in finding solutions assists them in learning through exploration (Huang et al., 2014), as indicated in the following observation:

After finishing the fish game, Randa told the teacher, 'I think fish do not need oxygen; they can live under water.'
Teacher – 'All living creatures need oxygen, so fish need oxygen to stay alive.'
Randa – 'How they get the oxygen?'
Teacher – 'They can get the oxygen from water, and they can breathe under water' (field notes, lesson 15).

Randa selected the fish app. After browsing it she told the teacher there are too many animals beside fish in the sea (she was surprised).
Teacher – 'Yes, not just fish. There are crabs, octopus, seahorses, and lobsters' (field notes, lesson 15).

Puzzle pictures that highlight details efficiently assist children in recalling information (George Korakakis et al., 2012). Children's imaginative abilities are affected by visualisations that are conceived as a form of cognition. Creating mental images through visualisation contributes to meaningful science learning (Barak et al., 2011), for example,

While solving the butterfly puzzle, Noor asked the teacher, 'Do butterflies make honey like bees?'
Teacher – 'No.'
Noor – 'But they always fly over flowers like the bees do.'
Teacher – 'Yes, that is right, but bees only produce honey' (filed notes, lesson 14).

The meaningful comprehension of science allows children to be capable enough to apply scientific principles for different situations requiring problem-solving (Chen & Chen, 2015). The adoption of mobile games is an effective method for children to learn scientific concepts and construct knowledge by exploring, analysing, and investigating (Ward et al., 2013). Furthermore, students can establish ideas and explanations that promote their learning (Lui & Slotta, 2014).

Randa selected the insect app wherein she looked at the insects' pictures and then told the teacher the fly and the bee could fly like birds.
Teacher – 'But they are different. Can you tell me how they are different?'

Randa – 'Yes, the bees and butterflies are small, and birds are bigger than them, and the birds have feathers, but bees and flies do not have feathers' (field notes, lesson 15).

Randa's analysis of the app pictures and animations enabled her to explore the common characteristic among flies, bees, and birds, which is their ability to fly. It also enabled her to compare them according to size and appearance. Puzzles and matching activities, including animal apps, insect apps, and fish apps, aim to help first grade children learn about animals, an important element of the Saudi science curriculum. In this example, the teacher's questioning enabled Randa to clarify her understanding. Animal apps offer children learning experiences about baby animals and their sounds, food, and habitats. Children are required in this game to match baby animals with the adults and match animals with a suitable environment, and they need to solve problems by deciding where each animal should live and which baby animal belongs to which mom. Likewise, the insect app provides children with a selection of insect puzzles and matching games. It also provides them with an interactive experience with app elements after solving the puzzle. The game attracts children due to its funny animated pictures. Utilizing this app helps children gain knowledge about some insects, for example, spiders, ants, snails, caterpillars, and flies. Finally, the fish app enables children to discover sea animals and explore sea creations that live under water by playing puzzle and matching games.

The children's interactions with apps and mobile games that were mentioned earlier evidence their role in supporting science learning. That is also supported by many researchers; for example, Jaipal and Figg (2009) found that children interacted with Evolution, which is a highly interactive game that requires children to personify animals' roles and perform problem-solving activities, as these skills are fundamental in science learning. In the same vein, Hautala et al. (2018) developed a virtual tutoring application to teach students about animal behaviours through audio-visual lessons. They found that the application improves students' understanding of scientific concepts and assists them in mastering core science principles.

Regarding insects, Su and Cheng (2013) proposed a mobile learning system to assist students in learning about insects (MILS). They employed a gamified learning approach. The result showed that incorporating mobile games within the learning process positively influenced students' achievement in science. Likewise, Tarng et al. (2018) found that learning about the butterfly life-cycle via Android-based mobile apps improved students' learning effectively, as they became familiar with the butterfly's development and behaviours. Moreover, they found that mobile learning was interesting and motivated their learning. Taking advantage of mobile tools is considered to be an appropriate aid for science education.

Lastly, Song and Wen (2018) found that the adoption of the BYOD approach and using apps as learning tools in the science class enhanced students' understanding of fish anatomy.
Science required children to gather information about animals and plants via observations and verification and by gathering knowledge through different methods such as experimentation. Children explored their natural environment through their interactive activities and daily experiences, as they became involved in the learning process (Lee & Tu, 2016). It cannot be denied that observation is an important scientific skill, but in some countries such as Saudi Arabia, outdoor observation is difficult because of climate conditions, as the desert is extremely hot in the summer and very cold in the winter. It is difficult for young learners to go outside for a long time to obtain information through observation. Furthermore, this kind of observation may take a long time. Additionally, as this is a desert environment, it is difficult to find insects, birds, animals, and plants, except for some types that adapt to this weather, as they live outside of urbanization (Tarng et al., 2018). Even though students have the opportunity to practice outdoor activities, in some situations students are unable to make observations and acquire deep understanding due to some environmental conditions or animals' behaviours; for example, in the bird lesson, not every child had the opportunity to watch the birds through the telescope because they might fly away (Huang et al., 2010). All of these circumstances adopt mobile learning as the most effective solution to obtain knowledge about natural science (Tarng et al., 2015). In addition, digital games facilitate children's understanding of such scientific concepts and assist them in obtaining knowledge about these concepts (Lee & Tu, 2016). Game-based science learning enhances children's concentration and active participation. Moreover, it leaves a deeper impression that cannot be reached using traditional methods (Zhi, Liu, & Chen, 2013). Additionally, mobile games and apps help children learn the relation between cause and effect as well as how to focus, find quickest direction toward the goals, apply reasoning, and recognize the existence of problems in the game, thereby finding the best solutions (Bulu, 2010).

Without a doubt, the most significant way to encourage children's science learning is practice, as it enhances instructional outcomes. However, in Saudi Arabia students learn about animals and plants in the classroom context due to environmental and climate circumstances that make them unable to apply science class knowledge, as they cannot use observation and practice some outdoor activities. As a result of that, their depth of understanding is affected. This limitation can be solved through the use of advanced technology and its applications to assist students in learning about some required outdoor scientific concepts. Handheld devices and their applications provide great opportunities to facilitate science learning, especially among children, as technology offers solutions for problems and allows them to overcome some circumstances in the learning process such as scientific concepts that require conducting dangerous experiments. Additionally, many science subjects need observation and recording, which sometimes need long periods of time. Some abstract concepts are difficult to understand. Multimedia representations, virtual reality apps, and augmented reality apps facilitate their understanding (Yen et al., 2013). Nowadays tablets and iPad are widely used among Saudi children. Working with these devices is shown to provide a strong link to children's lives, thus impacting their learning, as handheld devices assist them in making connections between newly acquired scientific concepts and existing knowledge (Hochberg et al., 2016).

5.5. Scaffolding of science learning

Scientific skills must be scaffolded by cultural and educational tools because they are not routinely developed (Morris et al., 2013). Furthermore, optimal challenges, when accompanied by appropriate scaffolds, contribute to maintaining children's engagement and keep them within ZPD zone proximal development. This helps children overwhelmed by or bored of conventional methods to be active and stimulated. This is broadly in agreement with Hamari et al. (2016). Vygotsky believed that providing children with proper instructions and support promotes their accomplishment of tasks. The scaffolding should be within children's zone of proximal development (Vygotsky, 1978). Children should be provided with opportunities allowing them to implement realistic tasks with scaffolding support which assists them in carrying out larger tasks without the requirement of learning sub-tasks (Lee & Dalgarno, 2012). Scaffolding can support two kinds of learning; these are self-regulated learning and independent learning. Providing children with appropriate scaffolding enables them to achieve their goals, perform tasks efficiently, and solve problems. In fact, cognitive support including apps, teachers, and peers contributes to bringing children closer to a state of independent competence (Warwick & Mercer, 2011).

The provision of multiple formats and levels of scaffolding can be tailored to the multiple children's zones of proximal development in any classroom, which guarantees that all of them have the opportunity to be supported and guided. A lack of scaffolding and guidance negatively influences children's discovery and excludes exploration that might not support their learning (Hirsh-Pasek et al., 2015). This is supported by many studies, such as Kim & Hannafin (2011), who examined how peer, technology, and teacher scaffolds impacted sixth grade students' inquiry and scientific problem-solving skills. The results of their study indicated that incorporating diverse types of scaffolds helps students solve scientific problems by applying and trying various inquiry patterns. Furthermore, scaffolding strategy facilitates inquiry activities. In the same vein, Palincsar, Fitzgerald, Marcum, & Sherwood (2018) examined the roles of digital device scaffolds, science teachers, curriculum, and peers in scaffolding sixth grade learning about the properties of states of matter. In particular, Palincsar et al. (2018) employed video clips as scaffolds for trigger students' thinking purposes. They found that offering students different scaffolding strategies assisted them in identifying states of matter, comparing models, revising, sharing, creating models, and recruiting their attention and interest.

Scaffolding is one of the more prominent findings that emerge from the data. I have found from extracting data three forms of scaffolding supporting first grade children's science learning in a mobile learning context; these are app-based scaffolding, science teacher-based scaffolding, and peer-based scaffolding. They will be explained in the following sections. Additionally, evidence arising from the interviews and observations will be provided in order to clarify how scaffolding assists children in performing science tasks and using navigation apps. Moreover, how scaffolds influence children's science learning is discussed.

5.5.1. Apps as a learning scaffold

Mobile apps provide learners with a variety of learning experiences and scaffolding activities which allow them to construct their knowledge and explore using suitable methods in multiple contexts to meet learners' needs. App scaffolds afford dynamic support to cater to the needs of every individual learner (Ward et al., 2013). App-based scaffolding is features of apps that offer instructions and guidance, helping children to understand tasks' purposes and use the apps correctly. Moreover, this kind of scaffolding makes complex tasks accessible and manageable, which makes learning tractable (Laru, 2012). In fact, appropriate help that apps provide children in the forms of feedback, hints, or rewards assists children to learn and become self-reliant (Melero, Hernández-Leo, & Blat, 2011). App-based scaffolding promotes children's engagement with tasks, even if they are difficult or complex. This type of scaffolding may reduce complexity by helping children focus on critical ideas (Barzilai & Blau, 2014). Digital scaffolding is utilised to bridge the gap between skills needed to complete a task successfully and current skills children already have (Kao et al., 2017).

Mobile apps afford many scaffolding features that match the learning activities' challenge with children's skills in order to facilitate children's learning (Hamari et al., 2016). For example, pointing out mistakes – this form of scaffolding helps children find mistakes immediately after making them by providing some instructions. This type of scaffolding helps children complete the task effectively (Yin et al., 2013). In addition, providing children with some hints about a solution when they are unable to solve the problem themselves helps them discover ways to perform the task (Yin et al., 2013). In other words, hints give children some suggestion or clues to help them go forward (Kim et al., 2018) for example:

Huda matched the baby animals with their mothers. When she made a mistake, the tablet vibrated. When vibrations occurred as feedback in response to mistakes, Huda was able to rethink her choice and select the best solution. Embedded scaffolds enable learners to infer a game's rules and help them make knowledge more accessible.

Farah selected an ocean animal puzzle app. When she chose the wrong piece to solve an octopus picture puzzle, the piece did not fit with the other pieces of the puzzle. This required Farah to choose a new piece that fit with the other pieces and position the pieces correctly to solve the puzzle.

Highlighting the pieces of a ladybird puzzle allowed Huda to recognize the pieces' correct location. In response, she changed the direction of highlighted pieces to fit the appropriate location. These supportive digital scaffolds in jigsaws puzzles helped Huda and Farah to reach solutions and overcome challenging tasks.

Furthermore, coaching, which is a form of scaffolding, supports children during learning tasks. This form of scaffolding is considered a reaction to misconceptions that affect children's understanding (Lee & Dalgarno, 2012). Lastly, the presence of feedback assists children to move toward competence. Naturally, in the same class, different students have different ZPDs. Mobile devices could help them deal with complex tasks through technical scaffolding; thus, learning takes place (Yin et al., 2013). This kind of scaffolding supports children by demonstrating the structure they need to perform complex tasks (Kao et al., 2017)

The data suggest that when the apps provided instructions within activities this allowed children to know: the activity's learning goals, available resources to use, where and how these resources can be found, and what will they achieve when they complete each activity (Aristeidou & Spyropoulou, 2015) as reflected in the following observation:

Noor selected the making pottery app and followed the steps to make a vase, and when she arrived at the baking stage, she asked the teacher the following:
Noor – 'Why did you burn it?' (meaning the vase).
Teacher – 'You mean bake it. What do you think?'
Noor – 'To make it dry'.
Teacher – 'We could put it under the sun in an outdoor place, and it will get dry'.
Noor – 'Hmm, I think because you can change its colour to black when burned'.
Teacher – 'I do not think so. We could paint it with black colour'.
Teacher – 'I will tell you why'.

Noor – 'Why?'

Teacher – 'We need to bake them to protect the vase from easy breakage and to make it stronger' (field notes, lesson 18).

Figure.5.13: technical scaffolding provided by pottery app.

This example indicates that the instructions provided support to Noor's learning, and she generated a question to make further understanding. This interplay of the teacher scaffolds (providing feedback, simplifying, questioning) and digital scaffolds (animation, instructions, and feedback) enabled Noor to acquire the relevant substantive knowledge of making pottery. The apps' multimodality and interactivity acted as mediational aspects that mediated teaching actions through highlighting and visualising activities, providing just in the point and just in time feedback to young learners, and moderating and creating discussion among science teacher and children, which enabled children to explore problems and concepts.

This is supported by Yu et al. (2013), who found receiving fifth-grade students' immediate scaffolds in a mobile learning context supported their generating questions in science class. Additionally, Wu, Weng, & She (2016) indicated that incorporating different instructional supports improved scientific inquiry among middle school students. Also, Wu et al. (2016), in line with those studies found explicit instruction scaffolding usually seems suitable for children in particular, which might assist them to correct misunderstanding. Indeed, receiving children's direct instructions supports their learning performance in contrast with free play that lacks defined learning goals (Hirsh-Pasek et al., 2015). Children often need instructional support while they engage in scientific activities, which helps them to understand (Wu et al., 2016). Mobile game scaffolds could contribute to reducing children's frustration, which assists them in creating effective strategies to solve problems (Sun, Chen, & Chu, 2018). Children engaging in problem solving need scaffolding support to promote their cognitive abilities (Belland, Weiss, Kim, 2018). Solving problems becomes more manageable and accessible when children are supported by scaffolding (Kim et al., 2018). They could receive scaffolding while they utilised apps through changing the difficulty of the problem, also it offers them just-in-time hints. For example:

Randa bought attention to hints the puzzle app provided it because they enabled her to solve the puzzle correctly after two failure tries. Which helped her control confusion and frustration (field notes, lesson 2).

When they encounter frustration, children tend to give up. Consequently, they could overcome game challenges by using scaffolds that the game provides, which increases their engagement and enjoyment (Yong Ming Huang & Huang, 2015). Incorporation of problem-based activities with appropriate scaffolding strategies increases children's problem-solving skills. Provision of scaffolding promotes children to challenge the problem and use strategic thinking in order to find suitable solutions (Phumeechanya & Wannapiroon, 2014). When children get stuck while they play the game, scaffolds can enhance their motivation to continue playing and create feelings of success. Providing children with optimal challenges that are convenient with their capacities fulfils their need for competence (Sun et al., 2018). Mobile games can afford children scaffolds and challenges in proper balance, which maintain children's motivation. In addition, they provide children with multiple chances to solve problems and succeed, which promotes persistence and risk taking (Riconscente, 2013). Employing scaffolding strategies in problem-based learning in science improves students' learning performance (Kim et al., 2018). This supported Kao et al.'s (2017) study to facilitate physics learning and a customized puzzle game called 'Crayon Physics Deluxe', which demonstrates two types of scaffolds to assess their influence on science learning. They found that various types of scaffolds can support acquiring knowledge and various creativity perspectives. Apps' scaffolding features can be used to elucidate game rules and discover strategies. Moreover, they make children familiar with needed skills to complete the levels of the game with minimum frustration (Sun et al., 2018). This is reflected in the following observation.

Reema – 'I collected six stars in the memory game'.
Wafa – 'Amazing'.
Reema – 'I will play another game to collect ten stars'.

Wafa – 'I think it will be harder'.
Reema – 'No, I do not think so. I just need to find the similar fruit pictures' (field notes, lesson 19).

The example indicated that the scaffolds that the app provides enabled Reema to understand the purpose of the game to play it in correctly to collect stars, which contributed to deeper engagement with game. This is in line with Sun et al. (2018), who found that rewards and scaffolds in the 'Professor Sudoku' game influenced children's engagement with activities positively, which led affected their learning positively. Motivational scaffolding has the ability to support children's autonomy, mastery goals, and self-efficacy. These scaffolds promote children's perseverance to keep trying during solving problems (Kim et al., 2018). Scaffolding strategies have the abilities to keep children motivated by controlling frustration and reducing difficulties. Moreover, they guide children toward playing goals clearly. Finally, they highlight needed information and required concepts to solve tasks (Kao et al., 2017). Guidance tools and scaffolds that mobile games and apps provide can support autonomous learning and impact children's engagement in the game positively (Sun et al., 2018). This finding is in agreement with Sun et al. (2018), who indicated that technical scaffolding can promote children's interest, engagement, and motivation (Kim et al., 2018). For example:

Farah selected the magical seed app. She followed the panda farmer's instructions to plant grape seeds, protect the grape tree from monkeys, and take care of it. When she saw the bunch of grapes, she was very excited, and she told Lamar, 'The grapes appeared because I looked after them. I will plant grapes in our patio. I know how to plant' (field notes, lesson 8).

Figure 5.14: technical scaffolding provided by magical seed app.

Educational mobile games, when they are embedded with appropriate scaffolding strategies, contribute to enhance children's learning motivation (Yong Ming Huang & Huang, 2015). Provision of scaffolding assist children to achieved desired outcomes when they suggest diverse ways to take advantages of tools and available resources (Lee & Dalgarno, 2012). Playing games supported with proper scaffolding and feedback meet learning needs that enable children finish tasks and solve problems, which satisfies them with the game experience (Kao et al., 2017), as reflected in the following observation:

Farah matched the polar bears to the environment they should live in. The app generated audio ('great job'). When she heard the audio, she smiled and told the teacher 'I'm smart. I put the bears in their favourite place. I know which place they prefer to live in. No one told me. They love snow and ice' (field notes, lesson 17).

The previous example indicated that feedback is considered a scaffolding strategy that provides children with information about their performance (Kim et al., 2018). Kim et al., (2018) indicated that feedback as scaffolding had a strong effect on students' learning. Handheld devices could provide technical scaffolding and summative feedback, recompensing the lack of teacher scaffolding sometimes (Nouri, 2012). Some children tend to use scaffolds to avoid losing points and advance to the next level of the game, and they relied on the scaffolding technique to reach correct answers (Sun et al., 2018). For example:

Abrar asked for Huda's help with playing the bird game. Huda told her that the first thing is to match the birds with their shades. If they give you stars, that means you have done a good job (field notes, lesson 13).

Feedback and hints that apps display assist children to recognise and correct their misconceptions and errors, develop efficient strategies to solve problems, and contribute to higher learning outcomes (Basu et al., 2017). The core element of scaffolding is feedback. It makes children ask themselves many questions about actions and the reasons, which boosts them to try various strategies until they arrive at solutions (Podolefsky et al., 2010). Educational apps and serious games can scaffold children through their ZPD with appropriate feedback where the feedback allows them to learn from their failures and rewards their success (Ward et al., 2013). Some apps such as simulation apps enable students to conduct experiments in quicker and more efficient ways due to their capabilities to scaffold the concepts to be completed during performing the task (Lee & Dalgarno, 2012). Receiving scaffolding through simulation helps children assimilate and build representations of scientific knowledge (Lee & Dalgarno, 2012). For example:

Sarah – 'What have you learned from the apps in science class?'
Farah – 'Hmm, how do you make delicious toast?'
Sarah – 'Can you tell me the recipe? I mean, how do you cook it?'
Farah – 'Yes, it is too easy. Add some flour, oil, water, and salt. Then mix them. Mix, mix, mix. Then put the mix in the pot, bake it, and eat it' (laughs).

Figure 5.15: scaffolding provided by bread factory app.

Virtual simulation cooking experience scaffolded Farah's learning about baking in less than five minutes, which enabled her to obtain knowledge about how get the flour and knead it then bake it. Scaffolds that mobile games offer are capable of assisting children's learning and help them in gaming processes (Kao et al., 2017). This finding is consistent with Ese Monica & Olatubosun (2013), who found provision of scaffolding helps children learn new concepts and develop new concepts where this support is removed when they achieve competence. Providing children with systemic scaffolding that matches their mental models enables them to internalise and integrate new concepts into structures of existing knowledge (Kao et al., 2017). As forms of scaffolds, some serious games require children to cooperate with virtual characters who have skills and knowledge the children might lack but that contribute to scaffolding and supporting their learning (Morris et al., 2013). When children work with virtual characters as a team, each member has specialist knowledge. They share the same goals and attitudes toward tasks. This scaffolding process supports their learning (Morris et al., 2013).

Visual and audio support which apps offer could reduce the complexity of the activity and assist children's thinking about scientific concepts (Yu et al., 2013). For example:

Sarah – 'What did you learn from apps in science class? Like new information or new skills?'
Randa – 'Something new'.
Sarah – 'Yes, please'.
Randa – 'I have learnt about how rain falls'.
Sarah – 'Can you show me the app that helped you learn about rain falling?'
Randa – 'That one'.
Sarah – 'The rainy cloud app helps you to learn about rain falling? How does the app help you learn?'
Randa – 'In the rainy cloudy app, I saw the story of clouds. The clouds in the sky got together, they clashed then turned into dark or grey colour. After that the rain fell. I love when it is raining because I like to play in the patio under the rain with my brother'.
Randa told the teacher, 'I love this app', (pointing on the screen) 'rainy cloudy app'. The teacher asked her why. She said, 'Because the little cloud talked and taught me about raining. I love the pink bow that she wore'.
App-based scaffolding could assist children in visualising and externalising their understanding (Kim & Hannafin, 2011). where this kind of scaffolding allowed children construct complex models with greater ease and better visualisation (Lei et al., 2016).

Visual representations can make knowledge of scientific phenomena explicit, as in the following examples:

While engaging with the Magical Seed app, Randa pointed to the roots on the screen and told the teacher, "The tree drinks water from here." (Field notes, lesson 5)

This app visualised planting stages. Representing the stages, needs, and parts of plant growth using animation elucidates the change from one stage to the next and clarifies the sequence. This helped Randa identify the roots' function and recognise how plants get water to stay alive.

While Randa engaged with Kingdom of Birds app, she told me, "Birds put their eggs in their nests because they do not want their eggs to fall from the trees and break." After two minutes, she added that birds' houses are very small. (Field notes, lesson 13)

The example above clarifies that Randa recognised the habitat of birds and understood that they build their nests in trees to protect their eggs. The app's unique representational opportunities assisted in scaffolding Randa's learning about birds. Such scaffolds can support children's efforts to refine their understanding and address learning needs.

Noor selected the cupcake baking and decorating app and followed the sequential steps to bake a cake by mixing ingredients, baking, and decorating. During the decorating step, she added chocolate powder to the mixture and told the teacher that the cream turned brown. (Field notes, lesson 18)

Step-by-step instructions that described the baking process enabled Noor to know that something has to come before something else. In addition, multiple representation led to a better visualisation of the cooking experience, which scaffolded Noor's learning about types of food such as, milk, flour, eggs, oil, and sugar. Changing the icing cream's colour allowed Noor to obtain information about how the colour of one type of food can be changed by adding another type of food.

Reema engaged with the Learn Animals app. She told the teacher that penguins can walk on snow, but lions cannot. (Field notes, lesson 16)

Observing the pictures of animals' habitats and playing a game in which she matched animals with their habitats allowed Reema to discover the characteristics of some animals' environments and compare them. Interacting with scaffolds helps children internalise knowledge and achieve their goals independently.

To engage children productively in the modelling of scientific phenomena, they need support from explicit scaffolds (Lei et al., 2016). In mobile learning environments, technical scaffolding allows children to be self-reliant through support they receive (Ed & Ed, 2013). MDK is an iPad app designed as a scaffolding tool to support fifth-grade students learning various species of birds. Knight & Davies (2016) found the students' use of the app allowed them to work at their own pace, encouraged collaborative learning, and engaged them, which decreased off-task behaviour. Technical scaffolding contributes to maintaining learning flow, decreases the need for teacher support, helps students face the obstacles that might impact learning, and familiarises students with necessary skills that they need to perform tasks in the correct manner (Nouri, 2012).

Serious game playing can develop independent learning and encourage transfer of knowledge so children are able to control their thoughts, select convenient strategies, set goals, and resist distractions. This indicates they are able to be self-regulated learners (Warwick & Mercer, 2011). Digital scaffolds help children find solutions for complex problems, thus increasing their knowledge (Kim et al., 2018). Receiving different types of scaffolds such as discovery questions, role playing, and instructions supports their self-directed learning (Michael, 2014). For examples:

Sarah – 'What is your favourite type of app that you have used in science class?'
Huda – 'I liked the app where I pretend to be a farmer'.
Sarah – 'Can you tell me why you prefer that app?'
Huda – 'Yes, because I planted the pumpkin seeds and took care of them'.
Raghad 'Yes, we took care of the plants by protecting them from monkeys'.
Raneem 'I liked the games because I can be a chief, I can be a farmer, I can be anything I want' (FG, 2).

Digital scaffolds offer children unique opportunities enabled them to practice activities that encourage scientific thinking, as happened in the previous example where presence of successful scaffolding (spoken instruction and digital animation) contributed children learning to perform tasks independently (Kim et al., 2018). Receiving proper scaffolding allowed them to organise their information by recognising the relationship between concepts.
Apps' multimedia abilities can scaffold children's science learning by offering them hints about important elements that might be misunderstood or not included (Ward et al., 2013).

Reema started the milk factory app and then selected the camel to get the milk from. She told Aya that the camel has milk like cows and sheep. She was surprised and found it very funny (field notes, lesson 19).

The Milk factory app was used as a depictive resource that enabled Reema to explicate her (mis)understandings.

Reema and Wafa used the same bread factory app. Reema told Wafa to kill the bugs, as they will eat the flour. Then she told the teacher, 'I think bugs like to eat flour. I should protect my flour from them'.

Teacher 'They ruin the flour. We should keep flour in a dry, clean place' (field notes, lesson 19).

This interplay of the Bread Factory app's scaffolds (instructions, animation, feedback) and the teacher scaffolds (explanation, elucidation) allowed Reema obtain accurate knowledge and correct the misinformation.

Using technology in science class might guide children to concentrate on critical aspects of problem that need to be solved through observing phenomena, identifying evidence, constructing solutions, and collaborating, which contribute to supporting children's effort to concretising abstract concepts and visualise thinking (Kim & Hannafin, 2011). Falloon (2017) found primary students' receiving scaffolding through apps to support their learning about energy concepts assisted them in structuring experiments, obtaining knowledge about procedures, and thinking about the influence of variables, as indicated in the following transcript:

Sarah – 'Do you think apps help you learn science?'
Reema – 'Yes'.
Wafa – 'Yes'.
Sarah – 'How do the apps help you learn?'
Wafa – 'They help me to have information'.
Sarah – 'Can you give me an example of the information you have received from apps?'
Wafa – 'Yes, do not throw rubbish in the street or in the sea because pollution can happen' (FG, 3).

Technical-based scaffolding is the support that apps offer learners during the quests (Neumann, 2014). In the current study, children received technical scaffolds through apps. These scaffolds were represented in various forms of multimedia; for instance, spoken instructions, signals (arrows), positive feedback and rewards, visual hints, visual aids, animation, tips, clues, highlighting, various levels of difficulty, and modelling. The apps provided scaffolds to navigate children in the right direction in the form of visual and auditory cues (Tucker, Moyer-packenham, Westenskow, & Jordan, 2016) . Examples of app scaffolds that children used in current study were as follows:

- *Magical seed* - The panda, which is the main character of the game, provided children with spoken instructions that start with selecting the seed, farming step by step, and collecting fruit or vegetables. The app provided children scaffolds besides instructions in the forms of highlighting, animations, spoken feedback, and signals, which helped them carry out the farming experience individually.
- *Bread factory* – Children's journey in the virtual bread factory was scaffolded, starting with farming wheat and ending with distributing toast into supermarkets. The scaffolds that children received were in the form of breaking the task into levels, with each level involving one step of preparing the toast. Spoken feedback (e.g., 'awesome nice job'), spoken instructions, and signals such as arrows, highlighting, and animations helped them to understand how they perform the activity. All of these scaffolds enabled the children to perform farming and bread-baking tasks. In addition, scaffolding helped children learn about producing bread, which enabled them to obtain knowledge about how the factory's machines work, while they not allowed to visit such factories to prevent sterilisation issues or injury.
- *Cloud adventure* – While using this app, the children received scaffolds through spoken feedback, the cloud's actions such as thumbs up, the cloud's emotional state such as happiness or sadness as reactions to children's decisions or selections, and the cloud's facial expressions. Therefore, children could manage the task due to theses scaffolds.
- *Healthy children app* – This app provided children scaffolds in the form of spoken instructions, highlighting objects, and signals, which helped children elicit that taking a shower and being clean affects their comfort and mood positively, which they deduced from characters' actions and facial or verbal expressions. Moreover, animations scaffolded children's learning about germs and bacteria, which can impact their health. These abstract concepts were scaffolded through animation, which clarified the small details. As a result, children gained important knowledge to keep them safe and healthy.
- *Milk factory* – The app's scaffolds were represented by spoken instructions, signals, animation, and breaking out the task into levels starting with taking care of animals that produce milk and ending by distributing the milk into bakeries. All of that helped children carry out task requirements and gain knowledge about dairy products and how they are processed.
- *Insects apps* – This app provided children scaffolds in the forms of selecting puzzle size or pieces, matching the pieces of puzzles with outlines of images, removing the outline choice by pressing on the magnifying glass icon, positive feedback, and rewards such as starts, claps, and balloons.

- *Fruit memory* – Children received scaffolds through selecting the number of cards that they wanted to play with, which enabled them to control the level of difficulty, and positive spoken feedback.
- *Bird app* – Positive feedback and arrows.
- *Sea creations app* - This app employed scaffolding strategies through providing children signals to direct children to use app functions, spoken feedback such as ‘great job’ and ‘amazing’, rewards such as stars and balloons, collecting stickers, dragging the puzzles’ pieces according to image outline, and selecting the level of difficulty.
- *Feed animals’ app* – The scaffolds represented were collecting toys as rewards to play with animals by using them, positive feedback, and the device shaking when children made wrong selections of foods that animals like.
- *Pottery factory* – Children could manage the app through arrows, highlighting, spoken instructions, and breaking the task into levels with each level involving one step of making pottery, starting with collecting clay and ending with decorating and packing the pottery to sell it.
- *Learn animal app* – This app provided scaffolds such as spoken instructions, signals, highlighting, positive feedback, and showing examples.

The purposes of scaffolding children’s science learning was to help them access resources, use effective strategies, understand, search for needed knowledge, encourage a focus on important steps leading to accomplishing tasks, make sense of complex principles, investigate, model, evaluate, hide complexity, use the tablets’ functions, plan activities, promote thinking, engage with science activities, communicate ideas, articulate thoughts, generate questions, share information, provide instructions, make thinking visible, offer explanations, prevent frustration, simplify tasks, suggest needed actions, make careful observation, obtain knowledge, and explore. In a few words, app scaffolds can guide children’s exploration and convert their experience with handheld devices using coincidence swiping and poking that offers them opportunities to benefit from the contents (Hirsh-Pasek et al., 2015).

When I selected the apps to support science learning, I took into account appropriate scaffolding strategies due to their roles in assisting children to carry out tasks independently and chose apps that did not require a lot of reading or writing because first-grade children still need time to master these skills. However, it is not impossible to find apps that do not require reading. When children need to know what these words asked them to do, some of them asked the teacher directly to read for them to make good decisions and be aware of next steps. Others chose randomly, discovering the responses of their selections by themselves and making decisions according to these responses. In sum, using mobile games to learn science means providing guidance and scaffolding to encourage deep, meaningful learning (Ahmed et al., 2012). Scaffolded experiences that apps offer children assist them to participate actively in their learning process. Children have full freedom to explore how to use various apps and discover their features, which helps them perform tasks and achieve goals. Games' technical scaffolds not only help children play the games effectively but also create visible learning behind the games (Herodotou, 2018). Moreover, educational apps might help teachers by providing children with technical scaffolds for individual learning tasks (Knight & Davies, 2016) that support children managing and carrying out tasks, which helps teachers to be free and makes them available to work with low-achieving children who need help. The prominent feature of app scaffolds is their capability to offer support for diversity by providing individualised support that can accommodate various skills, styles, and backgrounds of students when a classroom situation includes various students' situations.

5.5.2. Peers as a learning scaffold

Scaffolding offers children a strategic framework to assist them in the knowledge integration process. Different scaffolding forms support the occurrence of meaningful learning and assist children in making connections between new knowledge, prior knowledge, and experiences (Chen, Hwang, & Tsai, 2014). Peer-based scaffolding assists children to stay in their zone of proximal development, which engages them in the learning process (Vygotsky, 1978). Throughout this project, a science teacher broke a class into small groups of children in order to provide less capable children opportunities to benefit from capable peers and enhance social interaction between children. The data suggest that social interactions and discussion between peers about mobile learning activities help children construct their personal understanding and scaffold their science learning. This concurs with DeWitt, Siraj, & Alias (2013) who found that peer interactions in collaborative mobile learning environments facilitate students' building of science knowledge through scaffolding and promote their inquiry. CMI supports peer-scaffolded learning. Furthermore, Rahmani, Abbas, & Alahyarizadeh (2013) found that peer scaffolding in mobile learning environments engaged students in learning double-loop and improved their scientific skills. For example:

Huda asked her group, 'Do you know why woodpeckers dig at trees?' They all fell silent and looked at her. Then she told them, 'Because he makes a house' (field notes, lesson 13).

Reema utilized the fruit memory app; she told Samar 'A watermelon is like a large ball and an orange is like medium ball and a grape is like a tiny small ball' (field notes, lesson 4).

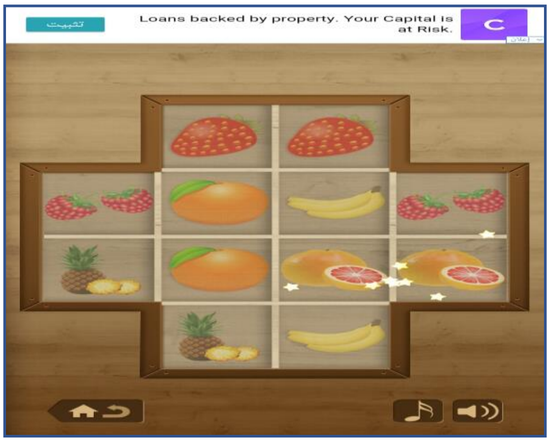


Figure 5.16: example of fruit memory game.

Farah selected the cooking app. She chose to make a cake, and when she put the cake inside the oven, she told Anfal, 'I made a cake and put it in the oven; the heat will rise the cake and it will become spongy. Looks delicious. I love cakes' (field notes, lesson 5).

Noor looked at the bee picture (the picture appeared after solving a puzzle) that clarifies the parts of a bee's body. Then she told Lama, 'If you see bees flying in the garden or on a flower, do not touch them because they will sting you. A bee stung my brother on his feet and he cried all day long'. She put her finger on the bee's bottom, precisely on the bee's stinger, and told Samar 'The bee stung my brother with this needle' (field notes, lesson 14).

The apps' multimedia features offered the students a variety of opportunities to animate and visualise scientific knowledge. The apps' animation of a bee prompted Noor to recall when a bee stung her brother. Recalling prior information about bees' behaviour enabled Noor to add to Lama's knowledge of bees by providing her with new facts about bees' body parts and where their stinger is located. In addition, Noor's clarifying how the bee sting hurt her brother provided a warning to Lama not to touch bees, which is an important learning point.

Scaffolding is considered an effective instructional strategy to impact children's learning positively (Yu et al., 2013). The previous examples clarified that children's discussion about multimedia representations such as the pictures and animations offered by apps scaffolded their science learning. More accurately, comparing and contrasting and determining cause and effect are scientific skills. Children support their peers' learning about these skills through discussion. Children in science classes need to communicate and interact socially, as well as debate issues related to science principles and topics. These actions allow them to link existing knowledge with new knowledge (DeWitt et al., 2013). Provision of discussion opportunities among children helps them in building personal understanding of science phenomena (DeWitt et al., 2013). When children engage in negotiation and dialogue, more knowledgeable peers contribute to building knowledge by providing clarifications, raising important issues, and pointing to resources. In fact, less knowledgeable learners can also contribute to the learning process through asking for clarifications and bringing up questions.

However, some children tend to engage in discussion and interact with peers more than with the teacher, which might lead to obtaining inaccurate information as a result of misunderstanding. Indeed, any learning strategy employing this type of scaffolding has disadvantages as well as advantages. Children receiving misinformation while scaffolded by peers is considered one of the negative effects of this form of scaffolding, and must be taken into account to avoid children obtaining incorrect knowledge. This happened in the current study, but in my role as a participant observer, I sat with the children in the same group and heard all of their discussions while the science teacher was busy with other groups. This allowed me to correct this misinformation. For instance:

Randa told Wafa, 'Octopi eat humans when they swim in the seaside' (field notes, lesson 15).

Reema told Aya, 'Chocolate is healthy food' (field notes, lesson 4).

Lama and Noor debated about cows' colours. Lama told Noor, 'There are no brown cows. Cows only come in black-and-white colour' (field notes, lesson 18).

The drawbacks mentioned here did not obliterate the positives of peer-based scaffolding, which when employed leads to exchange of information, social interaction, sharing resources, discussion, and debate (Rahmani et al., 2013) as indicated in the following examples:

Randa told her group when she saw the butterfly in the insects app that the butterfly was a caterpillar when it was a baby.
Wafa – 'How do you know that?'
Randa – 'I saw her story in the Bream (Arabic children's TV channel); she was a tiny green caterpillar, then she ate a lot of leaves, then she turned into beautiful butterfly'.
Wafa – 'I love butterflies'.
Randa – 'Me too; their colours are very beautiful, and they do not sting like bees' (field notes, lesson 15).
The digital animation of the butterfly that Randa saw in the app about insects prompted her to recall the information about the butterfly lifecycle that she watched on TV, thus linking knowledge gained across media. Randa was able to recall the lifecycle from her TV viewing and articulate it in this instance. This in turn scaffolded Wafa's learning about butterflies by providing her with new knowledge, not only about the lifecycle, but also about butterflies not stinging (thus relating the information about butterflies to knowledge on bees that had emerged in an earlier use of the insects app).

Noor discovered how to change the background of the drawing app. She told her group about her discovery and was excited while she explained to the other children how to change the background (field notes, lesson 6).

Farah pointed out on Samar's screen (on the learn animal app) and told her, 'This app has a lot of games. You can feed a baby giraffe or return the baby animals back to their homes or do puzzles. You can do a lot of things' (field notes, lesson 17).

My observation of the children revealed that children's interactions with skilled peers were for many purposes, such as learning how to do something that they could not do alone, as reflected in the following observation:

Huda selected a matching game. She was being asked to match baby animals to their mothers. She was able to finish the task in the right manner, and she told Wafa, 'I matched all of them correctly the first time; I did not make any mistakes'.
Wafa – 'Was it easy?'
Huda – 'Yes'.
(Huda explained to her mate how she could play the game) 'You have to help the baby animals find their moms. If you look at the baby animal and see that it looks like his mom, put him on the box with the mom. The mom was happy when I got her baby back and she smiled'.
Wafa – started the game and told Huda – 'Easy'.
Huda – 'Because I have taught you how to play it' (field notes, lesson 13).

Previous examples indicated that scaffolding could help children achieve goals which they are unable to achieve unassisted. Scaffolding seeks to bridge the gap between children's goals and their current abilities (Yu et al., 2013). Likewise, children playing as a pair contributes to better understanding of the game and boosts peer learning (Rahmani et al., 2013). The other purpose of establishing children's interactions with peers and groups was for them to have support for some technical problems. On the other hand, they exhibited helping behaviours when others asked for help, as reflected in the following observation:

When the app froze, Farah asked Lama for help.
Farah – 'I cannot play, nothing moves' (kept tapping on the screen).
Lama – 'Mmmm, I think you need to turn it off'.
Farah – 'No, I do not want to turn it off'.
Lama – 'Okay'. She turned back to her tablet for one minute, then told Farah, 'I have an idea, I think you need to press that button' (pointed to lock screen button).
Farah – 'Okay' (followed lama's instruction).
Lama – 'I think you need to wait'.
Farah – 'Okay'.
After almost 30 seconds, Lama told Farah, 'I think it will be fixed. Try it again'.
Farah – 'Okay' (touched screen to unlock it). 'It is working!' (smiling; field notes, lesson 5).

Also, some children asked for assistance and support from their peers in some situations. For example, children asked each other when they needed technical skills to deal with the tablet, to perform certain tasks, or when they experienced the same things that skilful peers had done (Kim & Hannafin, 2011) as follows:

Noor asked Amal about the matching game that she had played.
Noor – 'How did you get to the game? I cannot find it'.
Amal – 'It is in that app' (pointed out the learn animal app on the screen). Amal explained to Noor verbally how she could reach it and play it (field notes, lesson 18).

Randa told Mena, 'You cannot pop the balloons in this way. If you just touch them, they will not pop. You have to do it like this' (explained by practically tapping on screen). Then she looked again at Mena's screen and told her, 'Fast, fast, fast', to pop all of them (field notes, lesson 15).

Supportive scaffolding affords students advice and support while they do the tasks and serves three purposes, which are modelling, guiding, and coaching (Yu et al., 2013) as reflected in the following observation:

Abrar asked for Huda's help with playing the bird game. Huda told her that the first thing is to match the birds with their shades. If they give you stars, that means you have done a good job (field notes, lesson 13).

All the examples mentioned earlier demonstrate that skilled and capable children support their peers' utilization of apps and benefit from their functions. In addition, children benefit cognitively if they play serious games mediated by more capable peers and teachers (Herodotou, 2018). Furthermore, peer-based scaffolding, representing an exchange of multiple perspectives, assists children to challenge and check out their solutions and ideas (Kim & Hannafin, 2011).

5.5.3. The science teacher scaffolding learning

During scaffolding, the teacher helps children by providing them temporal support, enabling children to establish learning task which they are unable to establish alone (Driel, Slot, & Bakker, 2018). Vygotsky believed that children could advance their learning if provided with temporary guidance, and scaffolding is considered an instructional strategy to assist children with improving their learning abilities (Kao et al., 2017). in other words, children can use scaffolding tools and resources in an effective manner for learning purposes with teachers' guidance and orchestration (Yin et al., 2013). Children being scaffolded could complete the tasks – scaffolds make the tasks simpler by making the structure of the task explicit or encouraging children to start with simpler activities. In fact, the presence of teacher-based scaffolding in challenging tasks relieves children who experience discomfort due to frustration or confusion. This improves their emotional state as result of developing positive self-efficacy (Atwood-Blaine, Thomas, & Lee, 2015).

At the beginning of each science class, the teacher introduced the lesson and talked shortly and generally for almost ten minutes about the app selections and explained the activities and tasks that children needed to perform. After that, the children had freedom to select an app and an activity. When teachers' instructions take place before beginning in learning task, children's learning is supported in three ways: modelling, lectures, and demonstrations (Lee & Dalgarno, 2012). This is supported by Yu et al. (2013), who found giving children instructional scaffolds before starting an activity might help them cope with difficulties they might encounter that lead to initial failure. Certainly, effective scaffolding of children's learning requires that teachers be physically close to them when they perform the apps' activities; teachers should show children positive verbal or nonverbal reactions to their successes or overcoming of obstacles. Technological affordances have the power to convert a teacher's role as a source of knowledge to that of a facilitator of children's learning (Kim & Hannafin, 2011). In the current project, the science teacher's role was as a facilitator, which required that she guide and extend children's learning. She employed various scaffolding strategies because of some of them were suitable for some students while at the same time ineffective for others. This affirmed that some scaffolding forms are not useful for every student.

The science teacher had background information about children's abilities and their zones of proximal development through monitoring and observing children. This enabled the teacher to know about problems that they encountered related to science learning, then provide them appropriate scaffolding strategies to help them solve the problems (Jong & Tsai, 2016). In addition, the teacher's interaction with children enabled her to identify their current skill levels, thereby assisting them according to their current abilities. All of that helped the teacher provide support and guidance for children who could not accomplish the tasks. This appropriate support allowed children to move to higher levels of competence independently, and also assisted children as whole when they asked for help (Ed & Ed, 2013). Receiving supportive scaffolding helps children succeed in solving problems and helps them gain skills which are beyond their current abilities (Kim, Belland, & Walker, 2018). This form of teacher-based scaffolding contributes to developing self-regulation: children being held responsible for their learning improve their agency for achieving autonomy. In fact, self-regulation can move them away from dependency on the teacher to be more autonomous. The data obtained in this study indicated that the science teacher scaffolded children's learning during their interactions with apps by utilising questioning, modelling strategies, guiding, and activating prior knowledge (Neumann, 2014). This concurs with Melero, Hernández-Leo, & Blat (2011), who indicated that involving teachers in playing games with children in mobile learning environments requires them to employ some pedagogical methods such as inquiry-based learning and scaffolding, which assist children in constructing knowledge, as indicated by the following examples:

Huda selected the animal-feeding app. She saw a baby giraffe and baby sheep drink milk and then asked the teacher if baby animals drink milk.

Teacher – 'Yes, some of them'.

Huda – 'I think baby birds do not drink milk'.

Teacher – 'What do you think they love to eat?'

Huda – 'Hmm, worms. I saw on YouTube that baby birds in the nest cannot fly. Their mom brought them worms, and she put the worms in their mouths because they did not have hands' (field notes, lesson 16).

This example indicates that when children's understanding was scaffolded by their science teacher, they engaged with scientific activities and linked formal scientific principles to their everyday experiences, which assisted them in realising that science as tool can be used to learn about the world around themselves (Podolefsky et al., 2010). The interplay of the digital animations and teacher scaffold (clarification in this case) allowed Huda to obtain information about some baby animals' favourite food and recall prior knowledge about baby birds. The enabled Huda to recognise that not all babies' animals drink milk. The science teacher's scaffolds contributed to explicating co-existing intuitive ideas and scientific ideas and eliciting students' intuitive ideas or misconceptions.

Throughout the project, the science teacher employed different scaffolding strategies. For example, she selected the right time to ask the right questions, provoked children's inquires, provided proper assistance when children needed it, and offered alternatives so children could select freely from them. The following excerpt offers a typical example of this:

While Huda was using a tree colouring book app, the science teacher asked her, "Do all trees have the same shape?"
Huda said, "No."
The science teacher asked, "How they are different?"
Huda answered, "Um, some trees are tall, and some are short, but they are all brown and green." (field notes, lesson 1)

This interplay of the teacher's scaffolds (participating, questioning) and the app's scaffold (pictures of different types of trees) directed Huda's attention to compare between the tree shapes. The educational apps extended the teacher's pedagogical resources and also extended her ability to scaffold students' learning. Teacher scaffolds helped children to focus on overarching ideas and increased the salience of some key points.

While Reema was playing a cake baking game, the science teacher asked her, "What do you put in the mixture?" The teacher pointed to the mixing bowl on the screen.
Reema replied, "Flour, water, eggs…um, sugar…um, and oil."
The science teacher said, "Fantastic! Can you tell me which of these ingredients come from animals?"
Reema answered, "Eggs. Chickens make them and sit on them."
The science teacher said, "That is right, Reema."
Reema then told the teacher, "Grandma's eggs are brown, and ours are white." (field notes, lesson 5)

The cake baking game app scaffolds' (instructions, digital animation) and science teachers scaffolds' (participating, questioning, feedback) assisted Reema to compare between food from plants and food from animals and obtain information about ingredients recipe of baking cake. Using educational apps to assist children's science learning created a fluid space which facilitated teacher's and children's communications and interaction and enabled them to reconcile scientific and informal ideas, pose questions, and explore science ideas together

While Reema was using the fruits and vegetables app, the science teacher asked her, "How do we get fruits and vegetables?"
Reema replied, "Um, from trees."
The science teacher then asked, "Okay, what do trees need to give us fruits and vegetables?"
Reema said, "Um, water. Um, sun." (field notes, lesson 4)

Digital scaffolds, along with the science teacher's interaction with Reema, assisted her to construct their understanding about plants' needs, and helped her remember information from lesson one about the life creators' needs and link it to the current lesson while using the app.

Learning science involves the study of complex and abstract concepts; thus, children need support to understand them. Scaffolds could serve this purpose by encouraging children to concentrate on crucial concepts, explicate conceptual knowledge which they are unable to grasp, and obtain declarative knowledge. The previous examples clarified the role of the science teacher in scaffolding children's learning, which in this case involved focusing their attention toward the differences and similarities through asking questions. The science teacher's scaffolds took multiple forms in mobile learning contexts, such as giving comments on children's progress, providing technical support, helping children become familiar with the tasks' requirements, providing introduction to the activities, questioning, discussing, providing clear guidance to help children reach correct answers independently, and motivating children.

The science teacher employed this active communication as required, asking children for explanations and predictions, directing their attention toward relevant aspects of concepts, correcting their errors, encouraging making comparisons, asking discovery questions, and instructing (Hsin & Wu, 2011). Furthermore, the science teacher could scaffold children's learning through supporting them in applying previous lessons' knowledge, which was required to construct new lessons' knowledge (Palincsar et al., 2018). For example:

After finishing the fish game, Randa told the teacher, 'I think fish do not need oxygen; they can live underwater'.
Teacher – 'All living creatures need oxygen, so fish need oxygen to stay alive'.
Randa – 'How do they get the oxygen?'
Teacher – 'They can get the oxygen from water, and they can breathe underwater' (field notes, lesson 15).

The fish game's digital scaffolds aroused Randa's questions about fishes' need for oxygen, which made the science teacher provide her individual scaffolding. She scaffolded Randa's learning by asking her a question about living creatures. As a result, Randa could find an answer for her inquiry by remembering prior knowledge. The science teacher, along with the digital scaffolds, assisted Randa to develop a stronger understanding about how fish breath. This is broadly in agreement with Kim & Hannafin (2011), who found that teacher-based scaffolding is beneficial in elaborating children's emergent knowledge and eliciting their prior understanding. Likewise, the guidance and support that the science teacher provides children are necessary in helping them develop deeper understanding of scientific phenomena (Hsin & Wu, 2011). This is in line with Hsin & Wu (2011), who found that when kindergarten children received teacher-based scaffolding, it influenced their abilities and increased their ability to elucidate floating and sinking. Also, according to Inan & Inan (2015), science teacher guidance helped children utilise scientific skills and thereby learn about scientific concepts and principles. Additionally, Falloon (2017) found that providing children with scaffolding to support their science learning enabled them to interpret and analyse information to construct their own understanding. For example:

Reema told teacher the snakes and caterpillars look like each other.
Teacher – 'Maybe they look similar, but they are different. Who can tell me the difference between snakes and caterpillars?'
Reema – 'Snakes are longer than caterpillars'.
Samar – 'Snakes are bigger than caterpillars'.
Huda – 'Caterpillars have small feet, but snakes do not. They slither to go anywhere' (field notes, lesson 15).

The previous example illustrated how the use of open-ended questions in scaffolding conversation strategy contributes to children's science learning, knowledge construction, and hypothesis generation. Dialogue can support children until they are independently able to apply new skills (Ward et al., 2013). This is in agreement with Yin et al., (2013) who employed mobile learning simulation techniques to help students learn about conceptual knowledge. They found that scaffolding and discussion with the teacher assisted children in comprehending complex and abstract concepts. This could be observed in the following examples.

Noor was engaging with a cloud adventure app which included information about the water cycle. The app also included illustrations of clouds, lakes, plants and so on. Noor looked at Ayah and told her that water goes up to the sky and back down again to us
Science teacher – What happens to the water in the water cycle? (Field notes, lesson 20)

The science teacher utilised the multisensory resources of the app in scaffolded's Noor learning about rain falling and the water cycle. She named the cycle explained by Noor and provided her with a new scientific concept. The apps gave the science teacher a range of choices to enrich her teaching practices and enable the Saudi Arabian science curriculum to be delivered in an engaging manner.

While Noor was using the Kingdom of Birds app the teacher asked her, "Are there animals other than birds that can fly?"
Noor – No, only birds.
Science teacher – You think only birds can fly?
Noor – Yes
Science teacher – Okay, what about a small insect that produces honey? Could it fly or not?
Noor – Yes, bees can fly, and butterflies.
Science teacher – Very good. So not only can birds fly, but there are some insects that could do that too (field notes, lesson 13).

In this example, the science teacher used two scaffolds (which were asking questions about flying animals to prompt Noor to think the answer, as well as providing a hint), along with digital scaffolds of the app (digital animation and feedback) which assisted to think about flying animals.

While Reema was using a fruit-puzzle app, the teachers asked her the differences between a watermelon and a banana.
Reema – Mm, a banana is yellow, and a watermelon is green and red.
Science teacher – Can you give me another difference?
Reema – A watermelon is like a ball, and banana is like the letter R (the letter R in Arabic is ر).
Science teacher – Can you think of another difference?
Reema – Mm, I don't know [shrugging shoulders]

Science teacher – Okay, when you open up a watermelon, what do you find inside it?
Reema – Fusfus *[a type of seed that some Saudis eat with tea, which looks like watermelon seeds]*
Science teacher – You mean, black ones.
Reema – Yes.
Science teacher – What do we called these small ones? It is not fusus.
Reema – [She shrugs her shoulders]
Science teacher – We put them under soil and water them to get watermelons? Reema – Seeds, seeds.
Science teacher – Right. What about a banana?
Reema – No seeds in it.
Science teacher – Right, okay, that means some fruits and vegetables have seeds on them and others do not (fieldnotes, lesson 4).

In this example, the science teacher scaffolded Reema's learning about fruits and seeds by asking questions to help her think about and compare them. In addition, the teacher provided a clue to assist Reema in her ongoing inquiry. Apps were also indirectly supporting young learners by directly helping the science teacher to strengthen her teaching practices and become a more effective human scaffolding agent. The science teacher's scaffolding practices included: contextualising the concepts and scientific principles embedded within digital resources, explaining, and elaborating, assisting children in conceptual understanding. This showed the potential of educational apps in prompting conceptually oriented teacher–learner talk. Using apps to support science learning among first grade children enhanced interactivity, as the science teacher moved from an instructional to a guiding role and used tablets to integrate, develop, and stimulate the interactive learning environment.

My observation of children suggests that teacher scaffolds can help children in obtaining new knowledge or skills and developing learning habits. They can stimulate children and produce effective learning outcomes (Knight & Davies, 2016). Scaffolding positively influences students' stimulation and enhances their thinking about goals and problem-solving (Yu et al., 2013). Teachers and caregivers should design environments and contexts that provide children with opportunities to experience and do things independently in appropriate ways. That is possible with scaffold experiences, which provide children proper guidance. As a result, they develop a sense of accomplishment (Ward et al., 2013).

In the recent study, the teacher agreed that the role of all scaffolding types is to support children's learning. This was inferred from her criticism of parents who just give their children tablets without guidance solely for play, which wastes their time and does not benefit them:

Giving children handheld devices is not enough to guarantee that learning will occur. A lot of children consider these devices as entertainment tools rather than using them for educational purposes because of some parents' styles. They do not guide them to take advantage of good educational apps, share learning experiences with them, or provide support when their children need it. They just want their children sitting nicely and not bothering them, no matter what they use the tablets for. So as teachers and educators, we should guide children to pay attention to using tablets not for play only, but also to assist in the learning process (teacher interview).

The absence of science teachers' scaffolds may lead to children unable to concentrate on phenomena's crucial features or provide meaningful explanations (Hsin & Wu, 2011). Their instructions assist children with managing activities and guide them to deal with problems facing them while they perform the tasks. Children's scientific understanding can be optimised by appropriate instructional support (Hsin & Wu, 2011), and their confidence can be built and enhanced by scaffolding that provides support for different aspects of learning (Kao et al., 2017). Without a doubt, the science teacher was not able to provide scaffolding for all children in the classroom within a 45-minute period, but technical scaffolding and peer scaffolding could help students perform the apps' tasks and solve problems (Kim et al., 2018). I indicated in this section teacher and peer scaffolding even though my study was focused on apps and their support of science learning for many reasons. First, children received peer and teacher scaffolding within the mobile learning context, so I have pointed them out as very important for readers to get a comprehensive picture of scaffolding. Second, these two forms of scaffolding have impacted children's science learning as well as apps. Third, social constructivism theory emphasises that learning take place in a rich social context described by interaction, collaboration, articulation, and negotiation. Absence of teacher support in mobile learning contexts impacts the application of scaffolding negatively. App-based scaffolding alone cannot guarantee reinforcement of children's learning because some children ignore using the tablet as an educational tool and focus on entertainment aspects. In addition, this kind of scaffolding cannot prohibit erroneous thinking among young learners due to their various levels of prior knowledge and because each child is different with regards skills and abilities.

They sought their teacher's support when had difficulty. The children could not dispense with their teacher's support to construct their knowledge properly and avoid misconceptions. Implementing different forms of scaffolding contributed to ensuring that learning effectiveness was maximised for each form in complementary ways.

Application of different types of scaffolds in science class would be beneficial for children with regards to scientific observational skills (Knight & Davies, 2016). Consequently, teacher and peer scaffolding are worth explaining and elucidating. Briefly, numerous scaffolds are embedded in educational apps (e.g., procedural support, representing ideas by using multiple means, narrating, drawing, writing, and utilising simulation). Without a coherent, rich curriculum, peer interaction, and teacher mediation, the potential of these scaffolds will not be achieved (Palincsar et al., 2018).

In the science classroom, apps were used as resources that enabled children to explicate their (mis)understandings and obtain new knowledge. The apps scaffolded children's learning through a range of features such as their design, their structure, the prompts used to spark thinking, and the feedback given on activities. When children used the apps with peers, the rich discussions elicited understanding and enabled them to develop ideas together, which promoted development of the children's conceptual understanding. The tablets created an interactive space for young learners that involved them in problem-solving situations in which they could actively make choices and participate. Further, the science teacher guided the children's attention towards the apps' resources and structured, organised, and elicited their knowledge. In addition, the science teacher participated actively in the activities as a contributor and orchestrated the supportive aspects of the digital resources, instructional design, and peer collaboration to further develop the young learners' conceptual understanding. When the young learners were engaged in app activities, the science teacher acted as an important resource and provided different forms of guidance during the children's scientific learning activities. Moreover, the science teacher's and the apps' concrete and constructive feedback assisted children by making the problem-solving process more visible. Thus, the combination of the apps themselves, the peer-interactions and the teacher input was powerful and led to learning across a range of areas that were important elements of the Saudi science curriculum.

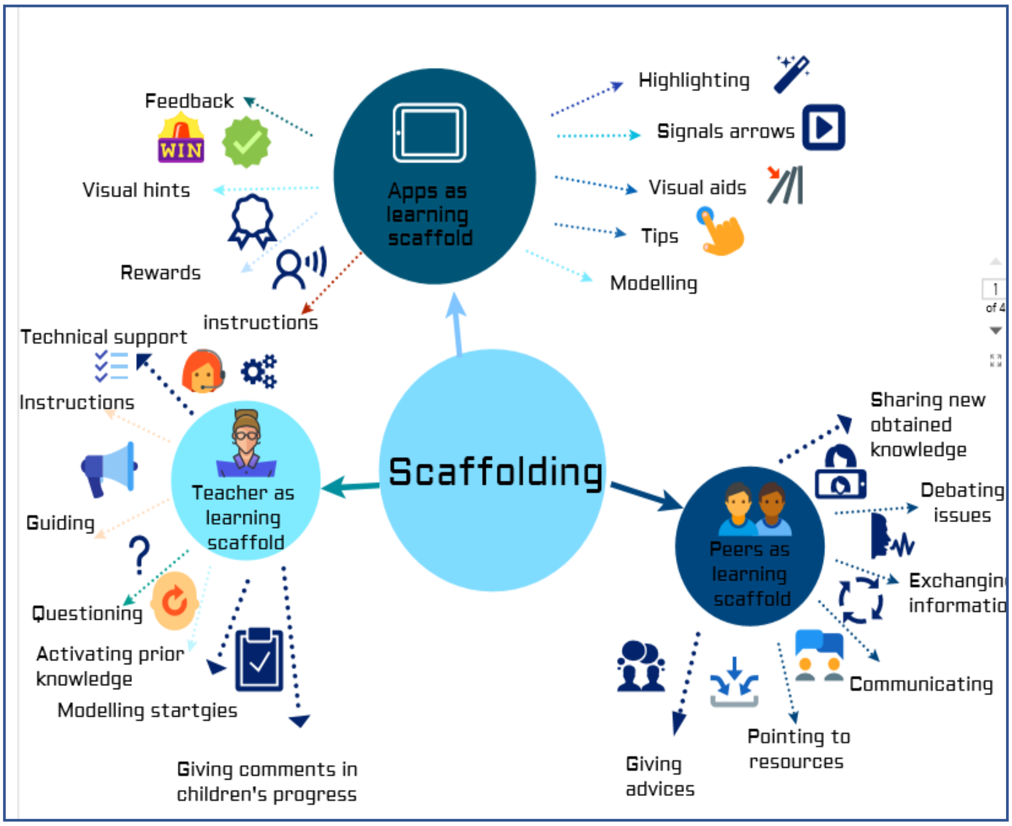


Figure 5.17: infographic of scaffolds that provided for children in this study

Conclusion

Integrating mobile devices into science education can influence children's learning positively if joined with adequate instructional scaffolding (Chang, 2017). The absence of scaffolding might breed among learners an unwillingness to repeat activities that have been not done correctly and impact children's engagement in exploratory activities negatively (van der Meij et al., 2015). Applying distinct types of scaffolding assists children in their learning experiences. Scaffolding should be taken into account while selecting apps and games for learning purposes because they contribute to deep engagement and immersion, thus learning take place (Hamari et al., 2016). Learning might occur through scaffolding students' interactions with handheld devices using apps' features (Neumann, 2018). A variety of sources of assistance (apps, peers, and teachers) helps children and directs their need to accomplish learning objectives (Knight & Davies, 2016). They recognize the sense of agency which enables them to direct their scientific exploration (Podolefsky et al., n.d.). Appropriate scaffolding supports self-regulated learning and assists students in managing and monitoring their learning, which involves setting learning goals, choosing proper cognitive strategies, and organising the learning process (Lee & Dalgarno, 2012).

5.6. Barriers and challenges encountered conducting mobile learning in science class

Despite the possibility that mobile learning as a new trend in education can enhance teaching and learning, this kind of learning has some limitations that should be taken into account as issues arise in its application. The challenges vary according to several factors, such as the education system, economic situation, and culture, which can hinder successful integration (Minshew & Anderson, 2015). I will explain some obstacles and barriers associated with mobile learning in this study.

5.6.1. No home button

Focus group discussions clarified that every child involved in this project had access to tablets at home. They owned iPads and Galaxy Tabs, which have external designs different from that of the Huawei media pads that were used in the current research. Galaxy Tabs and Huawei tablets run on the Android system, and iPads run on the iOS system.

Samar – I have iPad.
Wafa – Me, too. I have iPad.
Lama – I do not have iPad. I have Tab.
Amal – Me and my sister have one iPad. My mom told she cannot buy two.
Reema – I do not know its name. Its look like iPad, but it is not iPad. (smiled)
Lama – What its colour?
Reema – Black.
Lama – I think it is Tab, like mine.
Reema- I do know. I will ask my dad, then tell you tomorrow (FG, 1).

Figure 5.18: the design of Huawei Media pad tablet.

At the beginning of each lesson, the science teacher introduced the lesson and talked for about ten minutes about the installed apps and explained to the children what they needed to do, thus helping them deal with the new devices and apps. When I introduced the tablets, the teacher and I were amazed that children knew how to slide the screen to unlock the tablet, explore it functions, resize images, and increase and decrease the volume. The one task the majority of children had a problem with was exiting from an app to select another because the Huawei tablets do not have a home button. After almost one month using them, most children could leave the apps, which required them to slide their fingers on the screen downward from the top until the circle appeared on the bar and then tap on it to return to the home screen so they could switch apps. The children encountered difficulty moving between apps, and they needed assistance, which caused the teacher to break off from helping other children to advise them, even though she showed them how to do this task at the beginning of class. Some children kept asking questions:

Huda - How can I get out? (field notes, lesson 1)
Noor, complaining - I want to choose another game, but I'm stuck (field notes, lesson 3).
Reema - The circle did not appear, so I cannot get out (field notes, lesson 2).

As indicated in the previous examples, children faced difficulty in using Huawei tablets. They were used to dealing with another kind of tablet, and this difficulty caused disruption for the children and the teacher. However, they learned how to exit apps by following the teacher's instructions and through trial and error. The apps greatly motivated them to discover the new devices' functions.

5.6.2. Slow responses and freezes

Mobile learning is a key part of learning in the 21st century, and accessing mobile devices' latest features greatly benefits learners. However, continuous advancement in handheld devices might lead to multiple technical problems (Asiimwe & Grönlund, 2017). Tablets and their functions can encourage learning, engagement, and motivation in children. However, the introduction of mobile devices leads to some physical and technical challenges (Gedik, Hanci-karademirci, Kursun, & Cagiltay, 2012; Wu et al., 2012). Problems such as the tablets freezing, giving a slow response, and suddenly shutting down can easily frustrate children. Technical problems impact on children's interaction with tablets, satisfaction, and motivation negatively and affect teachers. Furthermore, unexpected and sudden technical problems distract children, make them concentrate on irrelevant activities, and cause them stress (Terras & Ramsay, 2012). Some apps on the tablets froze because of programming bugs, and the screens did not respond to the children's touch, thereby interrupting their work. This failure did not occur more than seven times, and we restarted the devices to solve the problem. The children were annoyed and kept tapping the screen, thinking they were helping us solve the sudden technical problem. In fact, this action aggravated the problem and lead to apps' slow responses. Even though this event was not observed frequently, it impacted learning and the class atmosphere. It might take the students off track for a few seconds, hampering their concentration and increasing the time needed to perform a task (Howard & Howard, 2017). Muehrer, Jenson, Friedberg, & Husain (2012) found that technical problems in their study often discouraged the children and made them lose interest.

The performance of mobile learning devices, along with their low screen resolution and uncomfortable backlight, negatively influenced the children when the touch screen had a delayed response or was unresponsive to their selections. Low and high backlights could affect children's eyes (Asmina & Mohd, 2018). I took that fact into account and set the device's backlight to medium to avoid children's unpleasant interactions with the tablets.

In the current study, some children appeared to easily handle the tablets freezing and helped their peers overcome these problems. The others asked for my and the teacher's assistance in such cases:

When the app froze, Farah asked Lama for help.

Farah – 'I cannot play. Nothing moves' (kept tapping on the screen).

Lama – 'Mmmm. I think you need to turn it off'.

Farah – 'No, I do not want to turn it off'.

Lama – 'Okay'. She turned back to her tablet for one minute, then told Farah, 'I have an idea. I think you need to press that button' (pointed to lock screen button).

Farah – 'Okay' (followed lama's instruction).

Lama – 'I think you need to wait'.

Farah – 'Okay'.

After almost 30 seconds, Lama told Farah, 'I think it will be fixed. Try it again'.

Farah – 'Okay' (touched screen to unlock it). 'It is working!' (smiled; field notes, lesson 5).

The advice that Lama gave Farah helped her fix the freeze when Farah did not want to turn the tablet off because she did not want to lose her work. We did not face any battery- or storage-related challenges. The devices were prepared and fully charged, allowing the children to work for 35 minutes without interruptions.

5.6.3. Lack of hands-on experience

Educational apps and mobile learning cannot replace learning from real science experiences, which allow children to interact with their surrounding environment by using all five senses to explore plants and animals in physics and chemistry. We also cannot replace simple experiments in real school labs, where children can interact with various materials to make discoveries about the world, find persuasive answers to their questions, and develop observation skills (Faour, Ayoubi, & The, 2018). Depending on apps as the way to teach science and neglecting simple experiences in the science curriculum prevents children from having the hands-on experience they need as a basis for later education and to construct their knowledge. However, some developing countries with a huge numbers of students in classrooms lack lab equipment. Technology and its means, such as virtual labs, can support science learning (Faour et al., 2018). Moreover, the simulation and modelling experiences that apps provide facilitate science learning and allow students to visualize and explain abstract concepts that might otherwise be hard for them to grasp. Combining multimedia with science learning is considered the best solution among educators to overcome cost and time constraints, especially in situations where science is taught only with printed books (Dewi et al., 2018).The multimedia experiences that apps provide, whether audio, video, images, 3-D, or animation, reflect the details and descriptions of real objects. Moreover, images from apps can provide explanations and information about concepts or phenomena better than written words can, and they can stimulate children's thinking (Hernawati, Amin, Irawati, Indriwati, & Omar, 2018). Based on the findings of this study, I would suggest that educational apps enhance science learning among children and provide them interactive learning experiences. However, tablets allow children to explore and learn with only three senses: hearing, touch, and sight. The other two senses, taste and smell, are not active because children do not need them in their interactions with apps. More precisely, learning science requires children to obtain knowledge and make discoveries using all five senses, and apps cannot provide this learning experience. That is one negative aspect of incorporating mobile learning into science classes, which teachers can overcome by providing children additional materials to support the development of taste and smell.

5.6.4. Lack of experience with mobile learning and training needs

The teacher appeared to have a positive attitude toward mobile learning due to its impact on children's science learning, but at the same time, she was still anxious about its successful application due to a lack of experience and training. Using technology every day may not guarantee efficient integration of mobile learning, which is still a new learning strategy among Saudi teachers, as the following quote shows:

I owned apple iPhone and iPad, but I never used them for teaching activities. I used them for texting, sending emails, playing games, and social networking (teacher interview).

The quote shows that the teacher had technical skills, but incorporating mobile learning into instruction required more than those simple technological skills. Teachers must obtain knowledge about technology's pedagogical role (Abidin & Parsons, 2015). They must not only effectively integrate educational apps into their curriculum; they must also employ a child-centred philosophy to take advantage of handheld devices and leverage their potential (Blackwell, 2014). Teachers need to enrol in workshops to learn how the technology can help them cover the curriculum's necessary objectives and how they can use it to help low-achieving students, encourage creativity, and enhance children's learning. They also need information about the available apps and programs that support their practice. In particular, science teachers need information about virtual worlds and simulations as well as their latest updates. These technologies enable learners to conduct scientific experiments in a safe environment without worrying about causing damage (Harjono, Sahidu, & Herayanti, 2017) . Furthermore, such technology is an excellent alternative if real lab equipment is limited or too expensive. These workshops add value to mobile learning and motivate teachers to replicate them (Minshew & Anderson, 2015). In addition, teachers need to learn how to select apps that build children's skills, involve content that at their level, motivate them to learn, connect them to the real world, support their creativity, and provide materials that will help them deliver their lessons. In fact, selecting the best app to support learning might be challenging step (Cojocnean, 2017).

Working with technology may involve some challenges that cannot be anticipated, such as technical problems, Internet availability, and bugs need to be fixed, all of which may impact the app or software. To tackle these challenges, teachers need regular training to prepare them for unexpected obstacles (Menon & Steinhoff, 2017). Indisputably, technology is permanently changing teachers' required professional development so they can stay up to date with recent innovations in technology, especially that which enhances their practice. Teachers' beliefs about, self-efficacy in, attitudes towards, and comfort in dealing with technology impact their integration of mobile learning into their practice (Minshew & Anderson, 2015). In the current research, the teacher believed that tablets impacted children's learning positively because she believed apps could present complex scientific lessons in a child-friendly manner, as the following quote shows:

At the end of each unit, I apply monthly school assessments to assess children's scientific skills related to that unit, monitor their progress, and check if they meet the curriculum objectives. I found that most of the students achieved the unit goals. I was surprised that some students had additional valuable information that does not exist in the book related to the curriculum topics, and they told me they got it from the apps. From my point of view, the apps facilitate learning difficult and abstract concepts by playing the games; as a result, indirect learning occurs (teacher interview).

Regarding engagement, the teacher believed that using tablets as an educational tool to support science learning motivated and engaged children. Mobile learning made them love science class more than other classes, as indicated in the following transcript:

Last year, I taught first-grade students. They did not like science classes at all, even if I brought some tools and samples to create simple experiences or changed my teaching style. They always told me science and math were very hard to learn. First grade this year surprised me. They told me and other teachers that science was their favourite class. I noticed their motivation, enthusiasm, and efficiency. There was a significant difference between the two classes I experienced as a teacher. I think tablets create a desire inside them to learn and love science (teacher interview).

Additionally, the teacher saw that apps and games provided children with enjoyable science learning experiences and fulfilled their desire to play, which children need in this stage, as she indicated in the following:

We all know that the children's main activity is playing. Through play, they can discover and settle into a new scholastic environment, but with these classes' possibilities, they could not play or have fun. Using a tablet as an educational tool helped them combine fun by playing educational games and learning science. Also, using tablets made science class the most important class among children and made children interested in and enjoy learning science (teacher interview).

Also, science teachers noticed that tablets' potential and the multimedia that apps provided allowed children to choose a method that was suitable and favourable to learn:

The variety of activities offered by apps such as matching, solving puzzles, drawing, colouring, and watching animations assisted children in selecting a preferred learning style, whether it was visual or auditory (teacher interview).

Children's interaction with educational apps helped them to learn independently. The multimedia assisted them by presenting the information in many forms. This made the teacher believe that adopting mobile learning could reduce reliance on her:

Last year, I was the only source of information. Children completely relied on me, even when they used the book, because they were unable to read. I read for them and we discussed the pictures together. Using the tablet decreased their dependence on me due to their interactions *with the apps and their multimodal features, which assisted them in learning and facilitated understanding (teacher interview).*

As indicated previously, the science teacher appeared to have confidence in technology, and she believed that incorporating handheld devices into science class supported children's learning. She recognized the value of mobile learning in her classroom (Minshew & Anderson, 2015), but she claimed that, *"We need as teachers training programs assist us to use tablets better in class, I think it will be very useful and have good impact on our teaching practice".* After her first experience with mobile learning, the teacher asked for training to be more confident and eliminate anxiety caused by lack of knowledge and experiences. In the classroom setting, tablets cannot be effective if teachers do not have technological knowledge and information about integrating technology to meet students' educational needs (Decoito, 2018). Successful attempts to incorporate mobile learning are limited when teachers do not have a background about the proper use of technology (Minshew & Anderson, 2015). Teachers should be provided ongoing development programmes to learn assessment methods and current standards, and they should be provided continuous training to help them maintain their current skills.

5.6.5. Workloads

It is time-consuming for teachers to explore ways to benefit from technology resources in the classroom and prepare high-quality lessons Alenezi (2017). I asked the teacher about what difficulties she thought were associated with using tablets. She said:

I will need time to preparing tablets, starting with search and find appropriate apps; download them in 18 devices, might be more; make sure they are working in all devices; and ending by taking care of devices; charge them; turn them back to the bags.

She believed that incorporating mobile learning into science class increased her workload due to the need for preparation, which gave her more responsibilities. Teachers spend countless hours preparing lesson plans according to specific standards to attract learners' attention and construct their knowledge. Modifying these plans to align them with mobile learning requires additional, exhausting work besides their normal burdens (Alenezi, 2017). They must also develop and teach lesson plans, assign homework, evaluate children's comprehension of lessons, prepare assignments and assessments, observe children in the classroom, and arrange meetings with parents to talk about their children's progress (Alwraikat, 2017). In fact, adopting new pedagogy and trends in mobile learning requires teachers to change their methods of teaching, adopt convenient teaching instruction for the mobile learning environment (Asiimwe & Grönlund, 2017);,cope with changes that affect activities, students, and processes (Alhajri, 2016) and redesign the current curriculum to suit mobile learning (Asiimwe & Grönlund, 2017).

Furthermore, finding suitable apps that match lessons is a great challenge that teachers might face. Successful app-based lessons entail teachers selecting apps that are aligned with the curriculum and lesson plans (Nang & Harfield, 2018). They also have to consider the number of apps with appropriate content that encourage learners to solve problems, encourage creativity, and increase curiosity. Content-rich media that involves animation, images, video, and audio makes apps more attractive, leading to improve children's learning experiences (Santos et al., 2014). Elements such as rewards and prizes are important in maintaining children's engagement, providing appropriate pedagogical strategies, meeting children's needs, fitting their skill levels, giving them the opportunity to learn at their own pace, correcting their misconceptions, providing culturally appropriate information, aligning tasks with the real world, and providing scaffolding (Baran, Uygun, & Altan, 2017). Teachers need to be able to identify these aspects of apps. On the other hand, teachers must avoid apps that ignore students' perspectives, do not consider their needs, focus only on entertainment, include scientific errors, or contain otherwise inaccurate content (Powell, 2014). Teachers must also find high-quality apps because poorly designed apps impact the technology's usability and may distract students (Damyanov & Tsankov, 2018). Teachers must avoid apps with interfaces that contain many visuals (Baran et al., 2017). The apps must also be simple to use to prevent frustration (Nang & Harfield, 2018).For usability, the apps should provide clear directions, visible functions, feedback, control over tasks, choices, a search option, tutorials, clear instructions, and a help menu (Baran et al., 2017).

Some teachers need to also obtain technological skills and information because their lack of experience may be a burden in implementation because they need more time (Asabere, 2013). For example, upgrading devices to a new version requires teachers to spend time examining the new operating system and its functionalities to become familiar with them (Amerul et al., 2017). It is not surprising that the most common barrier to mobile learning is teachers' time constraints because they must meet many requirements and demands (Alenezi, 2017;

Alwraikat, 2018) Unlike traditional classroom instruction, mobile learning changes teachers' roles, requiring them to design a delivery method and instructional materials to fit the mobile-learning format (Asiimwe & Grönlund, 2017).

5.6.6. Inadequate funding, lack of devices, lack of Internet access

Saudi Arabia is a developed country but is still undergoing a developmental renaissance in many aspects. The government has provided an infrastructure that enable schools and universities to utilize technology, but mobile learning is still in its infancy in Saudi Arabia due to related challenges: management, culture, evaluation, design, and pedagogies (Almutairy, Davies, & Dimitriadi, 2015). Financial challenges have arisen due to lack of funding from school owners. Private schools' owners receive funds from the Ministry of Education, and they are committed to offering students a high-quality learning environment. Moreover, they receive fees from each student of not less than 8000 riyals each school year, but they ignore this type of learning and its potential. Moreover, lack of support makes teachers think about the negative aspects of mobile learning, such as the high cost of Internet access and the lack of appropriate training programs and workshops that would enable them to use these devices efficiently to support children's learning. Embracing mobile learning is clearly a challenge for some schools due to lack of funding (Khaddage et al., 2015). I asked the teacher in the interview about what she needed to conduct mobile learning. She stated:

I need a lot: financial support from the government and the school owner to buy tablets. Also, I need high-speed Wi-Fi-enabled for students to use some apps and research. Finally, a designed plan from Ministry of Education allocated by educators who have a background in mobile learning to follow it (teacher interview).

According to the teacher, she would like to adopt mobile learning even though the school did not show support. It has no devices, Internet connectivity, or programs to develop teachers' and children's technological skills. Lack of Internet access limited the usage of tablets because many superb educational apps require Internet access to work appropriately. If this access is unavailable, the apps will be useless (Al-hunaiyyan & Alhajri, 2016.; Minshew & Anderson, 2015). Moreover, teachers might not adopt mobile learning due to a lack of hardware, which contributes to reluctance to adopt this kind of learning (Abidin & Parsons, 2015). Obviously, a lack of financial support affects technical support, which is the most prominent challenge in the integration of mobile learning in most developing countries. Specifically, teachers require the following: the maintenance of technology; fast connectivity; security; and installation of software updates to repair the devices' bugs, protect information and security, prevent crashes, add features, and boost performance. In fact, a lack of technical support makes keeping up to date with the latest technological developments difficult (Alhajri, 2016).

Implementation of mobile learning requires wireless connectivity, and its absence is a significant hindrance (Abidin & Parsons, 2015). Because we lacked this component, I prepared the tablets before each class where I met the teacher and showed her suggested apps that matched the curriculum's objectives. I also downloaded apps that worked offline.

The common definition of mobile learning is learners using handheld devices to research information without restrictions of time or place. A lack of Wi-Fi prevents learners from connecting to the Internet and attaining information (Al-hunaiyyan, Alhajri, & Al-sharhan, 2016). Without doubt, children need to acquire technological skills to make their learning and lives easy, such as searching engines, browsing apps, and appropriate apps, all of which can be used in a child-friendly setting and under parents' and teachers' supervisions to prepare them to encounter advanced technology, but that goal is impossible to reach without an adequate wireless network in the school (Dias, 2017). It is worth mentioning that learning to use technology should not mean children spend too much time on screens. Caregivers should provide them guidance and regulation to protect their cognitive, physical, and social development and to maximize the benefits of handheld devices and minimize their risks (Mashrah, 2017). Children's use of mobile devices for educational purposes enhances their skills and improves their abilities as 21-century learners. The teacher felt that keeping them from these experiences leads to a wrong conception at an early age about the use of these devices and causes children to treat them as toys for fun and entertainment only (Dewi et al., 2018), as the following quote shows:

Giving children handheld devices is not enough to guarantee that learning will occur. A lot of children consider these devices as entertainment tools rather than using them for educational purposes because of some parents' styles. They do not guide them to take advantage of good educational apps, share learning experiences with them, or provide support when their children need it. They just want their children sitting nicely and not bothering them, no matter what they use the tablets for. So as teachers and educators, we should guide children to pay *attention to using tablets not for play only but also to assist in the learning process (teacher interview).*

In this digital era, many children live in homes surrounded by various smart devices and are thus immersed in digital technology, but they feel that tablets cannot be used for learning because they have not experienced learning with those devices at school or home (Dias, 2017). Incorporating mobile learning into classes can help children take advantage of apps and programs to facilitate and support the learning process, combining learning with fun. In this case, I would suggest that teachers not ignore mobile learning because of a lack of financial technical support. They should try to find solutions to and overcome these problems. For example, they could suggest that children bring their own mobile devices and define rules about their use in the classroom. Technology has spread everywhere and has become an essential part of children's lives (Mashrah, 2017). It provides children an opportunity to learn how to deal with technology in school and at home, and it prepares them for technological advancement in the future.

5.6.7. Control and class management

At the beginning of this project, the teacher believed she lost control of her class because of some children's actions, such as using increased volume, talking with their peers loudly, running in the class, and using cameras to take pictures. I provided each child a small pink bag containing a tablet with a name sticker on the back and a booklet that clarified the rules for tablet use. The teacher always reminded them about the rules and the result of violating them, which was temporarily losing the tablet. She also reminded them that tablets were for learning in the classroom; they were not toys. Holding a tablet and running might lead to damage, such as a broken screen, and replacing them is expensive. A child could also be injured or hit other children. These rules helped her regain control. The children took almost three weeks to adapt to the tablets in science class. Teachers tries to shift the learning context from a traditional to a mobile or smart class, and engaging children with handheld devices might contribute to distraction, reduce concentration, and increase interruptions, which can impact classroom control and management negatively (Terras & Ramsay, 2012).

According to Abidin & Parsons (2015), teachers who participated in their study claimed the mobile devices disturbed their classes. Additionally, Francisco, Gabriel, Marina, Oliveira, & Manuel (2018) found that the presence of mobile devices in the classroom increases distractions among students. Noise, increased volume, and attentional distractions are all forms of interruption that might disturb children's engagement with educational apps, leading to negative consequences and causing children to take a longer time to complete a task (Terras & Ramsay, 2012). Also, other children cannot pay attention, which contributes to tardiness. Furthermore, noise and interruptions inhibit knowledge acquisition (Guliz & Koc, 2015). Moreover, noise in the learning atmosphere can affect children's self-regulation (Guliz & Koc, 2015). In mobile-learning environments, formality is decreased, which might lead to misuse of tablets and create disturbances that prevent teachers from providing a quiet and pleasant learning environment (Guliz & Koc, 2015). Informality makes the learning process more casual, leading to difficulties in controlling children and affecting educational gains. This challenge makes some teachers resist the change and stick to traditional learning because they are not able to manage the change (Al-hunaiyyan & Alhajri, 2016).

Conclusion

Integration of mobile learning into science classes is necessary; teachers, researchers, the Ministry of Education, and school principals must put forth a collaborative effort. Incorporating mobile learning into science classes provides young learners with an opportunity to gain skills, obtain knowledge, connect with the real world, improve their understanding and attitudes, enhance intellectual curiosity, apply scientific concepts, and discover them actively. Consequently, science teachers need to make decisions and demand support from the Ministry of Education to properly integrate this type of learning. Handheld devices can help teachers accomplish learning objectives, control children's actions, and improve their learning (Amran, Ananda, Festiyed, & Sumarmin, 2018). Fast development in technology impacts almost all aspects of life, including education. The handheld devices present fantastic opportunities to enrich learning and teaching experiences. Therefore, the Saudi Ministry of Education and education policy makers need to define clear policies regarding the implementation of mobile learning. The Saudi Ministry of Education is responsible for allocating staff to work in three areas: training teachers, developing software, and maintaining the system. Staff must also perform many other tasks, such as providing plans for financial support and implementation, paying for infrastructure and technical support, designing training programs for teachers and students, improving the quality of service, and offering advisory services for teachers (Al-hunaiyyan & Alhajri, 2016). They must help teachers adopt mobile learning in their practice and make it compulsory, not optional (Asiimwe & Grönlund, 2017). However, research on mobile learning, which would help educators and policy makers design frameworks and models to be integrated into classes, is rare in developing countries. In addition, some difficulties teachers face when implementing mobile learning are the learning environment, culture, and currently adopted pedagogies (Al-hunaiyyan & Alhajri, 2016). Such hindrances cannot be denied.

Chapter Six
Conclusion and Recommendations

6.1. Introduction

The objective of this chapter is to synthesise and assimilate the different topics that appeared in the findings chapter, which contribute to answering my research questions and reflect this study's objectives. The current study findings are addressed with regards to the research questions, which relate to mobile learning and the role of educational apps to supporting science education. In the following section, I present and explain the study's contributions and limitations followed by consideration of the study's implications. Finally, I conclude with recommendations for apps developers, policymakers, and future researchers. The key objective of this study was to understand and explore the impact of tablets' educational possibilities on first-year students in a science class context. I examined the children's use of educational apps in the classroom to determine their role in engaging children and supporting their learning. In this interpretative study, I used participant observations, interviews, and focus groups to examine children's perceptions, views, and attitudes. This study's findings suggest that using tablets and educational apps as learning tools in science class had positive impacts on Saudi Arabian children's learning, including engagement and motivation. Additionally, mobile learning promoted individual and social learning and provided children opportunities to work at their own pace.

6.2. Main Findings in Relation to the Literature

This study was guided by three overarching questions. Key findings were explained in depth in the previous chapter. In this chapter, findings will be synthesised and summarised to address the research questions.

RQ1: What are children's responses to using educational science applications that support science learning in a Saudi Arabian grade 1 class?

The majority of the children exhibited interest and positive emotions, such as enthusiasm, motivation, and enjoyment. Children in the study had fun and enjoyed the apps' games, animations, sounds, activities, and multimedia, which led to higher engagement with content than books with limited activities. They also seemed to enjoy the freedom offered by the mobile learning environment, as this increased the autonomy of their learning. These findings are similar to those obtained by Furman, De Angelis, Dominguez Prost, and Taylor (2018) and Crawford, Holder, and O'Connor (2017). Students in this study engaged in discussions and interacted in small groups with an emphasis on personal responsibility, and this is in line with data obtained by Bressler and Bodzin (2013) and Laru, Järvelä, and Clariana (2012). Additionally, children appreciated the flexibility and informality of mobile learning and thus became highly emotionally engaged. Two primary factors encouraged children's positive emotional engagement. The first factor was related to the tablets' affordances or the apps' features. The affordances that seemed to motivate the children included ease of use, the ability to play various roles, instant feedback, entertainment, games, encouragement of imagination, and the ability to use interactive touchscreens. Second, multimedia apps increased the children's sense of curiosity and engagement, which concurs with data obtained by Looi, Sun, and Xie (2015), Vogel, Spikol, Kurti, and Milrad (2010), Choi, Land, and Zimmerman (2018), Minshew and Anderson (2015), and Gronemann (2017).

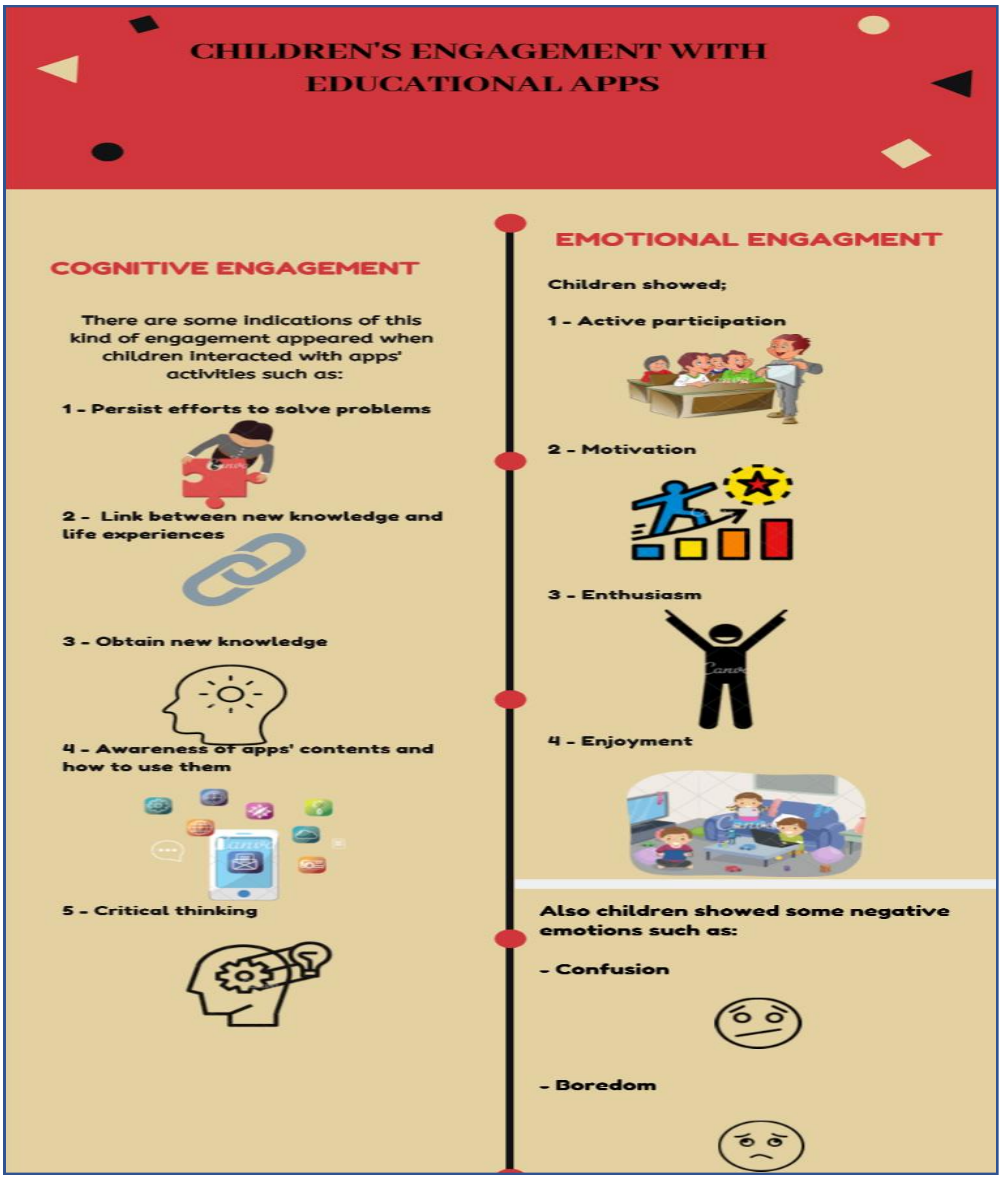


Figure 6.1: infographic of the findings of first research question.

RQ2: How far do educational science applications support science learning in a Saudi Arabian grade 1 class?

The data extracted from observations, interviews, and focus groups have revealed that apps and digital games support children's learning of science. Digital games and multimedia apps could provide unique learning experiences for children regarding abstract scientific concepts that they are unable to see through simple observation, such as why it rains, stages of plant growth, and how plants get their food and water. This finding supports those obtained by Asmina and Mohd (2017), Raditya, Eryanto, and Prestiliano (2017), Tarng, Ou, Yu, Liou, and Liou (2015), and Akcay and Akcay (2015). Tablet functions help children learn scientific concepts, and tools such as multimedia and animation offer them chances to move beyond the borders of the school and use their imagination to visit zoos, libraries, museums, other countries, and places that are impossible to view in reality. This finding is broadly consistent with data obtained by Hautala et al., (2018), Thomas and Israel (2013), Herodotou (2018), Wirawan and Arthana (2018), and Herga, Cagran, and Dinevski (2016). Furthermore, gamified apps allow children to immerse themselves in a virtual context where they can experience new things and repeat them. Role-playing games and apps can help children gain a broader understanding of the world around them by enabling them to experience events or characters that make scientific concepts relevant to them, which is in line with the work of Khan, Ahmad, and Malik (2017).My observations of the children in the science class revealed that their interactions with the educational apps helped them to cognitively engage and learn science. There were four main aspects that reflected cognitive engagement in the science class:

- Persistent effort to solve problems: children made efforts to complete the activities properly and accomplish their goals, thus enhancing their self-esteem and improving their basic skills.
- Obtain new knowledge: children's interactions with apps gave them opportunities to interact with multimedia components (including audio, images, and animations) that provide unique learning experiences, thus allowing them to acquire new scientific knowledge.
- Links between new knowledge and life experiences.
- Awareness of apps' content and of how to use them: Children were aware of how to operate the tablets, including the buttons' functionalities, and easily understand the apps' details.

Critical thinking encompasses several essential skills for learning in general and learning science in particular. Children showed some of these skills while they interacted with tablets and apps. For example, first they solved problems represented by puzzles and matching and memory games. Second, they learnt through playing and discovering. Third, they expressed their feelings appropriately. Fourth, they identified similarities and differences, and, finally, they made predictions of upcoming events, which is consistent with data obtained by Magana (2014), Wardani, Lindawati, and Kusuma (2017), and Harjono, Sahidu, and Herayanti (2017). Tablets enable children to take responsibility and ownership of their science learning by manipulating the device, selecting the app, and interacting with content through their preferred method. The sense of autonomy that is stimulated by offering children learning experiences allows them to experience freedom and extend their choices, and this in line with the work of Song and Wen (2018), and Yin, Song, Tabata, Ogata, and Hwang (2013).

With respect to scaffolding science learning, the provision of multiple formats and levels of scaffolding can be tailored to multiple children's zones of proximal development in any classroom, which guarantees that all students have opportunities to be supported and guided. In this study, children received technical, peer, and teacher scaffolding. Providing children with appropriate scaffolding enables them to achieve their goals, perform tasks efficiently, and solve problems, which is consistent with the findings of Ahmed, Parsons, and Mentis (2012).

A variety of sources of assistance (apps, peers, and teachers) helps children and directs their need to accomplish learning objectives. Mobile games can afford children scaffolds and challenges in proper balance, which help maintain motivation. In addition, they provide children with multiple chances to solve problems and succeed, which promotes persistence and risk-taking. Playing games supported with proper scaffolding and feedback meets learning needs that enable children to finish tasks and solve problems. The data suggest that social interactions and discussions between peers about mobile learning activities help children construct their personal understanding and scaffold their science learning. This finding is similar to data obtained by DeWitt, Siraj, and Alias (2013) and Kim and Hannafin (2011). Teacher scaffolding can help children obtain new knowledge and skills and correct misinformation. through questioning, modelling strategies, guiding, and activating prior knowledge, which concurs with Palincsar, Fitzgerald, Marcum, and Sherwood (2018).

Figure 6.2: infographic of the findings of second research question

RQ3: What are the issues and challenges related to implementing mobile learning in a science class in a primary school?

The introduction of mobile devices as educational tools to assist science learning can be associated with some physical and technical challenges, such as slow responses and app freezes. These problems negatively impact children's interactions with tablets, satisfaction, and motivation. Furthermore, unexpected and sudden technical problems can distract children, make them concentrate on irrelevant activities, and cause them stress, as Terras and Ramsay

(2012) identified. Control and class management can also be issues, as teachers try to shift the learning context from a traditional to a mobile or smart class. Engaging children with handheld devices might contribute to distraction, reduced concentration, and increased interruptions, which can negatively impact classroom control and management. Informality makes the learning process more casual, which may lead to difficulties in classroom management that affect educational gains (Al-hunaiyyan & Alhajri, 2016). Inadequate funding, lack of devices, lack of Internet access, and adoption of mobile learning can also be challenging for some schools due to lack of funding. Lack of experience with mobile learning and training needs also affect student learning outcomes. Teachers' beliefs about self-efficacy in, attitudes towards, and comfort in dealing with technology impact their integration of mobile learning into practice. Tablet-based learning can also result in a lack of hands-on experiences. Educational apps and mobile learning cannot replace authentic science experiences, which allow children to interact with their surrounding environment by exploring with all five senses. Nonetheless, in some developing countries with large classroom sizes and scant lab equipment, technology and its means, such as virtual labs, can support science learning.

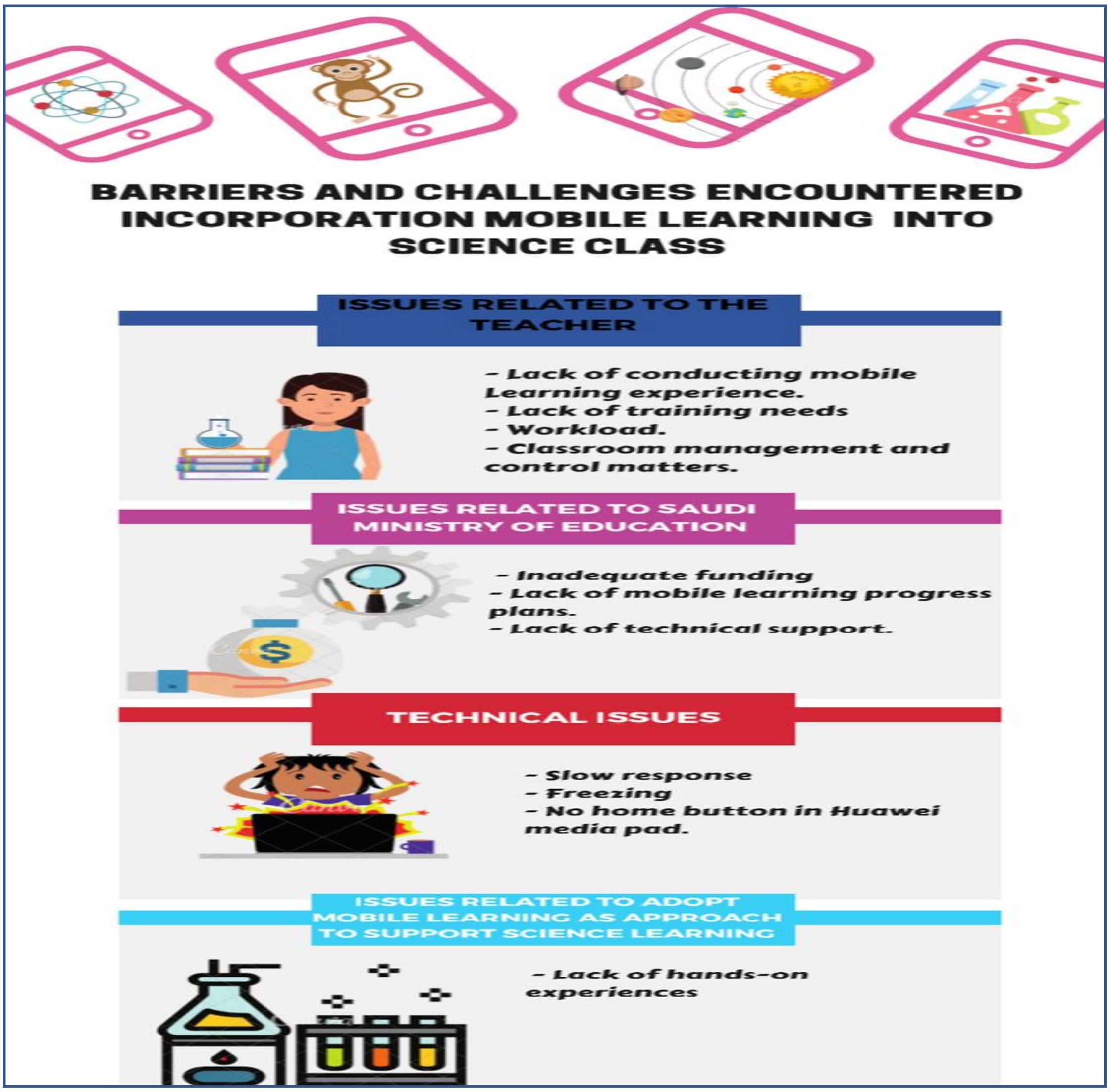


Figure 6.3: infographic of the findings of third research question.

6.3. Limitations of the Study

As previously explained in methodology chapter, the target group of this study was one class of 18 first grade children. To explore mobile learning in-depth, they were interviewed and observed closely. Without doubt, this class does not exemplify all science classes in Saudi schools. As result, the study's findings cannot be generalised. In other words, as this study involves a small sample size, the findings cannot be generalised to larger populations (Schewardt, 2007). Nonetheless, selecting this sample and method were convenient for fulfilling the objectives of this study. Moreover, this interpretative study adopted a qualitative approach in which analytical generalization was more appropriate than statistical generalization (Yin, 2009). Statistical generalization of the findings to wider settings was not the aim of this study. I looked to generalise and expand existing theories of using educational apps by children in a science class.Despite this, my study findings can be applicable in science classes with similar characterises of children, class size, and school mission (Lincoln & Guba, 1985). Moreover, the details and elaboration that I provided about the data collection methods and analysis may assist other researchers to transfer findings to their own context.

Another limitation was using just one brand of tablet, which was the Huawei MediaPad, powered by the Android system. Nonetheless, these tablets have many features, such as a large screen, appropriate size for children, light weight, clear sounds, long battery life, and easy handling. Google Play is the apps store used for this study, and it has thousands of free apps that can be downloaded for educational purposes. Additionally, by using tablets in a children's science class, I aimed to obtain knowledge about how educational apps can support science learning. The children only used Google Play apps and did not use essential tablet features, such as camera, notes, massaging, and browsers. Further, they did not use any apps that required Internet connectivity, such as YouTube or a search engine, and this is another potential study limitation. Conducting this study was a part of PhD degree. As I was the sole researcher, there were resource limitations and time restrictions. Perfection is impossible to achieve, but for researchers to achieve their desired goals, they must creatively and effectively exploit time and available resources.

6.4. Implications of Findings

My study provides description and in-depth perceptions of children's experiences with mobile learning and educational apps to assist their understanding of scientific concepts. Moreover, I measured the effects of using tablets as educational tools in a school context to engage children in learning science. The study's findings, which were extracted from children's lived experiences, suggest that using educational apps positively impacted on participants' science learning. The beneficial and enjoyable affordances of apps and tablets engaged them both cognitively and emotionally. However, participant engagement was somewhat impacted by factors such as lack of interest in the apps' content or types, selecting an inappropriate level of difficulty, and making mistakes. Eliciting, sustaining, and enhancing children's engagement with educational apps can assist them in constructing knowledge and finding useful strategies to solve problems, boost their focus and attention, and increase motivation. All of this supports science learning, whether directly or indirectly.

Contextual factors that encourage engagement related to tablets and apps were examined. The findings suggest that high engagement with apps was influenced by some tablet affordances, such as instant feedback, the ability to play different roles, multimedia, games, and collaborative learning. The informality associated with mobile learning also engaged children, and they enjoyed talking with group members, laughing, playing, and giving advice. Regarding the role of apps in supporting science learning, the children played gamified apps, including adventure games, role-playing games, and simulation games, all of which offered children opportunities to practice scientific methods, perform investigations, arouse curiosity, solve problems within their zone of proximal development, correct misconceptions, develop observations, and obtain knowledge about abstract concepts. Additionally, educational apps provided scaffolding that helped children perform tasks independently and make complex tasks more manageable. These findings might be of interest to educators, teachers, and other community members and individuals considering adopting mobile learning.

This research deepened my comprehension of this topic and may provide researchers and science teachers insight into potential uses of educational apps to assist in constructing scientific knowledge and developing children's scientific understanding. Also, this research offered powerful enlightenment about the possible role of tablets in engaging children to learn science. As explained previously in the findings chapter, children used different types of apps to facilitate learning different topics. This diversified typology can guide science teachers, particularly in primary classrooms. I shared extracted beneficial lessons learned from my experiences in exploring the incorporation of mobile learning into a science class. For instance, even though educational apps have wonderful possibilities that can greatly engage children, there are a few aspects related to use that can be disengaging.

I hope the practical implementation of mobile learning will encourage and guide science teachers to take advantages of handheld devices and educational apps' affordances and exploit their widespread use among children to enhance learning. Integrating mobile learning into children's science learning can satisfy their need for autonomy over their learning and help them exercise agency. Numerous teachers wish to employ these devices for learning purposes. However, they might be frustrated by inadequate research and lack of experiences about using mobile devices as educational tools. I witnessed this first-hand during my study as I sat with a group of teachers who teach other subjects. They were enthusiastic about adopting mobile learning, and they expressed their desire to learn how to employ such devices to serve their curricular objectives. Some of them asked me questions about how to search and find good apps, the standards for high quality apps, and advice for useful references about conducting effective mobile learning. Questions that teachers asked reflect their need for training programmes and workshops to obtain practical knowledge about potential pedagogical roles of technology and learn how to effectively integrate educational apps into their curriculum. Moreover, the findings of this study might be helpful for teachers who teach in schools located in low-income areas that lack simple, supportive means to facilitate science learning, such as materials and lab equipment. Such teachers can harness the apps' affordances to help children learn instead of teaching them only using perspective approaches.

Despite the educational uses of tablets, there are some technical limitations. Children's exposure to virtual learning experiences by using apps provides them opportunities to obtain basic science knowledge as first grade learners. Tablet affordances, including multimedia, various uses of apps, playing different roles, multisensory experiences, simulation, playing games that assist children in learning and understanding, particularly abstract scientific concepts, without proper training and support can lead to not maximising their potential or misunderstanding them. Taking advantage of these devices can help children develop a sense of agency and have greater control over their learning, which was one of the most interesting findings of this study. By using educational apps, children can learn autonomously, develop strategies to solve problems, and make their own decisions. Further, using tablets and apps as teaching tools also promotes collaborative learning where children enjoy being group members and sharing discoveries and information. This can promote teacher adoption of learner-centred pedagogical approaches and help overcome current domination of teacher-centred approaches in classrooms. These findings might be beneficial in contexts that stick to traditional learning and resist change. Such contexts are often characterized by ignoring the benefits of experiential learning, emphasising memorisation, using only printed books as sources of information, and teacher centeredness. All of these actions in teaching can negatively affect children's learning and prevent them from developing necessary and transferable scientific skills, such as critical thinking, curiosity, observation, communication, inference, prediction, and perseverance. Conversely, using tablets and their apps can help develop these competencies.

6.5. Practical Recommendations

The popularity and prevalence of handheld devices and apps among children cannot be neglected. Their prospects as engaging educational tools in science classrooms urgently needs further attention. However, implementing mobile learning requires adopting new and sometimes complex practices that need to be considered carefully. Thus, in the following section, I offer recommendations for future research, practice, and policymaking based on this study's findings.

6.5.1. For Policymakers

As previously described, presentation of tablets to first-grade children in science class was extremely popular. The students viewed the tablets as engaging, valuable, and enjoyable for science learning. Current primary school educational policies in Saudi Arabia do not appear to give careful consideration and sufficient response to young learners' need for competence, self-confidence, different types of play, communication, interaction, social learning, and autonomy. Where ministry of education science programs lack essential qualities to support collaborative learning, children can gain basic competence in science and autonomous learning thought the use of tablets, which is strongly demanded and encouraged by the Saudi Vision 2030. In particular, in primary schools there is no effective program or proposed plan to incorporate mobile learning into science classes to facilitate children's understanding and knowledge construction. Questions that need to be answered here are as follows. What considerations are needed to find and develop efficient mobile learning programs that support science education? In what ways can such a proposed program be applied in Saudi primary schools? Within these particular situations, many teachers lack experience in adopting mobile learning, and they are not supplied with technical support, technological competence, classroom-management skills, and proper methodological expertise needed to effectively conduct mobile learning. Currently, designing high-quality learning environments where instructors guide students through meaningful activities with tools that enable them to construct knowledge is a big challenge encountered by many educational systems (Pegrum, 2014). Additionally, educators must also take techno-pedagogical aspects into account when designing new learning environments. The Ministry of Education in Saudi Arabia should promote the importance of modifying learning systems to keep up to date with global development. Therefore, there is an urgent need to establish long-term plans that include the following aims:

- Integration of mobile learning with handheld devices into classrooms so as to support curricular objectives.
- Providing teachers with ongoing training in useful and effective ways to use handheld devices prior to application of mobile learning in classrooms.
- Earmarking additional financial resources to help build technical infrastructures of schools and educational institutions.
- Affording online and onsite support for instructors and staff that aims to promote discussion and collaboration among instructors, including recognising classroom management issues and instructional needs related to tablets and educational apps. It is also important to consider how tablet ownership is affected by economic and social advantages and disadvantages, as pointed out by Merchant (2015). Integrating tablets into educational systems might depend on some children's cultural capital, which could aggravate inequalities. This should be taken into account when planning to adopt tablets as learning tools in schools.

6.5.2. For Practitioners

It is important to assert that educational apps and tablets are not magical tools can engage young learners and facilitate their science learning without guidance. Science teachers must know that throwing tablets into children's hands cannot support their learning and does not support knowledge construction. Children must be supervised and guided in proper ways, whether methodologically or technologically, to achieve the greatest learning benefits. Not all children have the necessary experiences, skills and knowledge to handle and navigate new technology. Accordingly, developing mobile learning environments that aim to support children's science learning should include peer assistance and expert support. It is crucial that teachers guide children in harnessing educational apps to facilitate their science learning. Some children may not have any background in the technological possibilities of these handheld device, science learning's cognitive underpinnings, or how to combine these two things to enhance competence. The findings of the present study suggest that tablets and their apps' affordances assist and scaffold children's science learning and engage them cognitively and emotionally. To take full advantage of these powerful tools, science teachers should take into account individual student differences and obtain accurate information about every child's skills, interests, and needs. When science teachers decided to adopt mobile learning and incorporate tablets into their classrooms, they should take into account a number of considerations.

First, teachers should familiarize themselves with technological and curriculum objectives that are assigned at their schools. Second, educators should review potential use of selected apps thoroughly to comprehensively achieve science class objectives. This study provides a typology that can assist and guide teachers. However, teachers must examine app contents regularly, as some need to be updated and others may present distracting elements, such as advertisements and banners. Moreover, app stores offer new apps almost every day, and these need to be reviewed by teachers to maximize benefits and consider potential educational value for young science learners. Third, tablets and their apps' educational and motivational potential should be discussed with school principals and administrators to collaborate efforts for planning the implementation and funding. Fourth, educational science apps that are designed for children should be aligned with science objectives. Children's needs should also be taken into account, including their interest, which enhances motivation and engagement, especially in situations where children lacked background knowledge and curiosity. Apps and their activities should combine learning with fun at the same time. Additionally, teachers should choose apps that achieve the right balance between appropriateness, enjoyment, effectiveness, and functionality. Fifth, while teachers model learning practices and elucidate the main functions, children should be provided with opportunities to explore the apps' contents and functions and experiment with their tools. Sixth, children should be offered collaborative learning opportunities via educational apps and tablets, which should promote scaffolding and peer-to-peer teaching, sharing of discoveries and learning experiences, and exchanging newly obtained information with classmates. Furthermore, children should be given sufficient time to perform tasks and accomplish them to enhance their competence. Teachers are advised to orderly introduce new apps that include various features and multifunctional tools, as such aspects can be develop children's skills and cater to their different interests. Seventh, children should be encouraged to link acquired knowledge from apps to related situations and topics in their life, whether inside or outside school to expand their learning and understand complex phenomena. Eighth, teachers should train and encourage children to perform tasks using scientific skills, such as comparing, contrasting, observing, measuring, classifying, predicting, and communicating. Ninth, teachers are advised to remind children and how tablets can assist their learning by taking advantage of affordances and function and not to treat the devices as toys for playing only. Finally, teachers are recommended to develop mobile systems that allow children to monitor their progress and manage their work.

6.5.3 For App Developers

The current study's findings also provide suggestion and insight for apps developers who plan to develop educational apps that offer knowledge related science concepts and phenomena in enjoyable contexts for young learners. There are thousands of apps in the virtual stores, and their purposes are not always clear, nor do they always provide detailed instructions, which can make children feel lost and confused. In addition, as most apps are in English, children who speak Arabic may encounter difficulties in understand the content and rely on trial and error to explore the apps' functions. Hearing a language that they do not understand can frustrate children and decrease their engagement. Some simulation apps and games are designed with too many levels, which may make some children bored or lose their desire to finish the games. App developers should take into account some considerations when designing children's apps with educational content. First, they should allow children to select their preferred language to read or hear instructions and model how to use the apps in clear, visible ways via pedagogical agents or animated items. Additionally, app logos should be clear and represent the app's features distinctly, which will boost understanding of their use. Moreover, children should be given opportunities to personalize apps and customise their settings, for example turning notifications on and off. Furthermore, apps should afford great diversity of features, such as font size, backgrounds, and colours, and functions, such as using search engines, drawing, taking photos, colouring, and recording audios or videos. Also apps should offered rewards, instant feedback, and different levels of scaffolding. All of these features can enhance user engagement and motivation and satisfy children's personal preferences and fulfil their different needs and interests. Thus, all of these measures should be taken into account when designing apps for children. App developers should devote great attention to engagement and disengagement factors due to their influence on child engagement.

6.6. Directions for Future Research

The findings of this study shed light on a number of aspects that require further investigation and exploration. This interpretative study involved only one first grade science class concentrating on children's attitudes and perception about using apps to support science learning and investigating the apps' and tablets' engagement factors. Several areas need to be further examined, such as the relationship between engagement factors of educational apps and children's learning outcomes and achievement, which could offer broader perspectives on this topic and produce generalizable, quantitative data. In addition, further research needs to be conducted on some areas, including using apps and tablets amongst more diverse populations of children, such as different age group and school levels. Furthermore, to investigate this subject more deeply, researchers can extend their efforts to involve teachers' and caregivers' views to obtain a full picture of the engagement factors and the effect of apps and tablets on children's science learning. Moreover, to investigate this topic, future researchers can employ recorded video as a data gathering tool to maximise the analytical possibilities. In addition, future research on adopting apps and tablets as educational tools to assist children's science learning needs to include further longitudinal studies to identify if young learners' engagement with apps and tablets changes over time and examine the reasons for any changes.

6.7. Conclusion: Contribution of the Study

A number of researchers have designed and constructed mobile learning environments that concentrate on learning by using tablets and educational apps to help students obtain educational content aligned with course curricula. Prior research was helpful in understanding the possible uses of apps and tablets for educational objectives. However, the majority of these studies focused their investigations on using tablets as means to collect data in the life science domain, and most of these studies were conducted in informal settings, such as outdoor locations and field trips. Moreover, the majority of the apps used in previous studies were developed by researchers themselves for assessments purposes, and they are not accessible for public use. To the best of my knowledge, there is no previous research that uses existing educational apps in Google Play to support children's science learning and promote their engagement. Thus, my study includes data about the influence of adopting mobile learning to engage children and assist them in science learning.

No existing research has been conducted that examines how adopting mobile learning influences varied science topics, such as plants, animal behaviour, diseases, and the solar system in primary classrooms in Saudi Arabia. In the present study, students were involved in using apps to assist their learning of different topics that aligned with the curriculum, for example insects, earth resources, raining, planting, seeds, and animal needs. Furthermore, children were not restricted to a specific type of app. They used apps from various categories, including games, productivity, puzzles, and simulation. Children were free to select from five or six apps in each science class. This typology contributes to promoting our understanding of the role of the tablet apps in assisting science learning. This study offers new information about using children's educational apps for obtaining scientific knowledge in a formal setting, which was a private primary school in Saudi Arabia. Furthermore, the findings provide helpful insight into the factors that affect children's engagement with educational apps and the challenges encountered by using high-quality mobile learning tools in schools. Employing a qualitative approach in this study required obtaining data directly from children who lived the experience, which allowed them to express their feelings by using their own words. The data that were obtained from young children represent perspectives, opinions, and perceptions about the effects of apps on their science learning. Children who participated in this study were very pleased and proud about their involvement. They enjoyed the mobile learning experiences and felt that their opinions were heard and valued. Research that depends on the opinions and perspectives of children in Saudi Arabia (context of the study) is very rare. This study, which values children's voices, therefore makes an important contribution to the literature.

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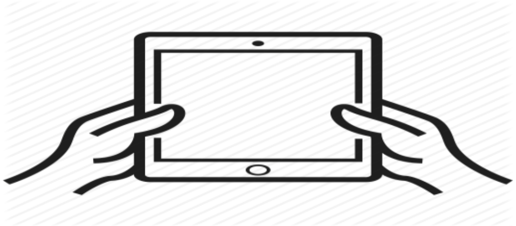
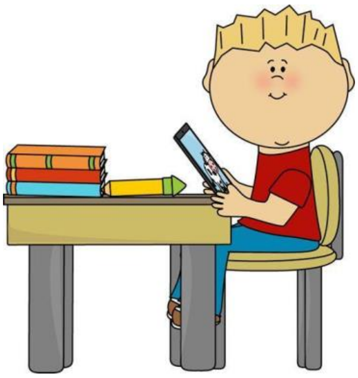
APPENDICES

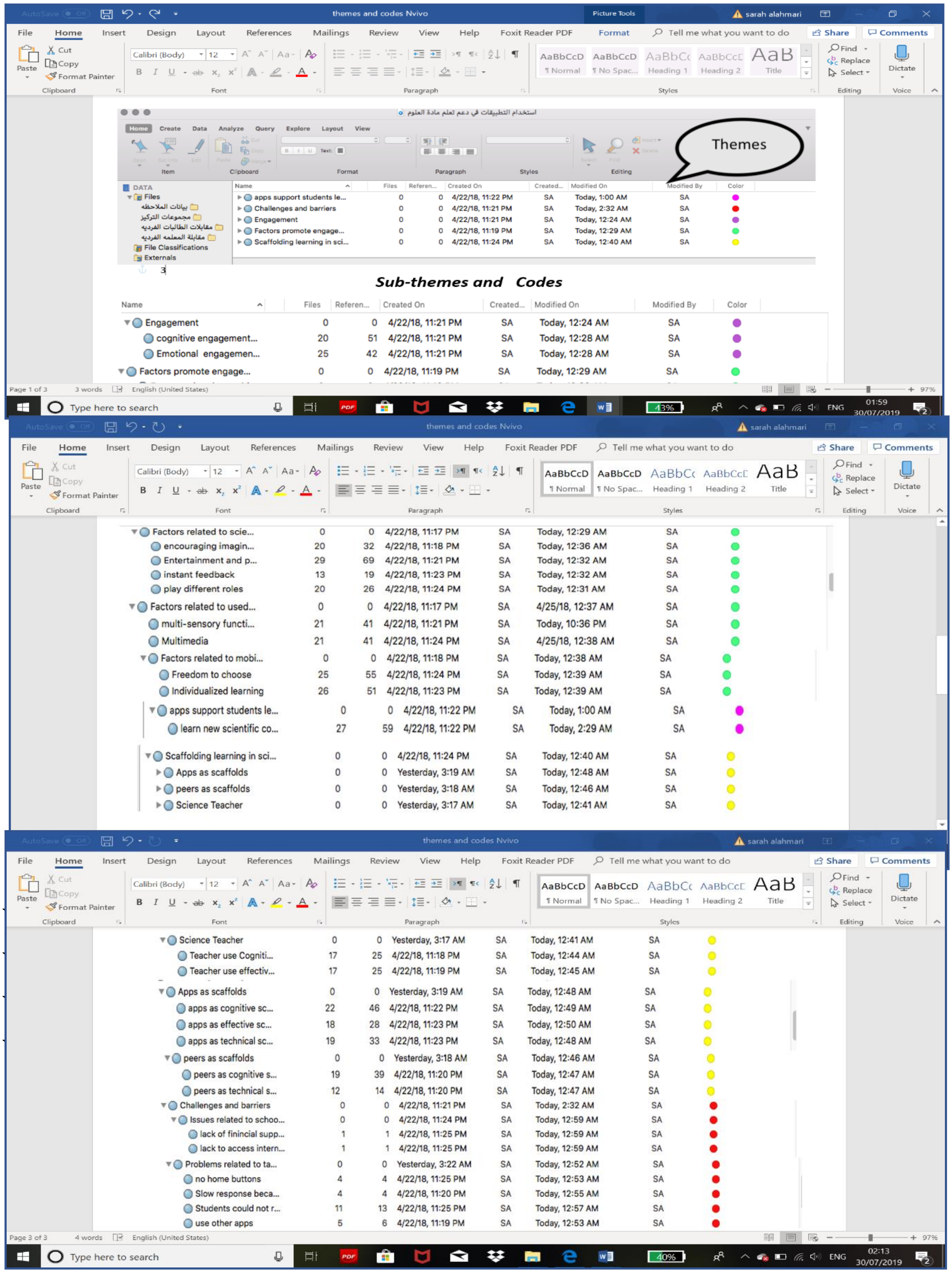
Appendix 1

Handouts of iPad use rules (Arabic version)

غسل اليدين وتجفيفها قبل استخدام التابلت 	حمل التابلت بيديك الاثنتين 
الجلوس وتجنب الركض او المشي أثناء حمل التابلت 	استخدام التطبيقات التي تشير المعلمة اليها 
اغلاق التابلت عندما تتحدث المعلمة 	لمس شاشة التابلت بكل لطف بواسطة الايدي وتجنب استخدام أدوات أخرى كالأقلام 

Appendix 2

Emergent themes and codes by using NVivo 12



Appendix 3

Ethical Approval Letter from University of Sheffield

The University Of Sheffield.

Downloaded: 16/05/2019
Approved: 04/09/2017

Sarah Alahmari
Registration number: 150254917
School of Education
Programme: PhD/Education

Dear Sarah

PROJECT TITLE: Using Educational Applications on Mobile Devices to Support Science Learning Among First-Grade Saudi Primary School Children
APPLICATION: Reference Number 015950

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 04/09/2017 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 015950 (dated 06/08/2017).
- Participant information sheet 1034299 version 2 (06/08/2017).
- Participant consent form 1034300 version 2 (06/08/2017).

The following optional amendments were suggested:

See comments from reviewer 3: I think that it would be possible for you to produce some protocol, perhaps using visual materials, to explore 'consent' with the children. You have mistakenly uploaded two information forms I think but I'm assuming you have a consent form for parents.

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

David Hyatt
Ethics Administrator
School of Education

Appendix 4

Consent forms (English version)

PARENTAL CONSENT FORM

***Research Study Title*: Using Educational Applications on tablets to Support Science Learning Among First-Grade Saudi Primary School Children**

Researcher: Sarah Alahmari

	Yes	No
I confirm that I have read and understand the information sheet for the above research and have had the opportunity to ask questions.		
I understand that my child's participation is voluntary and that he/she free to withdraw at any time without giving any reason.		
I agree that my child can be audio recorded/video recorded/photographed during the research study.		
I understand that my child's responses on audio recordings will be anonymised before analysis.		
I agree to allow my child to take part in the above research.		

Child's name ____________________________

Child's birth date __________________________

_____________________________ _________________ _________________

name of participant's parents Date signature

(mother / father)

Sarah Alahmari

_________________ ____________________ name of

researcher Date signature

Informal Consent Form for Child

My name is Sarah Alahmari. I will visit you in science class and give you and your friends tablets. You will be able to use the tablets' applications to learn science lessons.

When you are in science class, I would like to video record you using a camera and take photos. Also in interview I will ask you some questions about these applications and record your answers on my phone. If I ask you a question that you do not want to answer, that is fine just do not say anything, or tell me that you do not want to answer the question. If I say something you do not understand please ask me to explain it.

if you agree to take part in the research please tick this box:

☐

if you do not want to take part in the study then please put a tick here:

☐

Appendix 5

Interview Questions

Separate interview questions – Questions will be formulated so children can understand them	
1	How do you feel about using educational applications in science class?
2	How have applications helped you learn science?
3	If the applications helped you learn new scientific concepts, give examples of those concepts.
4	From the set of used applications, what was your favourite? Why?
5	From the set of used applications, which app was your least favourite? Why?
6	What types of applications do you like (e.g., puzzles, stories, colouring programs, flash card, or e-books)? Why do you like these types of apps?
7	Do you prefer using tablets or schoolbooks? Why?
8	Is there a school subject that would be easier to learn with an application? Why did you select this subject?
9	Do you prefer working in pairs, in groups, or individually when using a tablet in science class? Why?
10	When you used a tablet in science class, did you need the teacher’s help? If yes, what was the biggest challenge?
11	What problems do you face when using applications in science class?
12	Is there anything else you want me to know?

Teacher interview questions	
1	How do you feel about using tablet applications as educational tools to help teach science and conduct experiments?
2	Do you prefer using traditional teaching methods or modern technology to facilitate the education process? Why?
3	Do tablets and applications help you perform your tasks easily? If yes, how?
4	Does the use of tablets and apps affect children's learning outcomes? If yes, how?
5	Does the use of tablets affect your ability to manage and control your class? If yes, what do you suggest to help keep children under control?
6	What kinds of applications attracted children's attention and encouraged interaction?
7	What applications did children interact with? Why?
8	What problems did you notice during the application of mobile learning in the science class?
9	In your opinion, how can these problems be overcome?
10	What do you need, as a teacher, to apply mobile learning in your classroom?
11	From a teacher's perspective, what are the advantages of using tablets as learning tools?
12	From a teacher's perspective, what are the disadvantages of using tablets as learning tools?
13	Based on your experience, what advice can you give to other teachers about employing mobile learning on school property?
14	Is there anything else you want me to know?

Focus groups	
1	How do you feel about using tablets and apps to learn science and conduct experiments?
2	Can you give me examples of topics you have learned by using apps?
3	Can you give examples of applications you have liked? Why did you like them?
4	Can you give examples of applications you have not liked? Why did you not like them?
5	Who in your home owns a tablet? How do you use it?
6	How would you advise other children about the right way to use a tablet in school? At home?
7	Do you feel apps have helped you learn faster? If yes, how did they help?
8	What subject could you learn most easily using an app? Why?
9	Would you like to use tablets next semester in science class? If yes, why?
10	Is there anything else you want me to know?